GL01416

REFERENCE LIST

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Interim Report

Geothermal Resource Potential of New England

for the U. S. Department of Energy

Agreement No. DE-FC07-80RA50272

Gerald P. Brophy

Principal Investigator

Geology Department

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Interim Report

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Introduction

A two year investigation of the geothermal resource potential of New England was initiated by Amherst College on July 1, 1980 under terms of Agreement No. DE-FC07-80RA50272, with Dr. Gerald P. Brophy acting as Principal Investigator.

The initial phase of the program consisted of visits to the various State Geologists, the State Energy Offices, the U. S. Geological Survey offices in New England and the D.O.E. laison in Boston, to ascertain what records and information are available. A letter was also sent to all Mineral Clubs in New England requesting any information on warm springs and wells. Field visits were made to one known warm spring in New England and a nearby locality in New York. The team then began a search of the geological and hydrological literature and the U.S.G.S. Water Resources files. Unfortunately none of the New England states requires recording of any data other than location when a well is drilled so one of the principal sources of information becomes the individual drilling contractors.

During the academic year various maps and data have been compiled which will become a part of the final report.

General Geological Setting

Most of the formations exposed in New England consist of igneous and metamorphic rocks varying in age from Precambrian to Cretaceous. Detrital sedimentary rocks and basalts of Triassic-Jurassic age crop out in the Connecticut River Valley and southwestern Connecticut. Lucustrine and non-marine poorly consolidated sedimentary rocks of Cretaceous to Miocene age are found in the Cape Cod region of southeastern Massachusetts. All of New England is mantled with glacial and glacialfluvial deposits.

Major Tectonic Features of New England

In an assessment of the geothermal potential of a region such as New England major structural features and their possible relationship to sources of deep circulating warm waters needs to be considered. The major tectonic and structural features in the regions include anticlinoria and anticlinorial massifs, synclinoria, overthrust sheets, domes, basins and large fault systems. Maps illustrating these features are in preparation. The following is an inventory of these features:

Anticlinoria and anticlinorial massifs. The Green Mountain Anticlinorium of western Vermont, the Berkshire Massif of Massachusetts, the Housatonic and New Milford Massifs of Connecticut and the Hudson River Massif of New York are now considered to be possible overthrust masses that has spurred exploration for oil and gas deposits.

Taconic Allochthon. Thrust sheets of eastern New York and western Massachusetts and Vermont contain known geothermal springs.

Domes. Domal structures have deformed the nappes of central New England and sixteen have been mapped in Vermont, New Hampshire, and Massachusetts.

Basins. During the Permian Period the Boston, Narragansett and Norfolk were deformed to form deep sedimentary basins, and during the Mesozoic Era the Triassic Basin of the Connecticut River Valley was created.

Fault Systems: The history of faulting in New England is complex but the major fault systems recognized are:

Maine - The preliminary geological map of Maine (1960) shows a number of faults which are probably of greater extent than recognized at the time of publication. The map shows five major faults and fault zones, the longest extending from the vicinity of Westbrook northeast to Bangor. In western Maine a major fault is mapped extending from Flagstaff Lake to Moosehead Lake. A complex fault system is mapped near Houlton and Presque Isle.

New Hampshire - Three major thrust faults are recognized and from west to east are the Monroe, Ammonoosuc and Northey Hill respectfully.

Vermont - Western Vermont contains a number of thrust faults namely the Highgate Springs, Champlain-Orwell, Hinesburg, Pine Hill, Dorset Mountain, Maple Hill and Hoosic thrusts. Lesser well known and smaller thrusts are mapped in the region around Bennington.

Massachusetts - Western Massachusetts contains a number of thrust faults that are a continuation of those in Vermont. The Clinton-Newbury Fault in eastern Massachusetts is probably the largest and most extensive single fault in the state. Normal faulting along the eastern side of the Connecticut River Valley extends from Greenfield south to Long Island Sound, a distance of 105 miles. Other faults in eastern Massachusetts are the Spencer Brook Fault, the Bloody Bluff Fault Zone, the Mystic Fault and the Ponkapoag Fault.

Connecticut - In addition to the Connecticut River Valley Fault other major faults include the Lake Char and Honey Hill Faults.

Rhode Island - While there are no major faults mapped in the state the rocks in the Narragansett Basin are offset by a large number of small faults.

Plutonic and Volcanic Rocks

The plutonic and volcanic rocks of New England are extensive throughout time and space but four Series are of importance because of the abnormal amount of radiogenic elements they contain. The four are the White Mountain Plutonic-Volcanic series, the New Hampshire Plutonic Series, the Oliverian Plutonic Series and the Highlandcroft Plutonic Series. Of these the White Mountain Plutonic Series has received the greatest attention, particularly the Conway Granite of New Hampshire which has been under consideration for the development of a Hot Dry Rock geothermal power plant.

Maps showing the distribution of the plutonic rocks of New England by age and radioactivity have been compiled.

New England Geothermal Manifestations

Williamstown, Massachusetts

Several occurrences of abnormally warm waters or in one case of abnormally warm but dry ground have been noted in New England. Of these Sand Spring near Williamstown, Massachusetts, is the best known. The spring is located very close to the junction of the states of New York, Vermont and Massachusetts and lies within the Taconic Allochthone, and is the only occurrence of warm waters in New England listed by Warren (1965). The temperature is a constant 24.4°C (76°F) with a flow rate of 400 gallons per minute. Chemical analyses of the spring waters and nearby cool well waters show a significant difference in that the spring waters have four to twenty times greater silica content than the shallow groundwater wells. During a recent visit to the area another small thermal spring was located about one mile from the main spring.

Sand Spring was developed as a spa in the 1880's and the waters were later bottled. There is no current activity, however. Detailed geological work is currently being conducted.

Hadley, Massachusetts

An irrigation well sunk to 250' is supplying water from several levels and the wellhead temperature is 60°F. We are attempting to obtain a log of the well to ascertain, if possible, how much mixing of shallow groundwater and thermally heated deeper water has occurred. A temperature log will be run after the well is shut down following the growing season. This well was spudded in Pleistocene lake clays and should have penetrated into underlying till and possibly terminated at bedrock.

Bellows Falls, Vermont

The town of Bellows Falls drilled a well to a depth of 74' in 1966. The well was drilled into glacial till and has a reported bottom hole temperature of 68°F. The well was pump tested for 71 hours, and reached equilibrium after 15 hours with a drawdown of 15 feet. The well produced 575 gallons per minute but is currently shut in.

Monitoring shows that there is seasonal variation in the temperature recordings. The highest temperature was measured in October (68^{o}) and the lowest (52^{o}) in April. The warmest air temperature occurs in August and the lowest in February. It appears that the water temperature limits lag that of the air by two months. Since the bottom of the well lies 3 feet below the level of the Connecticut River (which is 2000' east of the well site) it is possible that the inflow of waters from the river with a two month time lag is responsible for the unusual behavior, but it is the only well in the area that attains the high temperature observed. Bellows Falls is also located on a thrust slice that contains a radioactive granite mass. Detailed geological work will be conducted during July, 1981.

St. Johnsbury, Vermont

An area of unusually warm but dry ground has been visited and thermally probed. The owner of the property notes (from diaries he found in the house) that in the 1870's mention was made of snow melting in a certain area near the residence, and he has observed the same phenomenon since taking residence in 1965. The property lies on top of Pleistocene beach sands about 175' above present river level. A series of shallow auger holes were put in to depths reaching twelve feet. The sand removed from the auger is noticeably warm to the touch and completely dry. Temperatures in the holes varied from 92^{o}F to 107^{o}F. The area is currently under study.

Bennington, Vermont

Morgan Spring, near what was the center of Bennington in the mid 1800's, was reported by Adams (1848) as being a warm spring. Stearns et al (1937) reported that the spring was still listed in 1934 as a warm spring with a temperature of 53^{o}F which is 8^{o}F above the mean annual temperature. A trip to the area will be made.

Canaan, Vermont

There is an unconfirmed report of a warm spring near Canaan and a search will be undertaken.

Providence, Rhode Island

There are reports of wells to the east of Providence that have slightly elevated water temperatures but these have yet to be confirmed.

Geophysical Investigations

Seismicity

With data obtained from the Weston Geophysical Observatory maps of seismic and microseismic activity in the various New England states are in preparation. In general, however, the region is certainly one that exhibits little activity.

Lineaments

A map of lineaments and magnetic lineaments for southern New England has been compiled, and maps for Maine, New Hampshire and Vermont will be prepared during the next year.

Heat Flow

Only a few heat flow studies have been made in the region and much of those data have been reported in the literature. Except for the area of the White Mountains in New Hampshire there does not appear to be any anomalous heat flow in the region.

Radioactivity

We have received the available airborne radiometric survey data for the region and analysis is currently underway. One area of abnormal radioactivity east of Springfield, Massachusetts, is interesting in that the source appears to be a mass of intrusive rock which is truncated by the Triassic age fault that borders the eastern side of the Connecticut River Valley. It is possible that Mesozoic sedimentary rocks to the west of the fault have covered a portion of the igneous mass and block the release of heat from the decay of radioactive elements in the mass. Surface outcrops of the igneous rocks show an unusual content of allanite, a thorium-rare earth rich member of the epidote mineral group.

Summary

From the information compiled to date it appears that the part of New England most likely to contain hydrothermal geothermal resources consists of the western thrust belt and possibly the Mesozoic age fault system that borders the Connecticut River Valley. Detailed geological studies are continuing.

Gerald P. Brophy
Principal Investigator

gpb/ep

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Location of in the United States

The following lists the positions of the hydrothermal systems, as given in USGS Circular 726 (1975) and the positions used in the geothermal energy resources map produced by NGSDC (1977). The NGSDC data were independently plotted on 1:250,000 maps and digitized from these maps. In general, for several reasons, perfect agreement should not be expected between the two methods of determining the positions. If the positions of a given system agreed within about 1 mile, the Circular 726 positions were adopted for use on the map.

Paul J. Grim
EDS/NOAA
Boulder, Colorado 80302
August 1977

ORIGINAL 726	CA	38 48.0	122 48.0	THE GEYSERS
USED BY NGSDC	CA	38 48.0	122 48.0	THE GEYSERS
ORIGINAL 726	CA	40 26.0	121 26.0	MOUNT LASSEN NATL PARK
USED BY NGSDC	CA	40 26.0	121 26.0	MOUNT LASSEN NAT

ORIGINAL 726	WY	44	37.5	110	26.0	MUD VOLCANO SYS YELSTN
USED BY NGSDC	WY	44	37.5	110	26.0	MUD VOLCANO SYS
ORIGINAL 726	AZ	33	17.1	111	41.2	POWER RANCH WELLS
USED BY NGSDC	AZ	33	17.1	111	41.2	POWER RANCH WELL
ORIGINAL 726	CA	41	40.0	120	12.0	SURPRISE VALLEY
USED BY NGSDC	CA	41	40.0	120	12.0	SURPRISE VALLEY
ORIGINAL 726	CA	40	23.0	121	31.0	MORGAN SPRINGS
USED BY NGSDC	CA	40	23.0	121	31.0	MORGAN SPRINGS
ORIGINAL 726	CA	39	1.0	122	39.0	SULPHUR BANK MINE
USED BY NGSDC	CA	39	1.0	122	39.0	SULPHUR BANK MIN
ORIGINAL 726	CA	38	34.9	122	34.4	CALISTOGA
USED BY NGSDC	CA	38	34.9	122	34.4	CALISTOGA
ORIGINAL 726	CA	38	41.6	123	1.5	SKAGGS H.S.
USED BY NGSDC	CA	38	41.6	123	1.5	SKAGGS H.S.
ORIGINAL 726	CA	37	40.0	118	52.0	LONG VALLEY
USED BY NGSDC	CA	37	40.0	118	52.0	LONG VALLEY
ORIGINAL 726	CA	37	37.0	119	4.5	REDS MEADOW
USED BY NGSDC	CA	37	37.0	119	4.5	REDS MEADOW
ORIGINAL 726	CA	36	3.0	117	47.0	COSO H.S.
USED BY NGSDC	CA	36	3.0	117	47.0	COSO H.S.
ORIGINAL 726	CA	34	35.7	118	59.9	SESPE H.S.
USED BY NGSDC	CA	34	35.7	118	59.9	SESPE H.S.
ORIGINAL 726	CA	33	12.0	115	36.0	SALTON SEA
USED BY NGSDC	CA	33	12.0	115	36.0	SALTON SEA
ORIGINAL 726	CA	33	1.0	115	31.0	BRAWLEY
USED BY NGSDC	CA	33	1.0	115	31.0	BRAWLEY
ORIGINAL 726	CA	32	43.0	115	31.7	HEBER
USED BY NGSDC	CA	32	43.0	115	31.7	HEBER
ORIGINAL 726	CA	32	47.0	115	15.0	EAST MESA
USED BY NGSDC	CA	32	47.0	115	15.0	EAST MESA
ORIGINAL 726	CA	32	44.0	115	7.6	BORDER
USED BY NGSDC	CA	32	43.3	115	7.0	BORDER

ORIGINAL 726	ID	45	18.8	114	19.2	BIG CREEK H.S.
USED BY NGSDC	ID	45	18.8	114	19.2	BIG CREEK H.S.
ORIGINAL 726	ID	45	.9	113	51.1	SHARKEY H.S.
USED BY NGSDC	ID	45	.6	113	36.5	SHARKEY H.S.
ORIGINAL 726	ID	44	17.9	117	2.9	WEISER AREA
USED BY NGSDC	ID	44	17.9	117	2.9	WEISER AREA
ORIGINAL 726	ID	44	18.3	116	44.7	CRANE CREEK
USED BY NGSDC	ID	44	18.3	116	44.7	CRANE CREEK
ORIGINAL 726	ID	44	34.4	116	40.7	NEAR CAMBRIDGE
USED BY NGSDC	ID	44	34.4	116	40.7	NEAR CAMBRIDGE
ORIGINAL 726	ID	43	23.0	114	55.9	WARDROP H.S.
USED BY NGSDC	ID	43	23.0	114	55.9	WARDROP H.S.
ORIGINAL 726	ID	42	2.2	115	32.4	MURPHY H.S.
USED BY NGSDC	ID	42	1.8	115	22.0	MURPHY H.S.
ORIGINAL 726	NV	41	55.3	118	42.7	BALTAZOR H.S.
USED BY NGSDC	NV	41	55.3	118	42.7	BALTAZOR H.S.
ORIGINAL 726	NV	41	21.0	118	47.0	PINTO H.S.
USED BY NGSDC	NV	41	21.0	118	47.0	PINTO H.S.
ORIGINAL 726	NV	40	39.7	119	21.7	GREAT BOILING (GERLACH
USED BY NGSDC	NV	40	39.7	119	21.7	GREAT BOILING (G
ORIGINAL 726	NV	41	28.2	116	9.0	HOT SULPHUR SPRINGS
USED BY NGSDC	NV	41	28.2	116	9.0	HOT SULPHUR SPRI
ORIGINAL 726	NV	41	10.9	114	59.4	NEAR WELLS
USED BY NGSDC	NV	41	10.9	114	59.4	NEAR WELLS
ORIGINAL 726	NV	40	35.2	115	17.1	SULPHUR H.S.
USED BY NGSDC	NV	40	35.2	115	17.1	SULPHUR H.S.
ORIGINAL 726	NV	40	34.2	116	34.8	BEOWAWE H.S.
USED BY NGSDC	NV	40	34.2	116	34.8	BEOWAWE H.S.
ORIGINAL 726	NV	40	24.5	117	52.9	KYLE H.S.
USED BY NGSDC	NV	40	24.5	117	52.9	KYLE H.S.
ORIGINAL 726	NV	40	36.2	117	38.7	LEACH H.S.
USED BY NGSDC	NV	40	36.2	117	38.7	LEACH H.S.

ORIGINAL	726	NV	40	45.7	117	29.5	HOT SPRINGS RANCH
USED BY NGSDC		NV	40	45.7	117	29.5	HOT SPRINGS RANC
ORIGINAL	726	NV	40	10.7	117	29.4	JERSEY VALLEY H.S.
USED BY NGSDC		NV	40	10.7	117	29.4	JERSEY VALLEY H.
ORIGINAL	726	NV	39	31.3	118	33.1	STILLWATER AREA
USED BY NGSDC		NV	39	31.3	118	33.1	STILLWATER AREA
ORIGINAL	726	NV	39	34.0	118	49.0	SODA LAKE
USED BY NGSDC		NV	39	34.0	118	51.0	SODA LAKE
ORIGINAL	726	NV	39	47.2	119	0.0	BRADY H.S.
USED BY NGSDC		NV	39	47.2	119	0.0	BRADY H.S.
ORIGINAL	726	NV	39	23.0	119	45.0	STEAMBOAT SPRINGS
USED BY NGSDC		NV	39	23.0	119	45.0	STEAMBOAT SPRING
ORIGINAL	726	NV	39	9.7	119	11.0	WABUSKA H.S.
USED BY NGSDC		NV	39	9.7	119	11.0	WABUSKA H.S.
ORIGINAL	726	NV	39	12.6	118	43.4	LEE H.S.
USED BY NGSDC		NV	39	12.6	118	43.4	LEE H.S.
ORIGINAL	726	NV	39	21.4	117	32.8	SMITH CREEK VALLEY
USED BY NGSDC		NV	39	18.5	117	33.2	SMITH CREEK VALL
ORIGINAL	726	NM	35	43.0	106	32.0	VALLES CALDERA
USED BY NGSDC		NM	35	54.0	106	32.0	VALLES CALDERA
ORIGINAL	726	NM	32	8.5	108	50.0	LIGHTNING DOCK AREA
USED BY NGSDC		NM	32	8.5	108	50.0	LIGHTNING DOCK A
ORIGINAL	726	OR	42	40.5	118	20.7	MICKEY H.S.
USED BY NGSDC		OR	42	40.5	118	20.7	MICKEY H.S.
ORIGINAL	726	OR	42	32.6	118	31.6	ALVORD H.S.
USED BY NGSDC		OR	42	32.6	118	31.6	ALVORD H.S.
ORIGINAL	726	OR	42	20.1	118	36.0	HOT LAKE
USED BY NGSDC		OR	42	20.1	118	36.0	HOT LAKE
ORIGINAL	726	OR	43	59.4	117	14.1	VALE H.S.
USED BY NGSDC		OR	43	59.4	117	14.1	VALE H.S.
ORIGINAL	726	OR	44	1.4	117	27.6	NEAL H.S.

ORIGINAL 726	OR	42	12.0	120	21.6	LAKEVIEW
USED BY NGSDC	OR	42	12.0	120	21.6	LAKEVIEW
ORIGINAL 726	OR	42	15.0	119	53.0	CRUMPS SPRING
USED BY NGSDC	OR	42	13.8	119	53.0	CRUMPS SPRING
ORIGINAL 726	OR	44	0.0	119	38.8	WEBERG H.S.
USED BY NGSDC	OR	44	0.0	119	38.8	WEBERG H.S.
ORIGINAL 726	UT	38	30.0	112	50.0	ROOSEVELT (MCKEAN) H.S
USED BY NGSDC	UT	38	29.8	112	51.4	ROOSEVELT (MCKEA
ORIGINAL 726	UT	38	36.0	112	33.0	COVE FORT-SULPHURDALE
USED BY NGSDC	UT	38	35.5	112	33.3	COVE FORT-SULPHU
ORIGINAL 726	UT	38	11.0	113	12.2	THERMO H.S.
USED BY NGSDC	UT	38	11.0	113	12.2	THERMO H.S.
ORIGINAL 726	WA	48	45.9	121	40.2	BAKER H.S.
USED BY NGSDC	WA	48	45.9	121	40.2	BAKER H.S.
ORIGINAL 726	WA	48	10.0	121	2.0	GAMMA H.S.
USED BY NGSDC	WA	48	10.0	121	2.0	GAMMA H.S.
ORIGINAL 726	WA	48	7.0	121	11.7	KENNEDY H.S.
USED BY NGSDC	WA	48	7.0	121	11.7	KENNEDY H.S.
ORIGINAL 726	WA	46	45.1	121	48.7	LONGMIRE H.S.
USED BY NGSDC	WA	46	45.1	121	48.7	LONGMIRE H.S.
ORIGINAL 726	WA	46	42.2	121	29.0	SUMMIT CREEK (SODA)
USED BY NGSDC	WA	46	42.2	121	29.0	SUMMIT CREEK (SO
ORIGINAL 726	WY	44	36.0	110	30.0	YELLOWSTONE NATL PK
USED BY NGSDC	WY	44	36.0	110	30.0	YELLOWSTONE NATL
ORIGINAL 726	AZ	34	21.5	111	42.5	VERDE H.S.
USED BY NGSDC	AZ	34	21.5	111	42.5	VERDE H.S.
ORIGINAL 726	AZ	33	59.1	112	21.6	CASTLE H.S.
USED BY NGSDC	AZ	33	59.1	112	21.6	CASTLE H.S.
ORIGINAL 726	AZ	33	4.7	109	18.2	NORTH OF CLIFTON
USED BY NGSDC	AZ	33	4.7	109	18.2	NORTH OF CLIFTON
ORIGINAL 726	AZ	33	3.2	109	17.8	CLIFTON H.S.
USED BY NGSDC	AZ	33	3.2	109	17.8	CLIFTON H.S.

ORIGINAL 726	AZ	33	2.8	109	28.6	EAGLE CREEK SPRING
USED BY NGSDC	AZ	33	2.8	109	26.4	EAGLE CREEK SPRI
ORIGINAL 726	AZ	32	58.5	109	21.0	GILLARD H.S.
USED BY NGSDC	AZ	32	58.5	109	21.0	GILLARD H.S.
ORIGINAL 726	AZ	32	51.4	109	44.9	MT. GRAHAM
USED BY NGSDC	AZ	32	51.4	109	44.9	MT. GRAHAM
ORIGINAL 726	CA	41	27.5	120	50.0	KELLEY H.S.
USED BY NGSDC	CA	41	27.5	120	50.0	KELLEY H.S.
ORIGINAL 726	CA	41	2.1	122	55.1	HUNT H.S.
USED BY NGSDC	CA	41	2.1	121	55.1	HUNT H.S.
ORIGINAL 726	CA	41	1.3	122	55.1	BIG BEND H.S.
USED BY NGSDC	CA	41	1.3	121	55.1	BIG BEND H.S.
ORIGINAL 726	CA	40	40.2	122	38.7	SALT SPRINGS (1)
USED BY NGSDC	CA	40	40.2	122	38.7	SALT SPRINGS (1)
ORIGINAL 726	CA	40	18.0	120	11.0	WENDEL-AMEDEE AREA
USED BY NGSDC	CA	40	16.0	120	11.0	WENDEL-AMEDEE AR
ORIGINAL 726	CA	40	14.5	122	8.4	TUSCAN (LICK) S.
USED BY NGSDC	CA	40	14.3	122	6.6	TUSCAN (LICK) S.
ORIGINAL 726	CA	39	24.8	122	58.6	SODA SPRING
USED BY NGSDC	CA	39	24.8	122	58.6	SODA SPRING
ORIGINAL 726	CA	39	25.8	122	32.3	SALT SPRING (2)
USED BY NGSDC	CA	39	25.8	122	32.3	SALT SPRING (2)
ORIGINAL 726	CA	39	17.4	122	49.3	CRABTREE H.S.
USED BY NGSDC	CA	39	17.4	122	49.3	CRABTREE H.S.
ORIGINAL 726	CA	39	21.0	122	40.1	FOUTS (REDEYE) S.
USED BY NGSDC	CA	39	21.0	122	40.1	FOUTS (REDEYE) S
ORIGINAL 726	CA	39	20.5	122	39.4	FOUTS (CHAMPAGNE) S.
USED BY NGSDC	CA	39	20.5	122	39.4	FOUTS (CHAMPAGNE
ORIGINAL 726	CA	39	13.8	123	21.9	ORRS H.S.
USED BY NGSDC	CA	39	13.8	123	21.9	ORRS H.S.
ORIGINAL 726	CA	39	9.9	123	9.4	VICHY SPRINGS
USED BY NGSDC	CA	39	9.9	123	9.4	VICHY SPRINGS

ORIGINAL 726	CA	39	15.2	122	31.4	COOKS SPRINGS
USED BY NGSDC	CA	39	15.2	122	31.4	COOKS SPRINGS
ORIGINAL 726	CA	39	10.5	122	58.7	SARATOGA SPRINGS
USED BY NGSDC	CA	39	10.5	122	58.7	SARATOGA SPRINGS
ORIGINAL 726	CA	39	2.2	122	25.2	WILBUR H.S. AREA
USED BY NGSDC	CA	39	2.2	122	25.2	WILBUR H.S. AREA
ORIGINAL 726	CA	39	5.1	122	27.4	DEADSHOT SPRING
USED BY NGSDC	CA	39	5.1	122	27.4	DEADSHOT SPRING
ORIGINAL 726	CA	38	52.6	123	30.6	POINT ARENA H.S.
USED BY NGSDC	CA	38	52.6	123	30.6	POINT ARENA H.S.
ORIGINAL 726	CA	38	54.7	123	18.4	ORNBAUN SPRINGS
USED BY NGSDC	CA	38	54.7	123	18.4	ORNBAUN SPRINGS
ORIGINAL 726	CA	38	52.5	122	41.3	SEIGLER SPRINGS
USED BY NGSDC	CA	38	52.5	122	41.3	SEIGLER SPRINGS
ORIGINAL 726	CA	38	53.6	122	31.9	BAKER SODA SPRING
USED BY NGSDC	CA	38	53.6	122	31.9	BAKER SODA SPRIN
ORIGINAL 726	CA	38	50.0	122	21.4	ONE-SHOT MINING CO.
USED BY NGSDC	CA	38	50.0	122	21.4	ONE-SHOT MINING
ORIGINAL 726	CA	38	39.5	122	28.7	AETNA SPRINGS
USED BY NGSDC	CA	38	39.5	122	28.7	AETNA SPRINGS
ORIGINAL 726	CA	38	39.2	122	21.4	WALTER SPRINGS
USED BY NGSDC	CA	38	39.2	122	21.4	WALTER SPRINGS
ORIGINAL 726	CA	38	32.9	122	43.2	MARK WEST SPRINGS
USED BY NGSDC	CA	38	32.9	122	43.2	MARK WEST SPRING
ORIGINAL 726	CA	38	31.1	122	15.6	NAPA SODA S. ROCK(PRIE
USED BY NGSDC	CA	38	31.1	122	15.6	NAPA SODA S. ROC
ORIGINAL 726	CA	38	23.7	122	33.0	LOS GUILICOS W.S.
USED BY NGSDC	CA	38	23.7	122	33.0	LOS GUILICOS W.S
ORIGINAL 726	CA	38	23.4	122	16.7	(JACKSONS) NAPA SODA S
USED BY NGSDC	CA	38	23.4	122	16.7	(JACKSONS) NAPA
ORIGINAL 726	CA	39	13.5	120	.4	BROCKWAY (CORNELIAN) H
USED BY NGSDC	CA	39	13.5	120	.4	BROCKWAY (CORNEL

ORIGINAL 726	CA	38	41.9	119	51.6	GROVERS H.S.
USED BY NGSDC	CA	38	41.9	119	51.6	GROVERS H.S.
ORIGINAL 726	CA	38	20.0	119	24.0	FALES H.S.
USED BY NGSDC	CA	38	20.0	119	24.0	FALES H.S.
ORIGINAL 726	CA	38	14.3	119	19.6	BUCKEYE H.S.
USED BY NGSDC	CA	38	14.3	119	19.6	BUCKEYE H.S.
ORIGINAL 726	CA	37	48.0	118	31.8	BENTON H.S.
USED BY NGSDC	CA	37	48.0	118	31.8	BENTON H.S.
ORIGINAL 726	CA	38	14.8	119	12.1	TRAVERTINE H.S.
USED BY NGSDC	CA	38	14.8	119	12.1	TRAVERTINE H.S.
ORIGINAL 726	CA	38	2.4	119	5.0	NEAR BLACK PT.
USED BY NGSDC	CA	38	2.4	119	5.0	NEAR BLACK PT.
ORIGINAL 726	CA	37	59.8	119	1.2	PAOHA ISLAND
USED BY NGSDC	CA	37	59.8	119	1.2	PAOHA ISLAND
ORIGINAL 726	CA	37	19.5	119	1.0	MONO H.S.
USED BY NGSDC	CA	37	19.5	119	1.0	MONO H.S.
ORIGINAL 726	CA	37	14.1	118	53.0	BLAYNEY MEADOWS H.S.
USED BY NGSDC	CA	37	14.1	118	53.0	BLAYNEY MEADOWS
ORIGINAL 726	CA	36	42.2	120	51.6	MERCEY H.S.
USED BY NGSDC	CA	36	42.2	120	51.6	MERCEY H.S.
ORIGINAL 726	CA	35	23.0	117	32.2	RANDSBURG AREA
USED BY NGSDC	CA	35	23.0	117	32.2	RANDSBURG AREA
ORIGINAL 726	CA	34	8.6	117	15.2	ARROWHEAD H.S. AREA
USED BY NGSDC	CA	34	11.1	117	15.2	ARROWHEAD H.S. A
ORIGINAL 726	CA	33	26.0	115	41.1	PILGER ESTATES H.S.
USED BY NGSDC	CA	33	26.0	115	41.1	PILGER ESTATES H
ORIGINAL 726	CA	33	17.0	116	38.4	WARNER H.S.
USED BY NGSDC	CA	33	17.0	116	38.4	WARNER H.S.
ORIGINAL 726	CA	32	58.0	115	11.0	GLAMIS (E. BRAWLEY)
USED BY NGSDC	CA	32	58.0	115	11.0	GLAMIS (E. BRAWL
ORIGINAL 726	CA	33	59.0	115	4.0	GLAMIS (EAST)
USED BY NGSDC	CA	33	0.0	115	2.1	GLAMIS (EAST)

ORIGINAL 726	CA	32 49.0	115 1.0	DUNES
USED BY NGSDC	CA	32 48.6	115 .7	DUNES
ORIGINAL 726	CO	40 33.6	106 51.0	ROUTT H.S.
USED BY NGSDC	CO	40 33.6	106 51.0	ROUTT H.S.
ORIGINAL 726	CO	40 29.1	106 50.3	STEAMBOAT SPRINGS
USED BY NGSDC	CO	40 29.1	106 50.3	STEAMBOAT SPRING
ORIGINAL 726	CO	39 44.2	105 30.2	IDAHO SPRINGS
USED BY NGSDC	CO	39 44.2	105 30.2	IDAHO SPRINGS
ORIGINAL 726	CO	39 33.0	107 19.3	GLENWOOD SPRINGS
USED BY NGSDC	CO	39 33.0	107 19.3	GLENWOOD SPRINGS
ORIGINAL 726	CO	39 13.9	107 13.5	AVALANCHE SPRINGS
USED BY NGSDC	CO	39 13.9	107 13.5	AVALANCHE SPRING
ORIGINAL 726	CO	38 48.7	106 13.5	COTTONWOOD SPRINGS
USED BY NGSDC	CO	38 48.7	106 13.5	COTTONWOOD SPRIN
ORIGINAL 726	CO	38 43.9	106 10.2	MT. PRINCETON S.
USED BY NGSDC	CO	38 43.9	106 10.2	MT. PRINCETON S.
ORIGINAL 726	CO	38 29.9	106 4.5	PONCHA H.S.
USED BY NGSDC	CO	38 29.9	106 4.5	PONCHA H.S.
ORIGINAL 726	CO	38 10.1	105 55.0	MINERAL H.S.
USED BY NGSDC	CO	38 10.1	105 55.0	MINERAL H.S.
ORIGINAL 726	CO	38 31.0	106 29.1	WAUNITA H.S.
USED BY NGSDC	CO	38 30.7	106 30.4	WAUNITA H.S.
ORIGINAL 726	CO	38 16.5	107 5.9	CEBOLLA H.S.
USED BY NGSDC	CO	38 16.5	107 5.9	CEBOLLA H.S.
ORIGINAL 726	CO	38 8.0	107 44.0	ORVIS H.S.
USED BY NGSDC	CO	38 8.0	107 44.0	ORVIS H.S.
ORIGINAL 726	CO	37 45.0	106 49.2	WAGON WHEEL GAP
USED BY NGSDC	CO	37 45.0	106 49.2	WAGON WHEEL GAP
ORIGINAL 726	CO	37 15.5	107 .5	PAGOSA H.S.
USED BY NGSDC	CO	37 15.5	107 .5	PAGOSA H.S.
ORIGINAL 726	ID	45 47.3	115 8.8	RED RIVER H.S.
USED BY NGSDC	ID	45 47.2	115 11.9	RED RIVER H.S.

ORIGINAL 726	ID	45	24.7	116	28.5	RIGGINS H.S.
USED BY NGSDC	ID	45	24.9	116	10.3	RIGGINS H.S.
ORIGINAL 726	ID	45	16.7	115	55.2	BURGDORF H.S.
USED BY NGSDC	ID	45	16.7	115	55.2	BURGDORF H.S.
ORIGINAL 726	ID	45	2.6	116	17.0	ZIMS (YOGHANN) H.S.
USED BY NGSDC	ID	45	2.6	116	17.0	ZIMS (YOGHANN) H
ORIGINAL 726	ID	44	58.1	116	11.4	KRIGBAUM H.S.
USED BY NGSDC	ID	44	58.1	116	11.4	KRIGBAUM H.S.
ORIGINAL 726	ID	44	51.2	116	25.8	STARKEY H.S.
USED BY NGSDC	ID	44	51.2	116	25.8	STARKEY H.S.
ORIGINAL 726	ID	44	40.9	116	13.8	WHITE LICKS H.S.
USED BY NGSDC	ID	44	40.9	116	13.8	WHITE LICKS H.S.
ORIGINAL 726	ID	44	35.0	116	37.7	NEAR COVE SCHOOL
USED BY NGSDC	ID	44	35.0	116	37.7	NEAR COVE SCHOOL
ORIGINAL 726	ID	44	32.4	116	45.0	NEAR DEER CREEK
USED BY NGSDC	ID	44	32.4	116	45.0	NEAR DEER CREEK
ORIGINAL 726	ID	44	28.3	116	43.9	NEAR MIDVALE
USED BY NGSDC	ID	44	28.3	116	43.9	NEAR MIDVALE
ORIGINAL 726	ID	44	28.2	116	45.9	NEAR MIDVALE AIRPRT.
USED BY NGSDC	ID	44	27.8	116	45.9	NEAR MIDVALE AIR
ORIGINAL 726	ID	44	38.5	116	2.7	HOT CREEK SPRINGS
USED BY NGSDC	ID	44	38.5	116	2.7	HOT CREEK SPRING
ORIGINAL 726	ID	44	38.3	115	41.6	MOLLYS H.S.
USED BY NGSDC	ID	44	38.3	115	41.6	MOLLYS H.S.
ORIGINAL 726	ID	44	34.1	115	41.5	VULCAN H.S.
USED BY NGSDC	ID	44	34.1	115	41.5	VULCAN H.S.
ORIGINAL 726	ID	44	25.0	116	1.7	CABARTON H.S.
USED BY NGSDC	ID	44	25.0	116	1.7	CABARTON H.S.
ORIGINAL 726	ID	44	21.9	115	51.4	BOILING SPRINGS
USED BY NGSDC	ID	44	21.9	115	51.4	BOILING SPRINGS
ORIGINAL 726	ID	44	5.1	116	3.0	NEAR PAYETTE RIVER
USED BY NGSDC	ID	44	5.1	116	3.0	NEAR PAYETTE RIV

ORIGINAL 726	ID	44	2.8	115	51.1	NEAR GRIMES PASS
USED BY NGSDC	ID	44	2.8	115	51.1	NEAR GRIMES PASS
ORIGINAL 726	ID	44	4.3	115	32.6	KIRKHAM H.S.
USED BY NGSDC	ID	44	4.3	115	32.6	KIRKHAM H.S.
ORIGINAL 726	ID	44	9.5	115	18.4	BONNEVILLE H.S.
USED BY NGSDC	ID	44	9.5	115	18.4	BONNEVILLE H.S.
ORIGINAL 726	ID	44	13.5	114	55.6	STANLEY H.S.
USED BY NGSDC	ID	44	13.5	114	55.6	STANLEY H.S.
ORIGINAL 726	ID	44	16.1	114	44.9	SUNBEAM H.S.
USED BY NGSDC	ID	44	16.1	114	44.9	SUNBEAM H.S.
ORIGINAL 726	ID	44	10.1	114	37.5	SLATE CREEK H.S.
USED BY NGSDC	ID	44	10.1	114	37.5	SLATE CREEK H.S.
ORIGINAL 726	ID	43	57.2	116	18.0	ROYSTONE H.S.
USED BY NGSDC	ID	43	57.1	116	21.2	ROYSTONE H.S.
ORIGINAL 726	ID	43	36.1	116	9.9	N.E. BOISE THERMAL ARE
USED BY NGSDC	ID	43	36.1	116	9.9	N.E. BOISE THERM
ORIGINAL 726	ID	43	45.5	115	34.7	NEINMEYER H.S.
USED BY NGSDC	ID	43	45.5	115	34.7	NEINMEYER H.S.
ORIGINAL 726	ID	43	47.7	115	25.5	DUTCH FRANK SPRINGS
USED BY NGSDC	ID	43	47.7	115	25.5	DUTCH FRANK SPRI
ORIGINAL 726	ID	43	33.2	115	16.3	PARADISE H.S.
USED BY NGSDC	ID	43	33.2	115	16.3	PARADISE H.S.
ORIGINAL 726	ID	43	33.5	114	47.2	WORSWICK H.S.
USED BY NGSDC	ID	43	33.5	114	47.2	WORSWICK H.S.
ORIGINAL 726	ID	43	40.5	114	24.6	GUYER H.S.
USED BY NGSDC	ID	43	40.5	114	24.6	GUYER H.S.
ORIGINAL 726	ID	43	33.6	114	24.9	CLARENDON H.S.
USED BY NGSDC	ID	43	33.6	114	24.9	CLARENDON H.S.
ORIGINAL 726	ID	43	30.3	114	22.2	HAILEY H.S.
USED BY NGSDC	ID	43	30.3	114	22.2	HAILEY H.S.
ORIGINAL 726	ID	43	32.4	113	30.1	NEAR BROCKIE AIRPT
USED BY NGSDC	ID	43	32.4	113	30.1	NEAR BROCKIE AIR

ORIGINAL 726	ID	43	25.4	114	37.6	ELK CREEK H.S.
USED BY NGSDC	ID	43	25.4	114	37.6	ELK CREEK H.S.
ORIGINAL 726	ID	43	18.1	114	54.4	NEAR PUNKIN CORNER
USED BY NGSDC	ID	43	18.1	114	54.4	NEAR PUNKIN CORN
ORIGINAL 726	ID	43	18.1	114	54.4	BARRONS H.S.
USED BY NGSDC	ID	43	17.5	114	54.4	BARRONS H.S.
ORIGINAL 726	ID	43	19.7	114	23.2	NEAR MAGIC RESERVOIR
USED BY NGSDC	ID	43	19.7	114	24.0	NEAR MAGIC RESER
ORIGINAL 726	ID	43	6.9	115	27.9	NEAR BENNETT CREEK
USED BY NGSDC	ID	43	6.9	115	26.8	NEAR BENNETT CRE
ORIGINAL 726	ID	43	7.0	115	18.3	LATTY H.S.
USED BY NGSDC	ID	43	7.0	115	18.3	LATTY H.S.
ORIGINAL 726	ID	43	5.8	115	24.6	NEAR RYEGRASS CREEK
USED BY NGSDC	ID	43	5.8	115	24.6	NEAR RYEGRASS CR
ORIGINAL 726	ID	43	2.2	115	27.5	NEAR RADIO TOWERS
USED BY NGSDC	ID	43	2.2	115	27.5	NEAR RADIO TOWER
ORIGINAL 726	ID	43	2.9	114	57.2	WHITE ARROW H.S.
USED BY NGSDC	ID	43	2.9	114	57.2	WHITE ARROW H.S.
ORIGINAL 726	ID	43	2.9	114	55.0	NEAR CHALK MINE
USED BY NGSDC	ID	43	2.9	114	55.0	NEAR CHALK MINE
ORIGINAL 726	ID	43	1.4	115	.6	NEAR CLOVER CREEK
USED BY NGSDC	ID	43	1.4	115	.6	NEAR CLOVER CREE
ORIGINAL 726	ID	42	54.3	115	29.5	NEAR GRAVEL PITS
USED BY NGSDC	ID	42	56.5	115	29.2	NEAR GRAVEL PITS
ORIGINAL 726	ID	42	56.0	115	56.0	BRUNEAU-GRANDVIEW
USED BY NGSDC	ID	42	56.0	115	56.0	BRUNEAU-GRANDVIE
ORIGINAL 726	ID	42	41.4	114	50.0	NEAR BANBURY
USED BY NGSDC	ID	42	41.4	114	50.0	NEAR BANBURY
ORIGINAL 726	ID	42	24.9	114	18.1	NEAR CEDAR HILL
USED BY NGSDC	ID	42	24.9	114	18.1	NEAR CEDAR HILL
ORIGINAL 726	ID	42	28.7	113	37.5	NEAR BRIDGER SPRINGS
USED BY NGSDC	ID	42	28.7	113	30.5	NEAR BRIDGER SPR

ORIGINAL	726	ID	42	10.4	113	51.7	OAKLEY WARM SPRINGS
USED BY NGSDC		ID	42	10.4	113	51.7	OAKLEY WARM SPRI
ORIGINAL	726	ID	42	6.1	113	22.8	RAFT RIVER THERMAL ARE
USED BY NGSDC		ID	42	5.1	113	22.8	RAFT RIVER THERM
ORIGINAL	726	ID	42	18.2	111	42.2	MAPLE GROVE H.S.
USED BY NGSDC		ID	42	18.2	111	42.2	MAPLE GROVE H.S.
ORIGINAL	726	ID	42	9.9	111	50.4	NEAR RIVERDALE
USED BY NGSDC		ID	42	9.9	111	50.4	NEAR RIVERDALE
ORIGINAL	726	ID	42	8.2	111	56.9	WAYLAND H.S.
USED BY NGSDC		ID	42	8.1	111	55.8	WAYLAND H.S.
ORIGINAL	726	ID	43	53.2	111	35.4	NEAR NEWDALE
USED BY NGSDC		ID	43	53.2	111	35.4	NEAR NEWDALE
ORIGINAL	726	ID	44	5.7	111	27.5	ASHTON WARM SPRINGS
USED BY NGSDC		ID	44	5.7	111	27.5	ASHTON WARM SPRI
ORIGINAL	726	MT	46	36.5	112	5.0	HELENA (BROADWATER) HS
USED BY NGSDC		MT	46	36.5	112	5.0	HELENA (BROADWAT
ORIGINAL	726	MT	46	32.8	110	54.2	WHITE SULPHUR SPRINGS
USED BY NGSDC		MT	46	32.8	110	54.2	WHITE SULPHUR SP
ORIGINAL	726	MT	46	27.0	111	59.0	ALHAMBRA H.S.
USED BY NGSDC		MT	46	27.0	111	59.0	ALHAMBRA H.S.
ORIGINAL	726	MT	46	12.0	112	5.6	BOULDER H.S.
USED BY NGSDC		MT	46	12.0	112	5.6	BOULDER H.S.
ORIGINAL	726	MT	46	2.6	112	48.4	GREGSON (FAIRMONT) H.S
USED BY NGSDC		MT	46	2.6	112	48.4	GREGSON (FAIRMON
ORIGINAL	726	MT	45	53.8	112	13.9	PIPESTONE H.S.
USED BY NGSDC		MT	45	53.8	112	13.9	PIPESTONE H.S.
ORIGINAL	726	MT	45	41.5	112	17.2	BARKELS (SILVER STAR)
USED BY NGSDC		MT	45	41.5	112	17.2	BARKELS (SILVER
ORIGINAL	726	MT	45	34.6	111	41.0	NORRIS (HAPGOOD) H.S.
USED BY NGSDC		MT	45	34.6	111	41.0	NORRIS (HAPGOOD)
ORIGINAL	726	MT	45	21.8	113	24.7	JARDINE (BIG HOLE OR J
USED BY NGSDC		MT	45	21.8	113	24.7	JARDINE (BIG HOL

ORIGINAL 726	NV	41	55.5	118	48.1	BOG H.S.
USED BY NGSDC	NV	41	55.5	118	48.1	BOG H.S.
ORIGINAL 726	NV	41	43.3	118	30.3	HOWARD H.S.
USED BY NGSDC	NV	41	43.3	118	30.3	HOWARD H.S.
ORIGINAL 726	NV	41	34.0	118	33.7	DYKE H.S.
USED BY NGSDC	NV	41	34.0	118	33.7	DYKE H.S.
ORIGINAL 726	NV	41	21.5	119	13.2	NEAR SOLDIER MEADOW
USED BY NGSDC	NV	41	21.5	119	13.2	NEAR SOLDIER MEA
ORIGINAL 726	NV	41	3.0	119	2.8	DOUBLE H.S.
USED BY NGSDC	NV	41	3.0	119	2.8	DOUBLE H.S.
ORIGINAL 726	NV	40	57.0	118	58.0	NEAR BLACK ROCK
USED BY NGSDC	NV	40	57.0	119	.2	NEAR BLACK ROCK
ORIGINAL 726	NV	40	52.0	119	20.9	FLY RANCH H.S.
USED BY NGSDC	NV	40	52.0	119	20.9	FLY RANCH H.S.
ORIGINAL 726	NV	40	46.0	119	7.0	BUTTE SPRS.
USED BY NGSDC	NV	40	46.0	119	7.0	BUTTE SPRS.
ORIGINAL 726	NV	41	47.3	114	43.3	MINERAL H.S.
USED BY NGSDC	NV	41	47.3	114	43.3	MINERAL H.S.
ORIGINAL 726	NV	40	49.1	115	46.5	HOT HOLE (ELKO)
USED BY NGSDC	NV	40	49.1	115	46.5	HOT HOLE (ELKO)
ORIGINAL 726	NV	40	42.0	116	8.0	NEAR CARLIN
USED BY NGSDC	NV	40	42.0	116	8.0	NEAR CARLIN
ORIGINAL 726	NV	41	9.4	114	59.1	HOT SULPHUR SPRS.
USED BY NGSDC	NV	41	9.4	114	59.1	HOT SULPHUR SPRS
ORIGINAL 726	NV	40	24.2	116	31.0	HOT SPRINGS POINT
USED BY NGSDC	NV	40	24.2	116	31.0	HOT SPRINGS POIN
ORIGINAL 726	NV	39	54.1	116	35.2	WALTI H.S.
USED BY NGSDC	NV	39	54.1	116	35.2	WALTI H.S.
ORIGINAL 726	NV	39	19.0	116	51.0	SPENCER H.S.
USED BY NGSDC	NV	39	19.0	116	51.0	SPENCER H.S.
ORIGINAL 726	NV	40	55.3	117	6.5	HOT POT
USED BY NGSDC	NV	40	55.3	117	6.5	HOT POT

ORIGINAL 726	NV	40 22.1	117 19.5	BUFFALO VALLEY H.S.
USED BY NGSDC	NV	40 22.1	117 19.5	BUFFALO VALLEY H
ORIGINAL 726	NV	41 25.4	117 23.0	HOT SPRINGS
USED BY NGSDC	NV	41 25.4	117 23.0	HOT SPRINGS
ORIGINAL 726	NV	40 57.7	117 29.6	GOLCONDA H.S.
USED BY NGSDC	NV	40 57.7	117 29.6	GOLCONDA H.S.
ORIGINAL 726	NV	40 5.4	117 43.5	SOU (GILBERTS) H.S.
USED BY NGSDC	NV	40 5.4	117 43.5	SOU (GILBERTS) H
ORIGINAL 726	NV	39 47.9	118 4.0	DIXIE H.S.
USED BY NGSDC	NV	39 47.9	118 4.0	DIXIE H.S.
ORIGINAL 726	NV	40 8.8	119 40.5	THE NEEDLES
USED BY NGSDC	NV	40 8.8	119 40.5	THE NEEDLES
ORIGINAL 726	NV	38 58.9	119 49.9	WALLEYS H.S.
USED BY NGSDC	NV	38 58.9	119 49.9	WALLEYS H.S.
ORIGINAL 726	NV	38 54.0	119 24.7	NEVADA H.S.
USED BY NGSDC	NV	38 54.0	119 24.7	NEVADA H.S.
ORIGINAL 726	NV	38 49.3	117 10.8	DARROUGH H.S.
USED BY NGSDC	NV	38 49.3	117 10.8	DARROUGH H.S.
ORIGINAL 726	NV	38 11.3	116 22.5	WARM SPRINGS
USED BY NGSDC	NV	38 11.3	116 22.5	WARM SPRINGS
ORIGINAL 726	NV	39 24.3	116 20.8	BARTHOLOMAE H.S.
USED BY NGSDC	NV	39 24.3	116 20.8	BARTHOLOMAE H.S.
ORIGINAL 726	NM	35 47.0	106 41.0	JEMEZ (OJOS CALIENTES)
USED BY NGSDC	NM	35 46.1	106 41.5	JEMEZ (OJOS CALI
ORIGINAL 726	NM	32 30.0	106 55.5	RADIUM H.S.
USED BY NGSDC	NM	32 30.0	106 55.5	RADIUM H.S.
ORIGINAL 726	NM	33 15.0	108 47.0	LOWER FRISCO
USED BY NGSDC	NM	33 14.7	108 52.8	LOWER FRISCO
ORIGINAL 726	NM	33 12.0	108 12.0	GILA H.S.
USED BY NGSDC	NM	33 12.0	108 12.0	GILA H.S.
ORIGINAL 726	OR	45 22.5	121 42.5	MT. HOOD
USED BY NGSDC	OR	45 22.5	121 42.5	MT. HOOD

ORIGINAL 726	OR	45	1.2	122	.6	CAREY (AUSTIN) H.S.
USED BY NGSDC	OR	45	1.2	122	.6	CAREY (AUSTIN) H
ORIGINAL 726	OR	44	51.9	121	12.9	KAHNEETAH H.S.
USED BY NGSDC	OR	44	51.9	121	12.9	KAHNEETAH H.S.
ORIGINAL 726	OR	44	46.9	121	58.5	BREITENBUSH H.S.
USED BY NGSDC	OR	44	46.9	121	58.5	BREITENBUSH H.S.
ORIGINAL 726	OR	44	11.6	122	3.2	BELKNAP H.S.
USED BY NGSDC	OR	44	11.6	122	3.2	BELKNAP H.S.
ORIGINAL 726	OR	42	15.0	121	45.0	KLAMATH FALLS
USED BY NGSDC	OR	42	14.0	121	46.0	KLAMATH FALLS
ORIGINAL 726	OR	42	43.5	120	38.7	SUMMER LAKE H.S.
USED BY NGSDC	OR	42	43.5	120	38.7	SUMMER LAKE H.S.
ORIGINAL 726	OR	44	55.8	117	56.4	RADIUM H.S.
USED BY NGSDC	OR	44	55.8	117	56.4	RADIUM H.S.
ORIGINAL 726	OR	45	14.6	117	57.6	HOT LAKE (2)
USED BY NGSDC	OR	45	14.6	117	57.6	HOT LAKE (2)
ORIGINAL 726	OR	45	1.1	117	37.5	MEDICAL H.S.
USED BY NGSDC	OR	45	1.1	117	37.5	MEDICAL H.S.
ORIGINAL 726	OR	44	53.7	119	8.6	RITTER H.S.
USED BY NGSDC	OR	44	53.7	119	8.6	RITTER H.S.
ORIGINAL 726	OR	42	17.9	119	46.5	FISHER H.S.
USED BY NGSDC	OR	42	17.9	119	46.5	FISHER H.S.
ORIGINAL 726	OR	44	21.3	118	34.4	BLUE MOUNTAIN H.S.
USED BY NGSDC	OR	44	21.3	118	34.4	BLUE MOUNTAIN H.
ORIGINAL 726	OR	43	53.5	117	30.0	NEAR LITTLE VALLEY
USED BY NGSDC	OR	43	53.5	117	30.0	NEAR LITTLE VALL
ORIGINAL 726	OR	43	56.7	118	8.2	BEULAH H.S.
USED BY NGSDC	OR	43	56.7	118	8.2	BEULAH H.S.
ORIGINAL 726	OR	43	28.0	118	11.3	NEAR RIVERSIDE
USED BY NGSDC	OR	43	28.0	118	11.3	NEAR RIVERSIDE
ORIGINAL 726	OR	43	26.4	118	38.4	CRANE H.S.
USED BY NGSDC	OR	43	26.4	118	38.4	CRANE H.S.

ORIGINAL	726	OR	43	10.9	119	6.2	NEAR HARNEY LAKE
USED BY NGSDC		OR	43	10.9	119	3.2	NEAR HARNEY LAKE
ORIGINAL	726	OR	42	11.3	118	9.2	NEAR TROUT CREEK
USED BY NGSDC		OR	42	11.4	118	23.0	NEAR TROUT CREEK
ORIGINAL	726	OR	42	4.1	117	30.0	NEAR MCDERMITT
USED BY NGSDC		OR	42	4.7	117	45.6	NEAR MCDERMITT
ORIGINAL	726	UT	41	8.0	112	11.3	HOOPER H.S.
USED BY NGSDC		UT	41	8.3	112	10.1	HOOPER H.S.
ORIGINAL	726	UT	40	29.0	111	54.0	CRYSTAL H.S.
USED BY NGSDC		UT	40	29.0	111	54.0	CRYSTAL H.S.
ORIGINAL	726	UT	39	36.8	112	43.9	BAKER (ABRAHAM, CRATER
USED BY NGSDC		UT	39	36.8	112	43.9	BAKER (ABRAHAM,
ORIGINAL	726	UT	38	51.8	112	30.0	MEADOW H.S.
USED BY NGSDC		UT	38	51.8	112	30.0	MEADOW H.S.
ORIGINAL	726	UT	38	38.2	112	6.4	MONROE (COOPER) H.S.
USED BY NGSDC		UT	38	38.2	112	6.4	MONROE (COOPER)
ORIGINAL	726	UT	38	36.7	112	11.2	JOSEPH H.S.
USED BY NGSDC		UT	38	36.7	112	11.2	JOSEPH H.S.
ORIGINAL	726	WA	47	58.1	123	52.1	SOL DUC H.S.
USED BY NGSDC		WA	47	58.1	123	52.1	SOL DUC H.S.
ORIGINAL	726	WA	47	58.9	123	41.2	OLYMPIC H.S.
USED BY NGSDC		WA	47	58.9	123	41.2	OLYMPIC H.S.
ORIGINAL	726	WA	48	15.3	121	10.8	SULPHUR CREEK H.S.
USED BY NGSDC		WA	48	15.3	121	10.8	SULPHUR CREEK H.
ORIGINAL	726	WA	47	20.5	121	53.4	GARLAND (SAN JUAN)
USED BY NGSDC		WA	47	53.5	121	20.5	GARLAND (SAN JUA
ORIGINAL	726	WA	46	44.2	121	33.6	CHANAPECOSH H.S.
USED BY NGSDC		WA	46	44.2	121	33.6	CHANAPECOSH H.S.
ORIGINAL	726	WY	44	7.0	110	41.0	HUCKLEBERRY H.S.
USED BY NGSDC		WY	44	7.0	110	41.0	HUCKLEBERRY H.S.
ORIGINAL	726	WY	42	49.5	111	0.0	AUBURN H.S.
USED BY NGSDC		WY	42	49.5	111	0.0	AUBURN H.S.

Glen Lowry - put him on mailing list

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PROGRAM PLAN FOR IMPLEMENTATION OF

GEOTHERMAL RESOURCE DEVELOPMENT IN THE SOUTHWEST

Presentation

to the

Rocky Mountain Chapter of the Geothermal Resources Council

January 26, 1978
Denver, Colorado

B. B. Barnes
Mission Team Leader
Southwest Region
Division of Geothermal Energy
Department of Energy

Presentation made to the Geothermal Resources Council, Rocky Mountain Chapter
Denver, Colorado - January 26, 1978

PROGRAM PLAN FOR IMPLEMENTATION OF GEOTHERMAL RESOURCE DEVELOPMENT IN THE SOUTHWEST

B. B. Barnes, DOE/DGE

Before describing to you the Federal program plan for implementation of geothermal resource development in the Southwest, I would like to reference an article published in the November 28 issue of TIME MAGAZINE. The article refers to the Administration's energy program and where it now stands as a legislative proposal before the Congress. A criticism and a recommendation are presented in the article which comprise the substance of my comments. What the article advises is directly related to an approach being taken by the Division of Geothermal Energy through a recently initiated effort to produce collective planning using state and regional planning teams. The bottom line of the article is a criticism that the energy plan's greatest weakness is it's lack of a strong program for developing alternative energy sources -- a criticism shared by many. Neither the Senate nor the House has succeeded in correcting the imbalance, although proponents for geothermal energy can take some satisfaction from several proposals that are included regarding tax incentives. Undoubtedly, these will go a long way towards helping to further development investment and thus stimulate activity, if enacted. The author notes that an important first step has been made in producing a National Energy Plan, but advises the Administration to make a serious effort to involve the public in it's preparation of future energy legilation. This recommendation has significance as we examine our own efforts to formulate a National Geothermal Program. You should be aware that a first step in this direction is already underway which will bring together Federal, state and local governments with the public and private sectors in a collective planning unit. In the Southwest Region, comprised of the states of Colorado, New Mexico, Arizona, Nevada and Utah, we have such a planning group. A grass roots approach is what is involved which we think will provide the kind of involvement the author of the TIME article felt was lacking in the energy plan for the Nation.

Moving now to the subject of my presentation, I would first like to outline for you the present program and then relate this to the strategy for implementation of geothermal resource development. The major subprogram elements (SLIDE 1) which relate to the Division of Geothermal Energy's research, development and demonstration activities are defined in six (6) budget categories and form the basis from which the Division funds contracts to carry out it's program responsibilities. The subprograms are identified as: (1) Engineering R & D; (2) Resource Exploration and Assessment; (3) Hydrothermal Technology Applications; (4) Advanced Technology Applications; (5) Utilization Experiments; and, (6) Environmental Control and Institutional Studies. A Geothermal Loan Guaranty Program, now administered by the Assistant Secretary for Resource Applications in the Department of Energy, also forms the basis of the Federal geothermal program. The specific programmatic substance contained in each of the subprogram elements are outlined in detail in the handout I have prepared for you. Time will not permit me to describe them completely, however I will elaborate on some specific projects that are significant to the region later.

The current program budget for Fiscal Year 1978 totals $103.7 million and represents a sizable increase over previous years (SLIDE 2) and if Congress is so inclined, we can expect an additional increase of about 20 percent for next year. At this point, it might be helpful if I described the organizational structure and respective functions for implementing the Federal Program. As you will see, the organizational structure is mission-oriented as opposed to research-oriented and it comprises many more participants than just the Division of Geothermal Energy (SLIDE 3). There is a certain uniqueness in this organizational structure -- not so much because of the mission-oriented approach and matrix management, but because of the tie the program has to the Interagency Geothermal Coordinating Council (IGCC) and the non-Federal entity, the Advisory Committee on Geothermal Energy (ACGE). The uniqueness comes from the fact that the IGCC is a statutory body provided for originally in the Geothermal Research, Development and Demonstration Act of 1974 (P.L. 93-410). Interagency coordination is mandated and not a perfunctory duty. The Division of Geothermal Energy (DGE), through the IGCC, has the responsibility of coordinating the planning of the Federal Geothermal R, D & D program and to coordinate activities of the several agencies involved in achieving the National program goal and objectives. The objectives of the Federal program are to provide the Nation with viable options, which if exercised, should lead to an environmentally acceptable, time-phased, commercial development of the resource, and encourage actively the exercise of these options to achieve National energy goals.

To facilitate the implementation of the program for geothermal development, the Division has adopted what I have referred to as a mission-oriented approach to assist the private sector in the commercialization of the resource. Under this approach, the goal is to accelerate actual commercial utilization in an environmentally acceptable manner. The objective is "power-on-line", (SLIDE whether it be electric generation or direct thermal (non-electric) utilization. Implementation is by way of Federal initiatives that are intended to produce results in a planned and rational time-phased manner. The planned time sequence for bringing about geothermal production in commercial quantities constitutes the <u>mission</u> and is described in the form of development <u>scenarios</u>

associated with site-specific development. The initiatives may be either technical or non-technical or both. Perhaps now you understand my earlier comments about efforts currently in progress by our regional operations research study team. This team, comprised of representatives from each of the states in the region, is preparing site-specific development scenarios that postulate our objective in terms of schedules for power-on-line by when and how much. Our success in achieving the mission will depend on the initiatives we employ and the strategy used to bring it about. The responsibility for success is shared by the many participants I have listed: the Federal, state and local governments; the private sector; and, the public interest groups. It is the intent of the Federal program, which I have outlined for you, to promote such technical, financial and institutional support, leadership and assistance as necessary to accomplish the power-on-line targets articulated in the development scenarios.

Thus far, I have made much reference to a regional structure -- please let me explain. The Division, in it's efforts to achieve mission-oriented program planning, has subdivided the United States into regions (SLIDE 4B) and assigned each region a Mission Team Leader; I represent the Team Leader for Region IV, the Southwest Region. Team membership is comprised of representatives from the Division's research components; the other organizations in the Energy Department; the other Federal agencies and the public and private sectors, as required. In a sense then, you represent part of the mission team as your representative is now engaged in designing the development scenarios and postulating site-specific and regional power-on-line targets.

Earlier, I made reference to wanting to elaborate on some of the Division's R & D projects currently underway and which hopefully will impact on development of geothermal energy in the Southwest Region. I think we would all agree that a list of our most pressing technology concerns would have to include those technical vagaries associated with our inadequate knowledge of the following: 1) resource availability; 2) reservoir reliability; and, 3) the environmental impact of development and how it can be controlled. We can also enumerate our non-technological concerns associated with our inability to deal with certain legal, institutional and regulatory impediments that act as barriers to geothermal development. I would like to take a moment to describe to you, briefly, some of the Division's planned and on-going efforts to reduce these concerns and build confidence in the future for geothermal resource development.

Several projects are in the process of implementation to deal with the technical concerns I enumerated. Three of these projects I will describe embody a strategy aimed at stimulating industry through Federal R & D subsidy in the area of resource exploration and assessment (SLIDE 5). The first of these projects is described as an industry-coupled case study program which consists of Federal cost-sharing with industry for exploration and step-out wells in return for data on the reservoir. This program is designed to accelerate confirmation drilling and provide basic information on the nature of geothermal hydrothermal reservoirs of apparent commercial production potential. The initial request for proposals (RFP), published last August, resulted in the awarding of six (6) contracts to drill and/or provide data from existing wells at sites in Southern Utah. Operations are currently underway, as I am sure many of you are already aware. We plan by August of this year, to award additional contracts under this project for drilling or data in the Northern Basin and Range Province, which includes the northern part of Nevada, southern Idaho, southwestern part of Oregon and part of the eastern edge of California to the north. The RFP related to this second in-

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dustry-coupled case study will be published within 30 days.

The second project, which incidentally may be part of the effort some of you here today are engaged in, is the State Cooperative Project in resource assessment of low to moderate temperature geothermal hydrothermal resources. It is a project that dove-tails with the regional operations research study which I mentioned earlier. The State Cooperative Project is a cooperative effort with the individual states, the Division and the USGS to evaluate low to moderate temperature reservoirs for possible direct thermal applications. It is a two-phase project involving first an inventory of available resource data, and second, actual exploration and assessment by drilling. The Pagosa Springs, Colorado site is currently be drilled as part of this project.

A third project consists of a cooperative effort with the USGS to confirm the existence of geothermal reservoirs, the potential of which is too speculative to attract industry. This project, dubbed the Pre-commercial Project, if successful, will substantially contribute to the number of new prospects required to reach mid and far-term objectives of the development scenarios and targets set for power-on-line. It will also provide the basic resource characterization necessary to guide the development of the Hot Dry Rock Program, currently underway at the Los Alamos Scientific Laboratory.

As we examine our concerns related to the environment, we need to recognize that geothermal energy, like most energy technologies, has certain undesirable environmental characteristics that affect its selection for use, whether for electric power generation or for direct thermal utilization. In contrast to conventional systems in which resource extraction, processing storage, and power conversion are geographically dispersed, the entire power cycle for geothermal systems takes place where the resource is located. Consequently, the environmental impact is largely confined to the region surrounding the resource extraction site. Concerns are being expressed regarding: 1) noise pollution during field development; 2) possible thermal release due to low efficiency of the power conversion system; 3) particulate and gaseous effluents, such as hydrogen sulphide; and, 4) possible land subsidence and induced seismic activity arising from withdrawal and reinjection of the fluids.

The approach the Division is taking towards alleviating concerns about the consequent environmental impact of the aforementioned items is to demonstrate that environmental control technology is well enough advanced to place geothermal development in the category of being environmentally neutral if compared to alternate energy sources, such as coal or nuclear energy. This can be accomplished by performing site-specific environmental analyses that compare alternative energy production with geothermal, using the best available technology for pollution abatement and Federal and State environmental standards as guidelines. The identification of geothermal energy as a "small-scale", "intermediate" or appropriate technology and a viable alternative to larger, centralized, electric, coal and nuclear-based technologies that are currently forecast to become an important part of the energy delivery system, can be an important part of the strategy to convince the public and industry that geothermal merits consideration over less environmentally secure alternatives. Indeed, the utilization of geothermal energy might, in certain alternative energy developments, actually assist in the mitigation of environmental restraints. One such application the Division is currently studying is in combining geothermal with fossil fuel in a geothermal/fossil fuel hybrid power plant concept. Geothermal energy, in addition to being used to increase overall energy productivity and economic efficiency, could be used in the coal preparation process to remove sulphur and thus enable coal-fired plants to meet environmental standards for sulphur dioxide emissions.

I would like to now shift the focus to several non-technical initiatives that are underway to help to reduce the legal, institutional and regulatory impediments I mentioned earlier. The Division has devoted considerable effort towards developing policy and measures to reduce the investment risk level so that geothermal development is compatible with normal private sector investment practices. These initiatives, many of which are now incorporated in the President's National Energy Plan and the Administration's legislative proposal now before the Congress, include recommendations to introduce new legislation, amend or revise existing legislation and/or regulations affecting: 1) tax policy; 2) leasing of public lands and land management policy; 3) streamlining the environmental review procedures; and 4) coordinating utility regulatory policy regarding transmission access and treatment of geothermal investments in the rate base. How successful these initiatives will be, in terms of their impact on geothermal development, remains to be seen as they are enacted. How well they are received by the decision-makers who will see to it they are enacted depends on the support and cooperation of many including, the Administration; the Congress; Federal, state and local government agencies; municipal and privately-owned utilities; environmental and other public interest groups; and, the industry itself. Coupled with initiatives to foster development through policy change, is an effort toward gaining public acceptance of geothermal resource development through the dissemination of information and education. In the very near future you will be hearing much more of this effort which I refer to as the "Outreach Project".

A number of other non-technical initiatives are underway or in planning, which, if implemented, could have significant impact on the rate of development.

A substantial effort is being made to develop the following initiatives:

-- reviewing the legal and institutional complications associated with providing Federal reservoir indemnity insurance to assure users of geothermal energy of the reliability and longevity of hydrothermal resource utilization

-- amending and/or revision of the legislation and regulations associated with the Geothermal Loan Guaranty Program

-- establishing task force groups made up of local, state and Federal participants to effectively deal with non-conformity in the various laws, definitions and policy regarding geothermal resources and its development

-- analyzing the economic and potential marketability of geothermal energy for both electrical and direct thermal applications at specific sites and for specific targets of opportunity (SLIDE 6)

-- initiating feasibility studies for utilization of geothermal energy in Government Buildings

Before concluding this presentation, I want to mention a policy which we in the Washington Headquarters are currently in the process of implementing. It has to do with energy programs under the Assistant Secretary for Energy Technology and is referred to as "decentralization". Although the Geothermal Division has been decentralized to a large extent, there will be an even greater effort in this regard. Essentially, the purpose is to move program management and project oversight to the field where it is felt their implementation can be most effective. In this regard, I am now preparing a Program Plan for the Southwest Region which includes management of the program in the field, particularly those program projects that are site-specific and regional in nature. I envisage an organization comprised of State Implementation Teams, using existing state teams now functioning as part of the Regional Operations Research Planning Study. The responsibility therefore, would not only encompass the planning of development scenarios that specify time-phased development activities associated with postulated electric and direct thermal power-on-line target dates, but also encompass taking the necessary action to bring about the realization of development. In a sense, the State Team Leader would wear two hats -- that of the government planner, and that of the implementer who must "think like a businessman". To help the implementation team I hope to be able to augment them with consultants from the private sector who can bring with them the businessman's viewpoint (SLIDE 7A).

Finally, I cannot resist imposing on you an amateur's approach to evaluating energy supply and demand projections with particular reference to the Southwest Region. This, incidentally, comes under the heading of "Impact of Regional Characteristics on Implementation Strategy" in the Program Plan for the region which I am now preparing. The history of energy consumption was obtained from sources in the Department of Energy and the projections are my own doing. Before presenting them, it is important to bear in mind the impact of changing demographic patterns, namely, population. One needs only to look at the population density of the United States to realize the regional posture (SLIDE 7B). Sparse as it may appear, however, statistics on the rates of population growth reflect a somewhat different pattern (SLIDE 8). Couple this now with statistics on the amount of lands controlled by the Federal Government in the region---upon which about 40 percent of the Nation's known geothermal hydrothermal resource base exists---and you have some conception of the future impact on supply and demand of resources in the region. I compiled data on consumption for the years 1960 through 1975 and plotted it to obtain trends (SLIDES 9 through 11). From this exercise, one quickly realizes how critical energy resource development is to providing the supply to meet future demand. When I first took on this job I was sure the region would be a net energy exporter -- I am convinced now that an ever increasing market exists within its boundaries. Forgive me for not discussing more the economics and work we are doing to relate market penetration of geothermal energy, especially as this resource relates to the comparative economics of alternative sources of energy. This is an area of concern to us and one which ultimately will determine the viability of geothermal resource development in the marketplace. We are in competition with other sources and economic viability is essential to compete. Perhaps at another meeting we can discuss this item.

I hope in the short time I have had that I have conveyed to you the broader perspective of where the Division's geothermal program is headed -- indeed the National Program for geothermal development.

If there are questions I will be happy to respond.

(1) 10 x 11 = 110 sentences
≈ 1 min / 6 sent = 20 min reading time

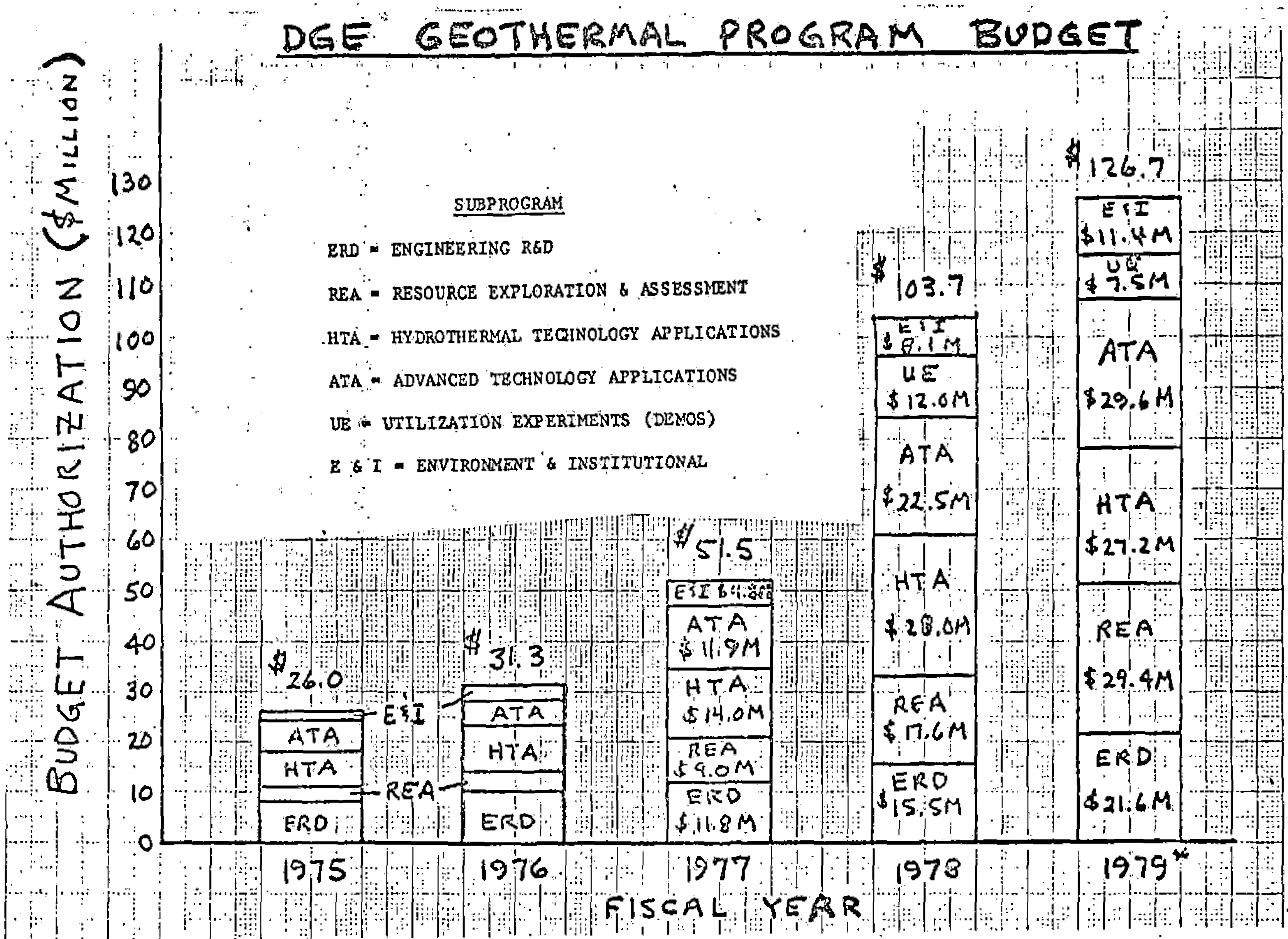
(2) 12 vu-graphs @ 2 min/vu-graph = 24

≈ 44 min

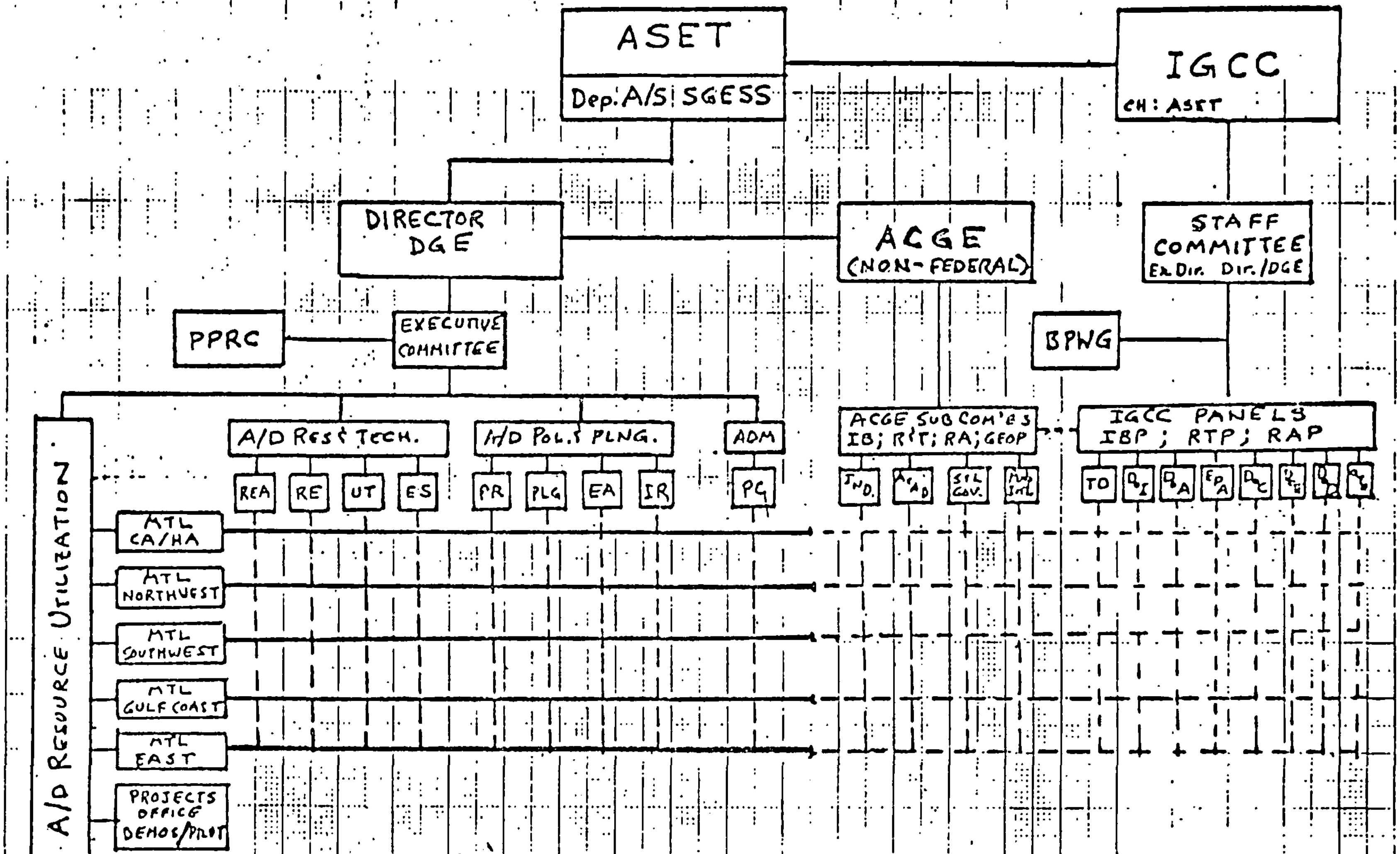
SLIDES & HANDOUT MATERIAL

GEOTHERMAL PROGRAM - FY 1978

DGE RD&D SUBPROGRAM ELEMENTS	BUDGET AUTHORITY ($MILLION)
1. Engineering R&D.......... - Drilling Technology (improved bits, downhole motor bearings) - Utilization Technology (high-temperature elements for well completion; materials research; improved elastomers for seals, packers, cables, blow-out preventers; fluid chemistry, process R&D, waste disposal; fluidized bed and direct contact heat exchangers; helical screw expander turbine generator; advanced downhole pump; well-head generator)	15.5
2. Resource Exploration & Assessment.......... - Exploration Technology (downhole instrumentation for high-temperature environments; MT and AMT techniques development) - Reservoir Assessment & Confirmation (Industry-Coupled Case S Studies Program; Low-temperature Resource Assessment)	17.6
3. Hydrothermal Technology Applications.......... - Engineering & Economic Studies - Direct Thermal Applications	28.0
4. Advanced Technology Applications.......... - Geopressured Deposits - Gulf Coast - Hot Dry Rock Program - LASL	22.5
5. Utilization Experiments.......... - Demonstration Plants (50 MWe power plant; Direct Thermal field utilization experiments) - Pilot Plants (GLEF, GCTF, Raft River Thermal Loop)	12.0
6. Environmental Control & Institutional Studies.......... - Environmental Studies (control technology, disposal, etc) - Economic, Policy & Planning Analysis (Regional Operations Research Studies; systems analysis; policy studies; economic & Legal studies for planning and policy evaluation) - Technology Utilization & Information Dissemination ("outreach Programs")	8.1
TOTAL FY 78 BUDGET..........	$103.7M



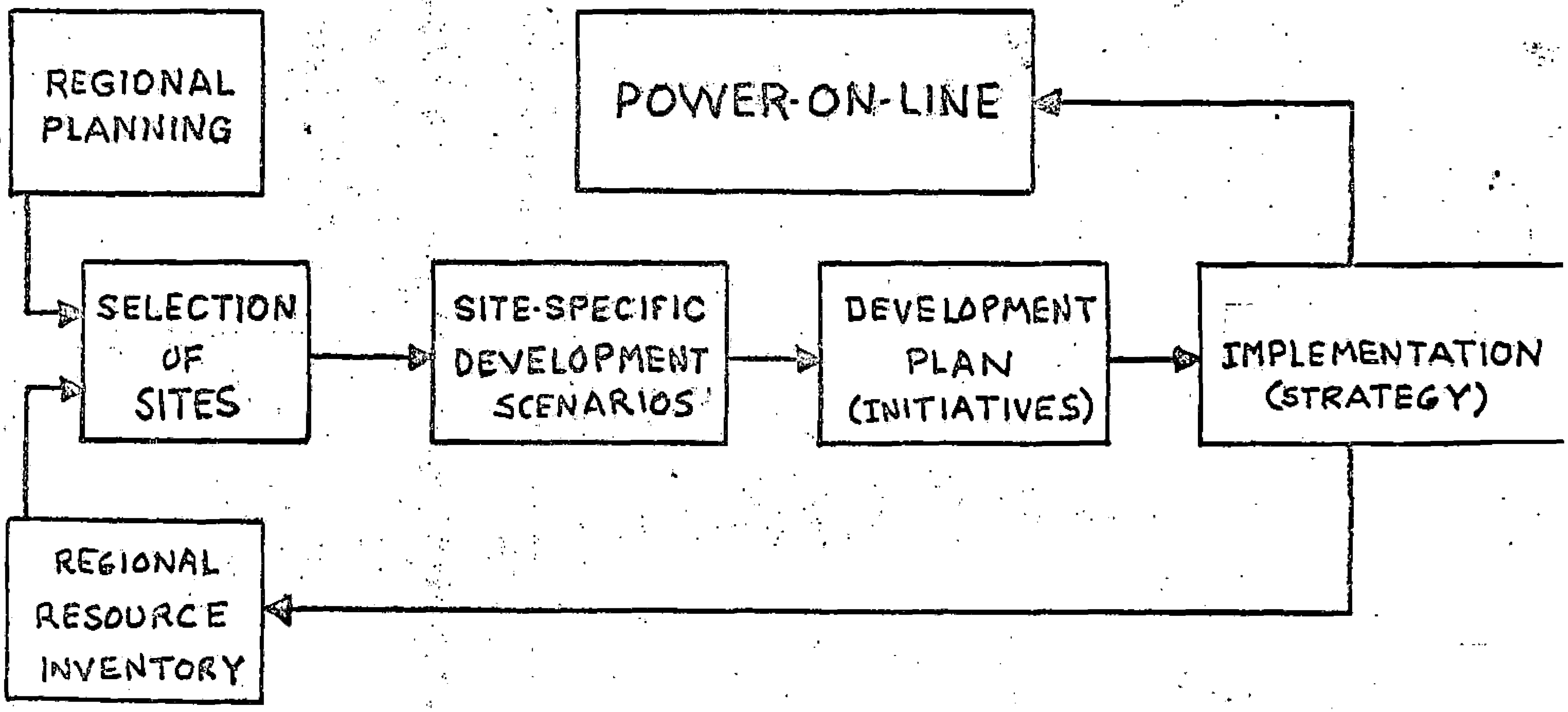
* SUBMITTED TO CONGRESS 1/23/78



FUNCTIONAL ORGANIZATION CHART MISSION-ORIENTED GEOTHERMAL RD&D PROGRAM

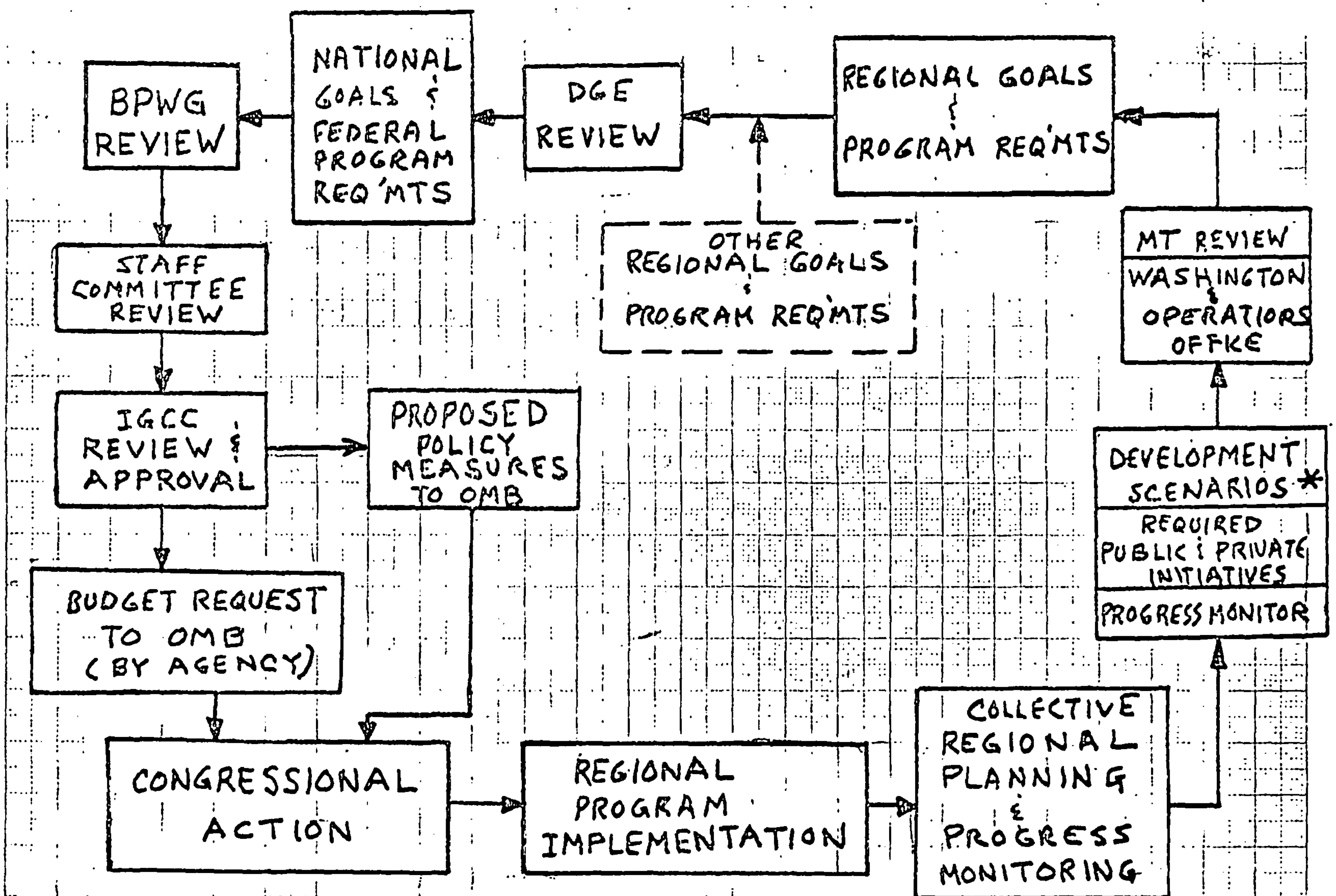
SLIDE 3

GEOTHERMAL COMMERCIALIZATION



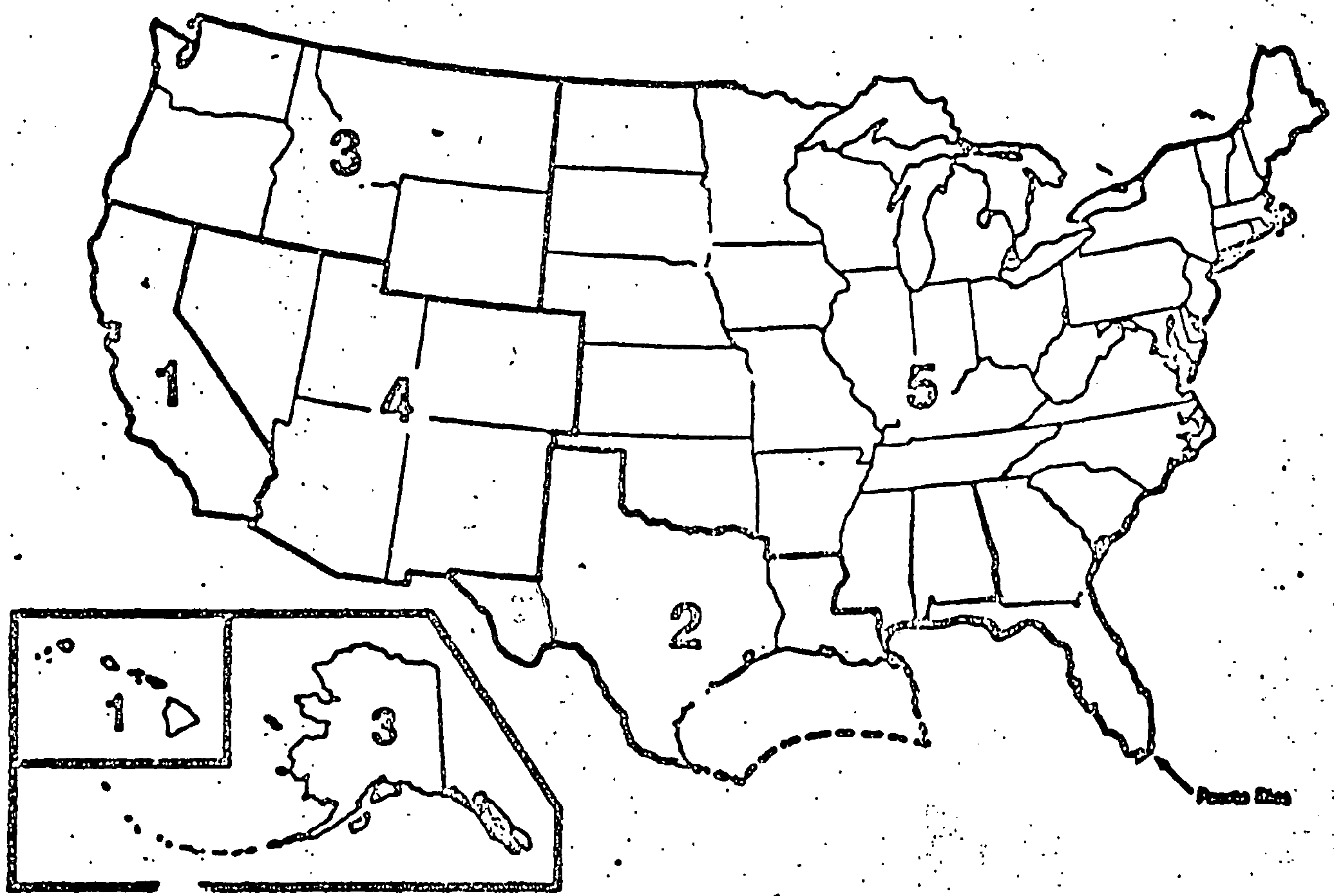
SLIDE 4A

MISSION-ORIENTED PLANNING, IMPLEMENTATION AND PROGRESS MONITORING



* Achievable Development Plan for Each Major Prospect

GEOTHERMAL REGIONS



SLIDE 4B

RESOURCE EXPLORATION AND ASSESSMENT

BUDGET CATEGORY	PROGRAM
EXPLORATION TECHNOLOGY	EXPLORATION TECHNOLOGY
RESERVOIR ASSESSMENT RESERVOIR CONFIRMATION	INDUSTRY-COUPLED PROGRAM PRE-COMMERCIAL PROGRAM STATE-COUPLED PROGRAM RESERVOIR ENGINEERING PROGRAM

TARGETS OF OPPORTUNITY

-- ELECTRIC POWER GENERATION (FOR GRID DISTRIBUTION)

-- GEOTHERMAL/FOSSIL FUEL HYBRID POWER PLANT

-- COAL PREPARATION

-- ORE BENEFICIATION & PROCESS APPLICATIONS

-- DISTRICT HEATING & COOLING

-- INDUSTRIAL PROCESSING

-- WASTE WATER UTILIZATION FOR SECONDARY CONSUMPTION

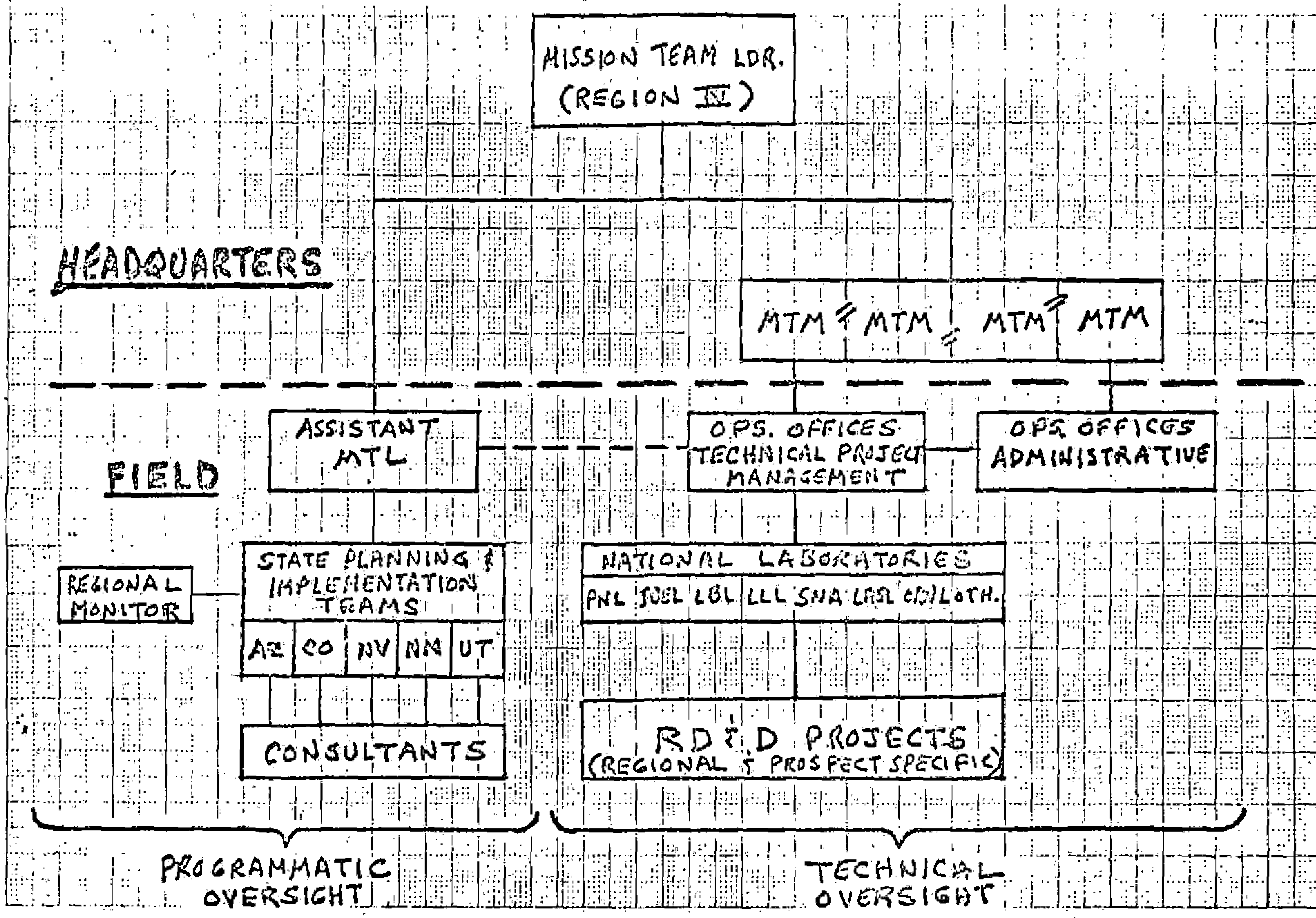
-- MINERAL RECOVERY

-- ELECTRIC POWER GENERATION (CAPTIVE UTILIZATION)

-- AGRIBUSINESS

-- FOOD PROCESSING

HQ/FIELD MISSION TEAM MANAGEMENT STRUCTURE



SLIDE 7.A

AVERAGE POPULATION DENSITY FOR THE SOUTHWEST REGION & U.S.A.

State	Population Density (Population per Square Mile)
United States	59.0
Arizona	18.9
Colorado	23.9
Nevada	5.2
New Mexico	9.2
Utah	13.8
Average Density Southwest Region	14.2

SLIDE 7B

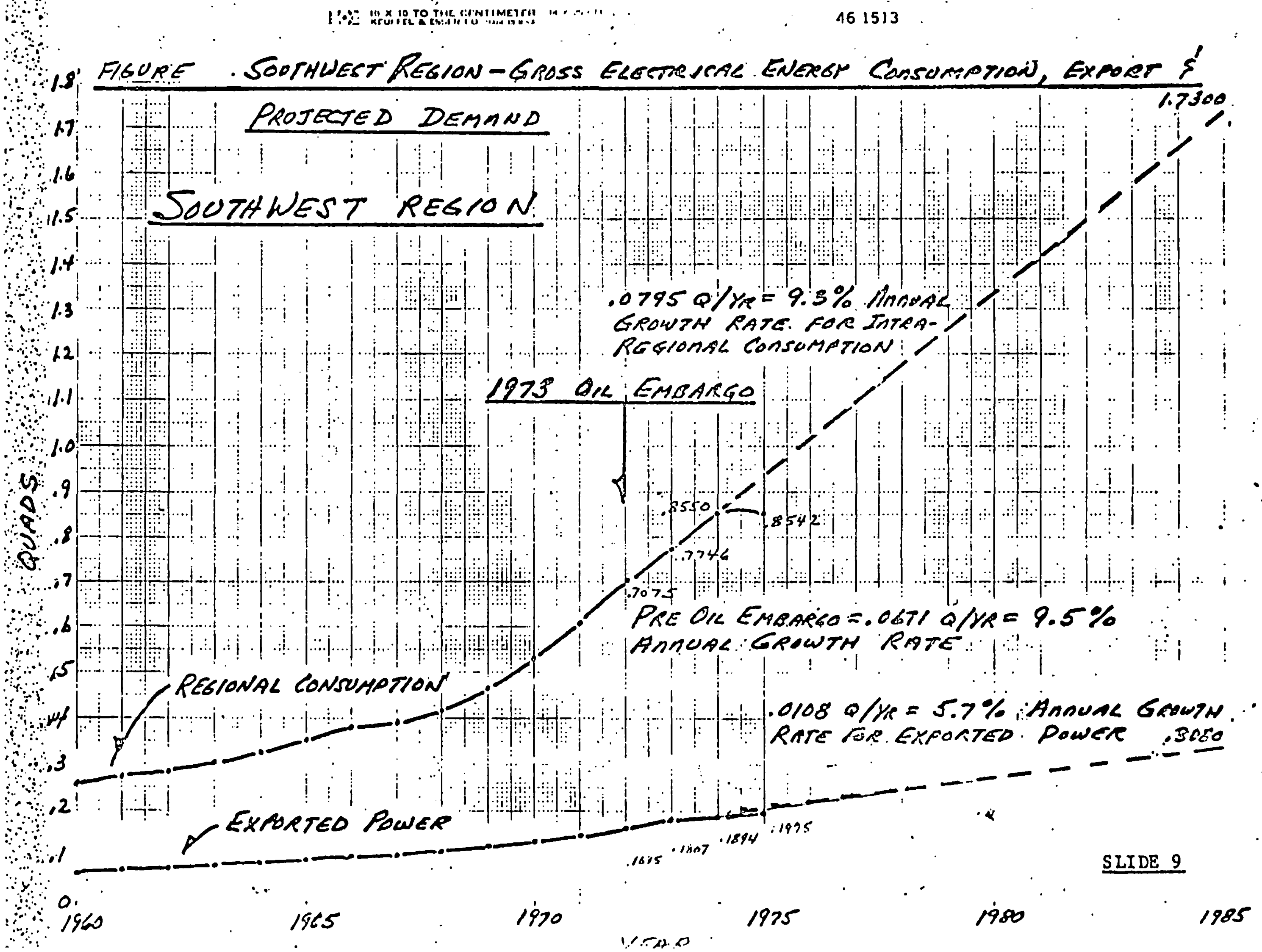
POPULATION GROWTH RATE RANK AMONG ALL STATES FOR THE SOUTHWEST REGION

State	Population Growth Rate Rank Among all States (1970-1974)
Arizona	1
Colorado	4
Nevada	3
New Mexico	8
Utah	7

LAND WITHIN THE SOUTHWEST REGION UNDER FEDERAL AND INDIAN CONTROL

State	Federally Controlled Lands	Indian Controlled Lands	State and Privately Controlled Lands
Arizona	44%	34%	22%
Colorado	36%	1%	63%
Nevada	86.5%	1.5%	12%
New Mexico	33.5%	4.5%	62%
Utah	66.2%	2%	31.8%

SLIDE 8


46 1513
FIGURE . SOUTHWEST REGION – GROSS ELECTRICAL ENERGY CONSUMPTION, EXPORT &
PROJECTED DEMAND
SOUTHWEST REGION
1.7300
.0795 Q/YR = 9.3% ANNUAL GROWTH RATE FOR INTRA-REGIONAL CONSUMPTION
1973 OIL EMBARGO
.8550
.8542
.7746
.7075
PRE OIL EMBARGO = .0671 Q/YR = 9.5% ANNUAL GROWTH RATE
REGIONAL CONSUMPTION
.0108 Q/YR = 5.7% ANNUAL GROWTH RATE FOR EXPORTED POWER
.3080
EXPORTED POWER
.1975
.1894
.1807
.1675
QUADS
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1960
1965
1970
1975
1980
1985

SLIDE 9

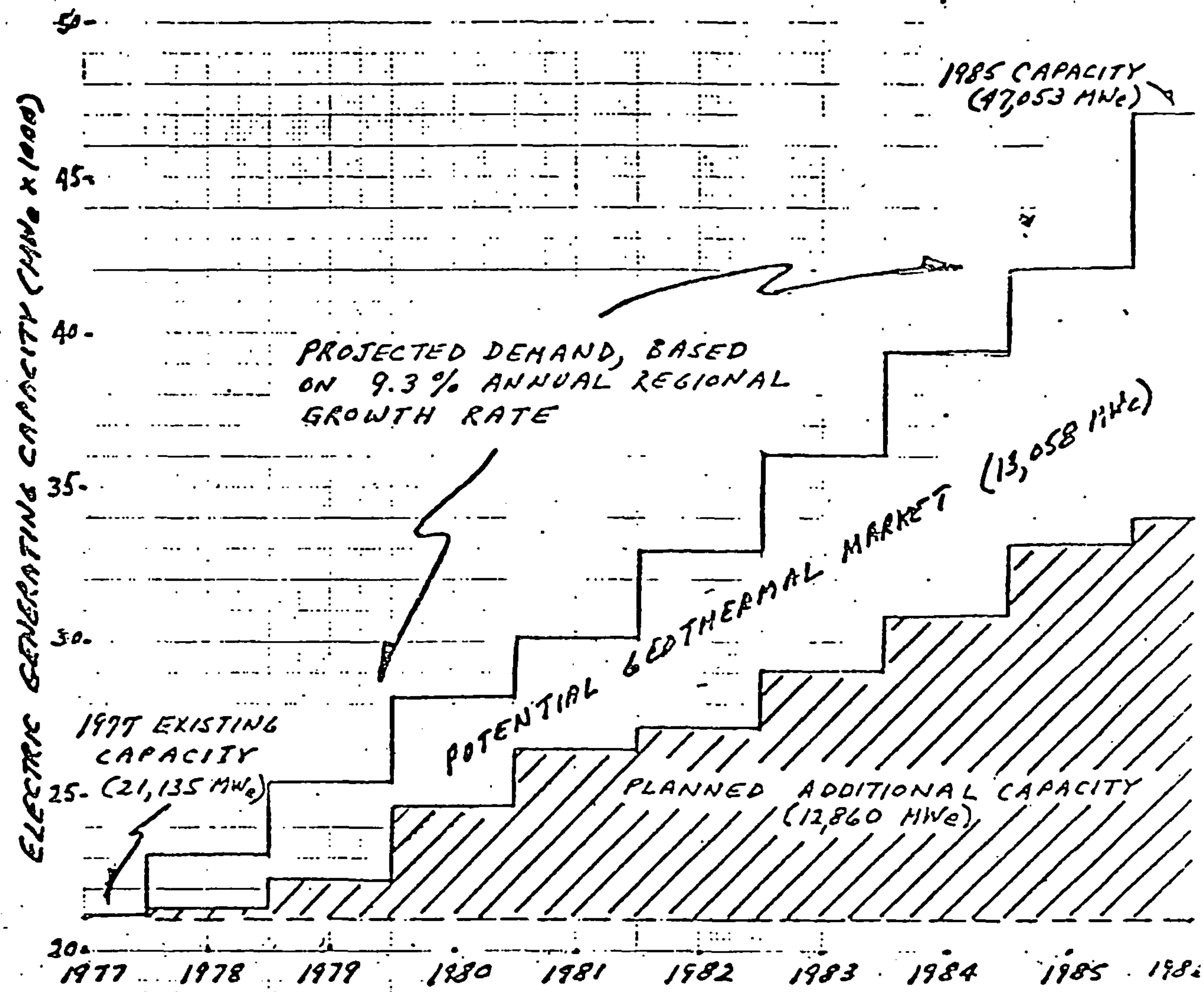


FIGURE . PROJECTED DEMAND FOR ELECTRIC CAPACITY IN THE SOUTHWEST REGION, PLANNED ADDITIONS, AND POTENTIAL GEOTHERMAL MARKET FOR ELECTRIC POWER GENERATION.

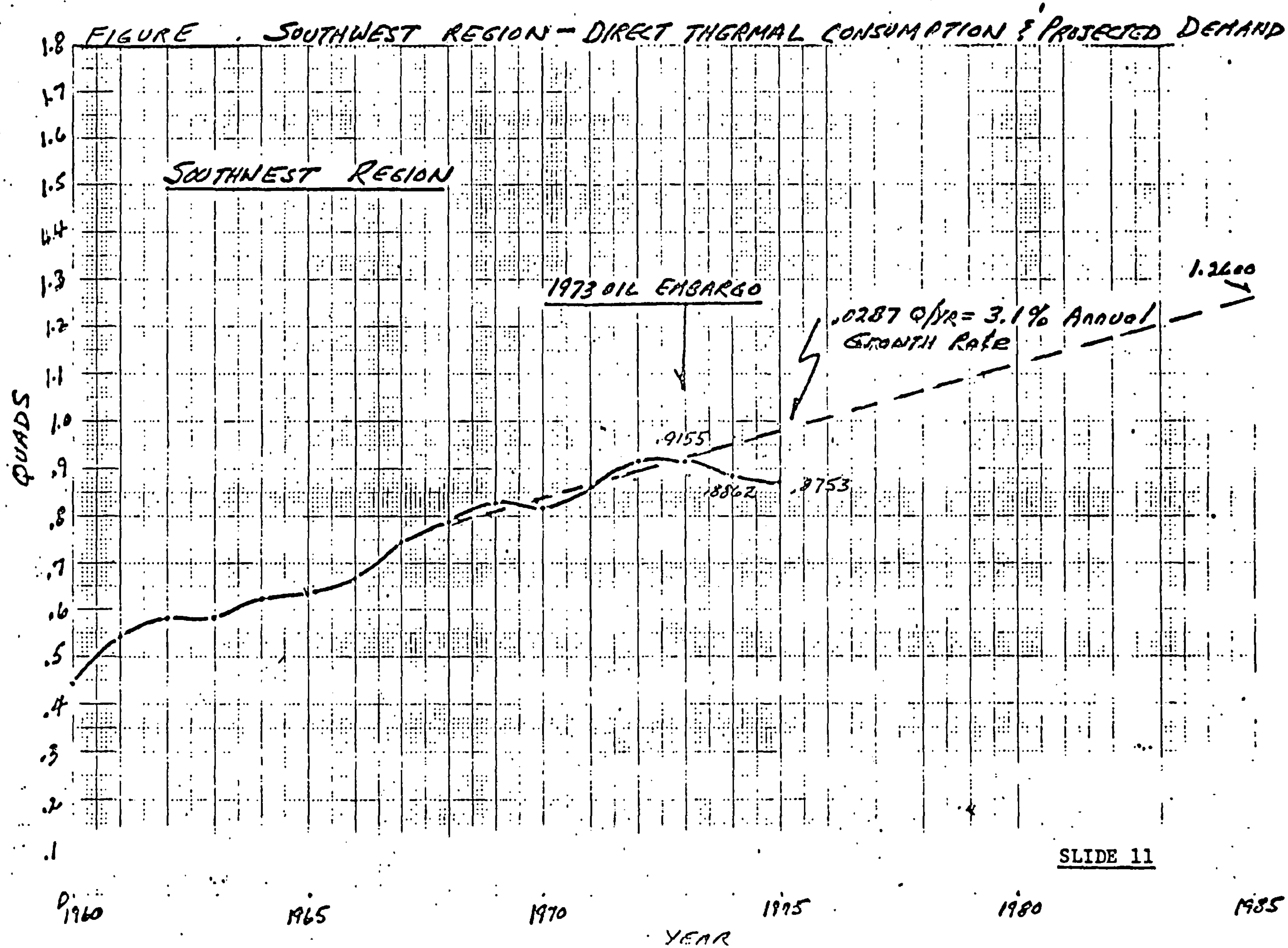


FIGURE . SOUTHWEST REGION – DIRECT THERMAL CONSUMPTION & PROJECTED DEMAND
SOUTHWEST REGION
1973 OIL EMBARGO
.0287 Q/YR = 3.1% Annual Growth Rate
1.2600
.9155
.8862
.8753
QUADS
YEAR
1960
1965
1970
1975
1980
1985

SLIDE 11

GEOTHERMAL ENERGY DEVELOPMENT

Program Plan

For Fiscal Year 1978

Division of Geothermal Energy
Department of Energy

HANDOUT

Program Title: GEOTHERMAL ENERGY DEVELOPMENT

1. Program Elements:

Geothermal Energy RD&D Subprograms

	Budget and Reporting Classification
Engineering Research & Development	AE 01
Resource Exploration and Assessment	AE 02
Hydrothermal Technology Application	AE 03
Advanced Technology Application	AE 04
Utilization Experiments	AE 05
Environmental Control & Institutional Studies	AE 06

2. Responsible Organization: Division of Geothermal Energy

Responsible Individual: Dr. James C. Bresée, Director

3. Program Plan:

3.1 Program Goal:

The objective of the Federal Geothermal Program is to stimulate the development of geothermal resources as economic, reliable, operationally safe, and environmentally acceptable energy sources. There are three principal types of geothermal energy resources of interest for the period through the year 2000. In increasing order of estimated magnitude of reserves, they are convective hydrothermal (vapor-dominated "dry steam," or liquid-dominated "super heated water"), geopressured hydrothermal (including contained natural gas), and hot dry rock resources. In addition, low-temperature resources in the Eastern U.S. (radiogenic reservoirs) may be developed in the mid-term.

The Division of Geothermal Energy (DGE) has shifted its emphasis to a mission-oriented approach to develop the nation's geothermal energy resources wherein the goal is to accelerate the actual commercial utilization of geothermal energy; that is, the production of electrical "power-on-line" and non-electric (thermal) power in commercial quantities. DGE goals are being developed in terms of bringing geothermal power (electric and non-electric) on line in a planned and rational time-phased manner. The planned time sequence for bringing power on line is expressed in the form of resource development scenarios for geothermal prospects. The DGE mission is to implement Federal initiatives to achieve the goals while emphasizing proper time phasing with initiatives of non-Federal entities which are implied by the goals.

The intended Federal Program impact is to increase the annual rate of commercial utilization of geothermal energy from the present 0.04 quads (500 MWe), to 0.3-0.5 quads in the near-term (approximately 1985), 4.0-9.0 quads in the mid-term (1985-2000), and 16.0-28.0 quads in the long-term (by about 2020) as shown in Table 1.

TABLE 1

INTENDED COMMERCIAL GEOTHERMAL
UTILIZATION POTENTIAL GIVEN
SUCCESSFUL FEDERAL PROGRAM IMPLEMENTATION

	1985	2000	2020
Electric Capacity (MW)	3,000–4,000	20,000–40,000	70,000–140,000
Electric Applications Equivalent Fossil Fuel Energy (quads/yr)	0.2–0.3	1.5–3.0	5.0–10.0
Non-electric Applications (quads/yr)	0.1–0.2	0.5–2.0	6.0–8.0
Geopressured Methane (quads/yr)	0.0–0.005	2.0–4.0	5.0–10.0
Total Energy (quads/yr)	0.3–0.5	4.0–9.0	16.0–28.0

The major program objectives for FY 78 are to (1) complete the first phase of geothermal development scenarios for regions 1 through 5; (2) begin initial design, site evaluation, reservoir verification, and environmental studies for the first 50 MWe geothermal demonstration plant; (3) begin construction of first 40 MWt unit (5 MW equivalent electric) of the Raft River thermal loop facility; (4) begin design of the High Temperature, High Scaling Test Facility in the Imperial Valley, California; (5) start first phase of field experiments of direct applications of geothermal heat; (6) complete a preliminary nation-wide inventory of low-temperature reservoirs suitable for direct heat uses; (7) implement reservoir engineering studies at Cerro Prito as part of a bilateral cooperative project with Mexico; (8) initiate geopressured reservoir assessment efforts using two new wells designed specifically for geopressured water production; and (9) continue test and evaluation of drilling equipment and utilization systems designed to reduce the cost of producing geothermal power.

3.2 Program Strategy:

The geothermal development strategy involves (1) reduction of uncertainty in assessments of the available resource base, on both regional and site-specific scales, (2) stimulation of the commercial development of hydrothermal resources through an RD&D program to reduce technological and environmental risks, (3) a loan guaranty program to reduce lenders' risks, and (4) development of policy measures to reduce institutional uncertainties to a risk level compatible with normal private sector investment practices. For the longer term, Federal RD&D programs are aimed at providing the advanced technology or other incentives required to make the large geopressured hydrothermal and hot dry rock resources commercially viable. A significant step in facilitating achievement of the operationally safe and environmentally acceptable components of the program objectives is the preparation of an environmental development plan (see section 3.3.6).

In support of the commercialization component of the strategy, the Federal Government is working closely with State and local governments, industry, municipal authorities, and environmental and other public interest groups in identifying appropriate Federal initiatives that would most effectively encourage investment in geothermal energy and promote public acceptance of its development. In order to plan an effective national, Federal and DOE geothermal energy program, DGE has instituted a system of national and regional operations research and system analyses contracts. These regional contractors, in cooperation with local entities (State/local government, industry, and special interest groups) will formulate realistic geothermal energy development scenarios for the assigned regions, and will identify the public and private initiatives required in order for these scenarios to materialize. The formulation of the geothermal development scenarios will provide the data bases for decision making as to required government resources, their allocation, and priorities among various program elements. Table 2 indicates the current assignment of DGE missions to five regions based in part on the principal hydrothermal resource type available for utilization in each region, and in part on institutional considerations.

TABLE 2

DGE Missions

Mission	Resource Type	General Area Assignment
Saline Hydrothermal	High-Temperature High-Salinity	Central Pacific Coast of U.S.
High-Temperature Hydrothermal	High-Temperature, Low-to-Moderate Salinity	Southwestern U.S.
Moderate-Temperature Hydrothermal	Moderate-Temperature, Low-Salinity	Northwestern U.S.
Geopressured Hydrothermal	Moderate-Temperature, Low-to-Moderate Salinity, Dissolved Methane	Gulf Coast of U.S.
Low-Temperature Resource	Low-Temperature Low-Salinity, Radiogenic	Midwestern and Eastern U.S.

DOE mission in international cooperation is to conduct mutually beneficial programs that will not only enhance DOE's ability to develop and demonstrate a wide range of energy options for the future, but will also contribute to the development of markets for U.S. geothermal technology. International cooperation is achieved either through bilateral agreements with individual countries or multilaterally under the aegis of an international organization such as the International Energy Agency (IEA) or the NATO Committee on the Challenges to Modern Society (CCMS).

Through the efforts of the Office of International Affairs, technical cooperative agreements in geothermal energy have been arranged with Italy, New Zealand, Japan, Mexico, Iceland, and the Republic of Germany as part of an overall technology exchange program. DGE is participating in multilateral cooperative activity through its membership on four recently formed panels of the IEA Geothermal Energy R&D Working Party. DGE is also participating in multilateral cooperative agreements under the aegis of the NATO CCMS. In particular, the U.S. has been designed the "pilot" or "lead" country for geothermal energy (with Italy and Turkey as co-leaders).

3.3 <u>Program Content</u>:

The program for implementing the strategy is comprised of the following six RD&D subprograms:

(1) Engineering Research and Development; (2) Resource Exploration and Assessment; (3) Hydrothermal Technology Applications; (4) Advanced Technology Applications; (5) Utilization Experiments; and (6) Environmental Control and Institutional Studies.

Responsibility for the Geothermal Loan Guaranty Program was transferred from DGE to the Office of the Assistant Secretary for Resource Applications at the time of formation of the Department of Energy. The Geothermal development strategy assumes continuing benefits from the implementation of this loan guaranty program.

3.3.1 <u>Engineering Research and Development (FY-78 B.A. $15.5 million)</u>

Engineering R&D efforts underway are aimed at reducing the cost of producing geothermal power. Some projects address problems that must be solved if exploitation of geothermal energy is ever to support a significant industry. Other projects seek to improve existing technology. Near-term projects are expected to have payoff in the next two to five years. Longer term projects may contribute to the near-term work, but are expected to produce major payoffs after 1982. The Engineering Research and Development Subprogram is composed of two major elements: Geothermal Drilling Technology and Utilization Technology.

a. Geothermal Drilling Technology: The Drilling Technology element has two main components. The first concentrates on improving existing methods and equipment to reduce costs and environmental hazards in severe downhole environments commonly found in geothermal reservoirs: high pressures, high temperatures, corrosive brines, and hard crystalline rocks. This work covers development of improved rotary drill bits, down-hole drill motors and drilling fluids. The second component involves the development of high-temperature drilling fluids and new drilling concepts which will be required to reduce costs for exploitation of all geothermal resources over the long-term. The most important efforts associated with reducing drilling costs in the near-term are:

- Roller cone bits: Improved roller cone bits are undergoing final laboratory testing. Field testing will begin in January 1978 leading to commercial availability by May 1978.

- Compact diamond bit: The compact diamond bit is currently undergoing laboratory tests. First field trials will begin in February 1978 and be completed by May 1978.

- Test and evaluation of a prototype continuous chain bit were completed in June 1977. Full-scale field testing of this drill bit will be conducted in late FY 78.

- Down-hole motors: The development of improved bearings and seals for downhole motors for geothermal application has been underway since FY 76. Field testing of the first improved seal/bearing assembly will begin in September 1978.

b. Utilization Technology: This subprogram element includes projects associated with geochemical engineering, advanced heat exchanger development, advanced energy conversion systems, extraction technology, and well stimulation. The solution of geochemical engineering problems and the development of stimulation technology will bring about a significant reduction in the cost of power. Projects designed to gain increase in the efficency of conversion equipment and prime movers offer less opportunity to reduce initial capital investment, but they should prolong reservoir life.

Geochemical engineering projects cover two areas of interest: fluid chemistry and materials. Water utilization, fluid control, fluid chemistry and process R&D associated with geothermal fluid management and disposal are expected to provide near-term benefits. Materials research is expected to provide near-term benefits through the development of new high temperature elements for geothermal well completion, less expensive materials of construction for geothermal power plants, and improved elastomers for seals, packers, logging cables and blow-out preventers. Results attainable in FY 78 under the geochemical engineering projects will provide essential corrosion and scaling information for large R&D test facilities, such as those at Niland, Ca.; Raft River, ID.; and East Mesa, Ca.; as well as the hydrothermal utilization experiment to be initiated in FY 78.

Advanced heat exchanger projects include work on direct contact heat exchangers, fluidized bed heat exchangers, organic working fluids, and heat rejection techniques. The development of advanced energy conversion systems includes work on conversion machinery such as the helical screw expander and the geothermal rotary separator as well as wellhead generator systems. Extraction technology projects address the problems of increased production from geothermal wells by the use of down-hole pumps and well stimulation techniques. Twenty projects are underway in the following areas: heat exchangers, energy conversion systems (turbine-generator), and down-hole pumps.

Heat Exchangers:

- Field tests of the fluidized bed and direct contact heat exchangers, at the East Mesa test facility will be completed in August 1977. Results of follow-on tests will lead to the establishment of commercial design criteria by September 1978.

- The fluted tube condenser component test which will begin in late FY 77 at the East Mesa test facility, will be expanded in June 1978 to a full field test of a fluted tube and shell condenser unit.

Energy Conversion Systems:

- The total flow (mixed phase) impulse turbine being is currently undergoing preliminary lab tests. A go - no go decision whether to continue this effort will be made in November 1977 following completion of system lab tests and related engineering and economic analyses.

- The helical screw expander has been under development since FY 76. Field testing of the screw expander will be completed in June 1978.

- The design contract award for development of an improved binary turbine (central power plant) will be made in December 1977.

- Design contracts for two wellhead generator systems (flash steam turbine generator; binary thermal pump) will be awarded in early FY 78.

Down-Hole Pumps:

- Four projects are being conducted in the area of advanced down-hole pump technology. These efforts are directed at providing improved pumps for industry and DOE use by December 1977.

The Engineering Research and Development Subprogram activity schedules and milestone charts are presented in attachments 1.1 and 2.1 respectively.

3.3.2 Resource Exploration and Assessment (FY 78 BA $17.6 million)

The objective of the Resource Exploration and Assessment Subprogram is to assist industrial development of geothermal resources by reducing the technical and environmental risks of exploration and improving the technology for reservoir assessment needed to accelerate development of confidence in predictions concerning geothermal reservoirs with respect to temperatures, flow rates and longevity sufficient for long-term commercial operation. Reservoir confirmation now requires up to 2 or 3 years of flow testing. The rationale for the subprogram is the need to stimulate at least a factor of 2 or 3 increase in industry activity in the discovery and confirmation of high grade resources (particularly hydrothermal), in order to meet the 1985 goal for geothermal electric power-on-line. This subprogram consists of two main activities--exploration technology and reservoir assessment and confirmation.

a. Exploration Technology: The exploration technology efforts are oriented toward the development of new and improved surface and subsurface techniques for the detection and delineation of geothermal reservoirs with the aim of reducing the risk and cost for industry during the exploration and reservoir confirmation phases of geothermal development.

- o Subsurface Technology Development: Improved down-hole instrumentation with a temperature capability to 320°C is being developed. Newly developed well logging equipment will be field tested in FY 78. Upon completion of field tests in June 1978, a decision will be made by DGE whether to initiate a very high temperature systems development effort.

- o Surface Technology: Field testing of magnetotelluric (MT) and audio-magnetotelluric techniques will be completed in May 1978. This will be followed by MT system technology transfer to industry to provide rapid, inexpensive, and reliable reconnaissance tools. Optimum mix of exploration tools and associated data interpretation methods will be specified for basin-and-range geology in March 1978. Investigations intended to determine optimum exploration strategies for a new geologic setting will be completed in September 1978, at which time DGE will evaluate the need for additional studies.

b. Reservoir Assessment and Confirmation: The reservoir assessment and confirmation projects are directed toward the development of improved reservoir engineering techniques to facilitate the accurate prediction of the long-term production behavior of a reservoir.

Selected reservoir assessment projects associated with large, high-temperature hydrothermal resources will be carried out in cooperation with industry (Industry-Coupled Case Studies). DGE will also carry out a small amount of direct assessment of geothermal systems with large potential which, for a variety of institutional and technical reasons, are not being investigated by industry (precommercial case studies). A low-to-moderate temperature reservoir assessment effort has been initiated that will stimulate the development of individual reservoirs that have a marked potential for non-electric utilization. A total of forty projects are being pursued under this subprogram element in FY 78.

- Industry-Coupled Case Studies: Case studies covering a second geothermal field will be initiated in October 1977. Case studies of the first and second geothermal fields will be completed in April 1979 and September 1979 respectively.

- Precommercial Case Studies: Reservoir studies at Coso Hot Springs will continue through FY 78 to define reservoir characteristics and evaluate the commercial potential. A similar evaluation will be performed at a site in the Snake River Plain during FY 78.

- Non-electric Reservoir Confirmation: Four assessment projects were initiated in FY 77 in cooperation with state authorities and the USGS. Ten second-generation assessment projects will be started in late FY 78. Shallow drilling as part of the first generation assessment projects will be initiated in March 1978. In addition, four studies are underway to define low temperature resources in the Eastern U.S. (radiogenic reservoirs). A DGE decision will be made in December 1978, based on the results of these studies, whether to proceed with deep drilling at a site to be selected in this geographical region.

- Reservoir Engineering: Reservoir performance model development will be continued in FY 78 with an emphasis on two-phase (steam/water) reservoirs. Verification of the Raft River reservoir model with field test data will be completed in September 1978. Initial regional base level surveys and well testing at the Cerro Prieto reservoir will be completed in September 1973, as part of a bilateral cooperative project with Mexico.

The Reservoir Exploration and Assessment Subprogram activity schedules and milestone charts are presented in attachments 1.2 and 2.2 respectively.

3.3.3 Hydrothermal Technology Applications (FY 78 BA $28.0 million)

The objective of the Hydrothermal Technology Applications subprogram is to improve subsystems and systems engineering for the utilization of liquid-dominated geothermal resources, for electric power generation and for non-electric uses. Development effort will progress systematically from the testing of subsystems and processes in field test facilities to scaled testing of integrated energy conversion or utilization systems in pilot plants. Improvement of the engineering design for such plants is intended to reduce the technical and environmental risks to a level that is reasonably acceptable and attractive to industry. Verification of commercial, economic viability and environmental acceptability of full-scale systems in demonstration plants would normally follow. The projects concerned with test facilities and pilot plants will provide technical and environmental operating data under actual field test conditions in order to verify the ability of developed systems to meet performance, reliability and environmental criteria.

a. Electric Applications: The use of vapor-dominated hydrothermal resources for production of electric power is a fully proven application, with years of profitable operation at The Geysers in California. However, achievement of the near-term goals for geothermal power-on-line will depend primarily on utilization of the more abundant liquid-dominated resources, particularly those yielding higher temperature fluids that offer higher overall thermodynamic efficiency and thus lower unit cost of electric power. The major efforts are:

- Niland, California: A jointly funded industry/DOE Geothermal Loop Experimental Facility (GLEF) using a flashed-to-binary energy conversion cycle with the hypersaline brines of the reservoir near Niland was placed in service in June 1976. Comprehensive thermal loop tests, currently underway, are scheduled for completion in December 1978. A decision will be made in November 1977 whether to add a turbine-generator to the GLEF. Design of the High Temperature, High Scaling Test Facility will be started in May 1978.

- East Mesa, California: A high-temperature, moderate-salinity test facility for prototype components and subsystems testing has been constructed in cooperation with the Bureau of Reclamation at East Mesa, California. The installation of four test pads in this DOE Geothermal Component Test Facility was completed in February 1977. Operation of the test facility will be continued through FY 78 and beyond to accommodate increased requirements for components and subsystem testing.

- Malta, Idaho (Raft River Project): The Raft River thermal loop facility is designed to test integrated energy conversion systems specific to the upper range of moderate-temperature, low-salinity resources. In order to provide a phased program wherein technologies are employed as they become available, two 40 MW thermal units (equivalent to 5 MW electric each) will be installed sequentially. Construction of the first unit, using currently available technology, will begin in March 1978. Effort relating to the second 40 MWt unit which will provide for testing advanced heat exchangers and related advanced technology, is planned to begin in FY 79.

- Hawaii: Additional drilling, resource assessment and reservoir engineering activities will be pursued at DOE's test site in Hawaii, leading to the installation and testing of a well-head generator beginning in February 1978.

b. Non-electric Applications: There is a large potential market for non-electric uses of geothermal heat contained in low-to moderate-temperature (50 to 150 degrees C) hydrothermal resources. DOE/DGE is fostering diverse applications in the direct use of geothermal heat in order to encourage wider utilization of these resources. A number of engineering and economic studies of non-electric applications were initiated in FY 77. The non-electric program will be expanded further in FY 78 and FY 79 by additional site-specific application studies directed toward broadening the scope of involvement of various non-electric industry sectors. Selected non-electric applications experiments covering residential/commercial space heating and cooling, industrial processing, and agricultural uses will also be initiated in FY 78 to obtain data on site-specific and applications-specific economics under actual field conditions, with a view toward expediting industrial commitment to various sites and to provide early momentum to growth in the utilization of the low-to-moderate-temperature resources.

The Hydrothermal Technology Applications Subprogram activity schedules and milestone charts are presented in attachments 1.3 and 2.3 respectively.

3.3.4 Advanced Technology Applications (FY 78 BA $22.5 million)

Longer-range expectations for extensive utilization of geothermal resources are embodied in the Advanced Technology Applications subprogram. Specifically, the major targets are the huge resources represented by the geopressured systems along the Gulf Coast which are believed to include large quantities of methane, the hot dry rock systems expected to be found over large areas of the Western states, and ultimately the widely distributed conductive heat of the earth's crust (normal gradient resources).

The objective of the Advanced Technology Applications Subprogram is to establish the feasibility of using geothermal resources that require technologies beyond those presently available. Development effort will progress systematically from characterization of the resources (see section 3.3.2), identification of environmental issues, and evaluation of new concepts for energy recovery, to the testing of components, subsystems and processes in field test facilities, and to the testing of systems in pilot-scale electric plants. By this means, technical and engineering feasibility, and environmental acceptability will be demonstrated and technical and environmental risks will thereby be reduced to a level that is considered reasonable and acceptable by industry. The need for demonstration on a commercial scale will be evaluated as the technologies mature.

a. Geopressured Utilization: Efficient utilization of geopressured resources will require the recovery of thermal energy, conversion of hydraulic energy, and the separation of contained methane gas. Due to the high cost of drilling and well completion under typical conditions at the depths and pressures involved, there are two major reservoir uncertainties that need to be resolved before commitment to expensive technology development projects. The uncertainties are (1) the number, producibility, and size of individual geopressured aquifers, and hence their ability to sustain large flows of water over long intervals of time, and (2) the amount of recoverable methane, a key factor in the economics of the utilization of geopressured resources. To this end an assessment of all known onshore geopressured formations in Texas and Louisiana is now underway. Six projects are directed toward defining the geopressured resource properties. In FY 78, production tests will be continued in Texas and

Louisiana using existing petroleum wells. A new well designed specifically for geopressured water production will be drilled in Texas beginning in November 1977. Results from well tests planned for FY 78 and FY 79 will permit accumulation of sufficient data to support an FY 79 decision to proceed with development of the technology for utilizing energy from geopressured reservoirs. The anticipated economics of exploiting such reservoirs also needs to be refined, and actions taken to reduce first costs and operating costs to an attractive level through technology development and reduction of institutional barriers. However, progress in this area will be enhanced by the fact that some of the technology developed for hydrothermal energy conversion and utilization will be transferable.

b. Hot Dry Rock: One form of hot dry rock extraction technology is currently being tested at the Fenton Hill site in the Jemez Mountains in New Mexico. In particular two closely spaced holes have been drilled in granitic rock to a depth of 9,600 feet, where the bottom-hole temperature is 197°C. The two drilled holes have been interconnected by a hydraulically stimulated fracture system. The current program emphasis is to develop a controllable and effective fracturing-circulation technology with the highest possible heat-extraction capability and efficiency. The hot dry rock subprogram element includes instrumentation and equipment development, drilling and hydraulic fracturing, borehole and fracture mapping methods, and extraction experiments. The effort to determine the operational characteristics of the system and to establish and operate the 10 MW thermal loop experiment at Fenton Hill will continue through FY 78. Studies of the economic potential of the present approach, and of alternative approaches to heat extraction, will be performed.

The Advanced Technology Applications Subprogram activity schedules and milestone charts are presented in attachments 1.4 and 2.4 respectively.

3.3.5 Utilization Experiments (FY 78 BA $12.0 million)

The objective of the Utilization Experiments Subprogram is to demonstrate the technical reliability, economic potential, and environmental acceptability of a commercial-scale geothermal power plant utilizing liquid-dominated hydrothermal resources. In order to stimulate industrial development of this alternative energy source, it is critically important to be able to offer convincing evidence of the technical and environmental reliability of integrated geothermal systems at acceptable operating costs to electric power utilities, financial institutions, regulatory agencies, and local government. Utilization experiments involve the construction, operation, and maintenance of first-of-a-kind, large scale, electric power plants specifically designed to (1) demonstrate that near-term technologies are now ready for commercial-size plants to produce electric power from hydrothermal resources; (2) obtain realistic cost data from which production costs can be extrapolated with confidence; (3) provide adequate instrumentation to obtain operating data; and(4) demonstrate reservoir deliverability and longevity.

A Program Opportunity Notice (PON) was issued in September, 1977 for the first utilization experiment (50 MWe Geothermal Demonstration Plant) involving joint industry and government funding. This initial demonstration plant is expected to confirm the technical reliability and economic feasibility of an electric power plant using a high-temperature, low-to-moderate salinity resource with a binary or flashed steam power conversion cycle. With initiation of the project activities in FY 78, this demonstration plant could be made operational by FY 82.

In FY 78, efforts associated with the first experiment will involve initial site evaluations, design studies, reservoir verification, and environmental studies. Twelve million dollars (BA) are authorized for implementing the first 50 MW geothermal plant. The current TEC for the governments' share under a 50/50 government/private sector arrangement for construction of this plant would be in the range between $50-60 million.

The activity schedules and milestone charts for the Utilization Experiment are presented in attachments 1.5 and 2.5 respectively.

3.3.6 Environmental Control and Institutional Studies (FY 78 BA $8.1 million)

The objectives of this subprogram are to determine environmental implications of large-scale geothermal energy utilization and the means by which undesirable effects may be kept within acceptable limits; to provide the technical capability to meet environmental standards at reasonable costs; to analyze economic and institutional impediments to the aspired timeline for development of a geothermal industry infrastructure, and to evaluate alternative options for removing or circumventing the impediments; and to encourage the utilization of geothermal technology through the organization and dissemination of information to potential users in industry, commerce, laboratories, governments, and the public sector.

The subprogram is divided into three areas:

a. Environmental Studies: Eight projects covering improvements in environmental control techniques, principally the reduction of hydrogen sulfide and other atmospheric pollutants to acceptable levels and the disposal of geothermal fluids, are to be pursued in FY 78. Construction of a pilot subsystem facility at Niland, California for hydrogen sulfide steam scrubbing will begin in February 1978. Field tests of the oxidation process for hydrogen sulfide removal will start in June 1978.

To assure program consistency and compliance with environmental, health, and safety (EH&S) have, regulations, and policies, DGE has prepared, jointly with representatives of the Assistant Secretary for Environment, an environmental development plan (EDP), entitled Geothermal Energy Systems, September 1977, which will be updated yearly, and is incorporated in this MRCD by reference.

The EDP provides a guide for planning and managing EH&S activities required by the program, including identification of EH&S issues, plans for solutions, and key milestones for environmental impact assessments and statements.

b. Economic, Policy and Planning Analysis: Work in this area provides for analysis of the economic, institutional, legal and technological framework for geothermal energy exploration, development and utilization; and the identification and assessment of policy options and technical programs to encourage and expedite its development according to the aspired schedule.

- The major component of the planning effort is a series of continuing regional operations research and systems analysis studies, carried out in cooperation with appropriate state authorities. The first regional planning study, which was initiated in California in mid FY 76, is scheduled to provide first phase geothermal development scenarios in the last quarter of FY 77. Three additional regional studies were initiated in FY 77, with first phase development scenarios scheduled for completion by mid-FY 78. One additional regional operations research study will be initiated in the first quarter of FY 78.

- Federal policy studies, carried out in part through the Institutional Barrier Panel of the Interagency Geothermal Coordinating Council and in part through university contracts, have concentrated initially on land leasing policies, taxation policies, utility regulation policies, and state legal and regulatory systems.

- The economic and legal studies serve principally as essential components of the overall planning and policy studies.

Work under this subprogram element in FY 78 includes a significant acceleration of effort in regional planning and market assessment studies, policy research, socio-economic analyses and cost benefit analyses of alternative Federal policies and programs. Proposed measures for sharing the risk of premature reservoir failures will be submitted for consideration late in FY 78.

c. Technology Utilization and Information Dissemination: The major objective of this subprogram element is the distribution of current geothermal information to interested participants in electric and non-electric applications, consumer groups and local officials. Six ongoing efforts will be continued in FY 78 with emphasis placed on the establishment of the National Geothermal Information Resource (for collection, evaluation, and dissemination of geothermal data) by September 1978.

The activity schedules and milestone charts for the Environmental Control and Institutional Studies Subprogram are presented in attachments 1.6 and 2.6 respectively.

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GEOTHERMAL POWER IN THE WEST

State of Washington

Department of Natural Resources

"The First Northwest

Conference on Geothermal Power"

Olympia, Washington

May 21, 1971

Joseph W. Aidlin
Secretary and General Counsel
Magma Power Company, Los Angeles

GEOTHERMAL POWER IN THE WEST

You know there are advantages and disadvantages in being in the middle or near the end of a program. The advantages are that you learn things from prior speakers, and you find that the things that you were going to say were either correct or incorrect, and you have time to correct your incorrections, and you have time to add to your remarks those things that you have learned. But, there is also a great disadvantage and that is many of the things you had planned on saying have already been said.

So, I decided, after hearing the very complete remarks by Al Bruce and Carel Otte and the introductory remarks by Mr. Cole, to omit further reference to The Geysers that I had intended to discuss and to omit use of my slides, because I feel that we have seen enough steam wells blowing to the atmosphere. I have made some notes which I will try to follow and have taken one or two subjects that have come to mind during this conference, which I think will be of greater interest and probably be more constructive than the remarks that I had originally prepared.

So I hope you will forgive me if I stumble a little. My handwriting is very poor and my eyesight is inadequate, and when I combine the handwriting and the eyesight and my reluctance to use reading glasses, I, at times, run into some difficulty, but I am sure that you will forgive me.

Since my talk is titled "Geothermal Power in the West," I do want to make some remarks on the areas which we have explored in the West. That is, not only Magma Power Company, but other companies that have been involved in the last few years in exploring the western region. A number of companies have been involved in the geothermal steam field for some years. Among them, and I am not trying to list all of them, are Union Oil Company; Thermal Power Company, the Magma Power Company partner at The Geysers; Signal Oil and Gas Company, that has drilled a number of outpost wells at The Geysers; Geothermal Resources International, that also drilled at The Geysers; Sun Oil Company, that drilled in conjunction with D. D. Feldman at Wilbur Hot Springs, California; and the Western Geothermal Energy Company, that drilled, I believe, a well in Lassen County and also one or more wells in Imperial; and then, of course, in Imperial Valley there were a number of wells drilled by Morton Salt International through a subsidiary, Imperial Thermal Products, and some Texas oil men who were early in the business, O'Neill and Ashmun. Shell Oil Company took a hand at drilling a few wells in the Imperial Valley, so there have been a number of people involved one way or another in this industry.

Magma Energy is a two-thirds owned subsidiary of Magma Power Company, and it succeeded to a number of the areas that were originally owned by Magma Power Company and also succeeded to the development of the Magmamax Process which had been started by Magma Power Company. The principal areas, aside from The Geysers, in which Magma and the various partners of Magma have drilled wells, represent quite a list.

In California, wells were drilled in Clear Lake in Lake County. One of the gentlemen attending this conference is Jim Bradley, on whose land we drilled a couple of wells in Clear Lake. We had certain problems there in utilizing the hot fluid, although I think now we have reached the point with the development of new technology where we might be able to utilize what appears to be a very, very great source of energy.

We also drilled in the Casa Diablo area in Mono County. I am sure it got the name Casa Diablo from the natural steam vents that are found in the area of Casa Diablo. We drilled in Surprise Valley in Modoc County. That is very close to Oregon, and in Calistoga in Napa County, in Fales Hot Springs and Bridgeport in Mono County, in Tecopa in Inyo County, and in Randsburg in San Bernardino County. In all these areas we did find hot water, geothermal resources of varying degrees, but none of them has been developed to this point.

In Nevada we drilled in an area called Beowawe. Beowawe is an Indian name. It is located in Eureka and Lander Counties, an area of very intense geothermal activity with steam vents, some fumaroles and leached land. Adjacent to Beowawe, we drilled in Crescent Valley in Eureka County.

We also drilled in Steamboat Springs near Reno, an area which has been described as having enough heat in it to last for, I believe, a million years. Unfortunately, we found the area not too permeable, and we found problems of plugging of wells that we could not overcome at that time. We might be able to overcome them at some future time.

We also drilled in Brady Hot Springs where we feel there is a very promising area for immediate development, in Wabuska in Lyon County, Fernley in Churchill County and Darroughs Hot Springs in Nye County.

In Oregon we drilled in Crump Valley. As a matter of fact, we created a little geyser there that became a tourist attraction. I understand from Mr. Bowen that vandals have plugged the geyser and just a trickle of water comes out of it now.

We also drilled in Lakeview, Oregon. I heard the other day that one of the wells we left there for one of the owners is being utilized by a very adventurous and aggressive farmer in growing tomatoes in a hot house and that he is very successful and his yield is great. He is using the hydroponic method, using the hot water for warming. He has talked to us about using the hot water for growing in the ground, organically growing, using hot water for warmth in hot house growth.

There is a great possibility for growing flowers and things of that sort as well as vegetables. I hope those of you from Oregon will forgive me for mentioning that, because in Lakeview there is probably not quite enough sunshine, not as much as there is in California. That is, we may be able to utilize that hot water a little better in California.

In Hawaii we drilled a number of wells right at Kilauea volcano, right along the rim where you could not even walk because the ground was so hot it burned your feet. But we got nothing. Apparently there just is not any reservoir. Apparently the subterranean tubes that have been created by volcanic action or lava flows over the years have let the natural steam flow into the ocean. Maybe that is what created the Gulf Stream—I have had that feeling. At any rate, we had no success in Hawaii.

Others have drilled in Imperial Valley, Plumas County, and Wilbur Hot Springs, in an effort to see if there is any steam, in Humboldt County, and, of course, The Geysers, in California. Recently there was a well completed in Sandoval County, New Mexico, and apparently it is a very good well and indicates the possibility of a rather substantial commercial geothermal deposit in that area.

In most of the areas the wells have been rather shallow. There have been a few deeper wells. Outside of Imperial Valley and The Geysers, the wells have been quite shallow, and I feel, and I am sure others in the industry and certainly in Magma Power Company feel, that we have not completely tested many of the areas where we drilled. But we were pioneers and in a sense we did pretty much as the early oil developers did. They just dug into the hill and let the oil flow into a little sump. Then they dug it up with a shovel if it was heavy oil or siphoned it up if it was lighter oil. That is the way we prospected for steam in the early days.

But we did develop the potential of many areas and discovered that these areas had great possibilities. The major problem in the early days was that we were oriented toward the type of generation which takes place at The Geysers, that is, using the dry, hot steam or the flashing process; in other words, allowing the hot water to flash into steam, utilizing that steam and wasting the rest. So far, I am informed, the only two areas where pure dry steam has actually been discovered are at The Geysers and in northern Italy at Larderello.

It may be that some of the areas that we have prospected at depth may produce pure dry steam. But after hearing Mr. Bruce answer the question today about the utilization of the heat energy of dry steam, I feel more enthusiastic than ever that the Magmamax process, which I will now describe, offers a great deal more in terms of development of this resource than we really had expected. It will make possible the utilization of more of the energy which is found in heated water.

If the steam, which flashes from the superheated hot water, is utilized to drive the generating turbine, more heat energy is lost than used. Of course, at a time when we want to conserve energy, conserve our resources, this represents a tremendous loss, a tremendous waste which we must overcome if we possibly can. We knew that there was more energy in superheated hot water and, if we somehow apply that heat to vaporize a low-boiling point fluid, that vapor would operate a turbine.

In the Magmamax process the geothermal fluid hot water is kept under pressure in the well and it passes through the heat exchanger. This prevents the hot water from flashing into steam. Keeping this water, as it travels from the well through the heat exchanger, under pressure not only avoids the loss of heat through flashing, it also reduces deposition of dissolved minerals in the hot water. As you know, minerals will deposit at different stages with the loss of pressure or the loss of temperature, or the loss of both, and, if you keep the water as close to its natural state as you find it in the well, you will have less deposition.

After the water has had its heat energy extracted in the system, it is re-injected into the rock formation. This later procedure requires testing, engineering and experience to determine the most suitable formation to re-inject the water, the extent to which it affects the heat of the producing formation, and so on. But these are matters that are within our present know-how.

It is obvious that this process, which our president whimsically named "Magmamax"—Magma because we like the name "magma" and max because I presume he figured that means maximum utilization of heat energy. And since we live in a world where everything has to be consolidated, for example, KGRA, which means known geothermal resources area, or Magmamax, which means maximum utilization of heat energy, we called it Magmamax (by the way, it is one word, not two)—will enable the extraction of more of the heat energy contained in the fluid and thereby conserve the energy for useful purposes.

In the Magmamax process, the pipes transporting the fluid to the plant need not be as large or as unsightly as those now required at The Geysers for the transportation of the dry steam. You saw pictures of these lines which were transporting the steam, and I have always felt that if we could somehow solve that environmental problem, the esthetic aspect would be very much improved. Additionally, these pipes can lie on the ground or be buried, and the water can be transported for distances of a half to three-quarters of a mile. This depends upon the pressure, the heat and how much contained heat you are willing to lose.

Another important factor in the use of the Magmamax process for electric generation is that the testing of the wells is less of a problem. In the testing of a dry steam well, for example, the well has to be blown into the atmosphere for a period of time, and that creates a very substantial noise problem. And, when many wells are blown into the air at one time, as they had to do at The Geysers to determine whether or not there was a pressure drop, there is a very substantial noise problem. That is another important factor in terms of the environment. But with Magmamax that is not necessary. The testing of a hot water well does not require the blowing of steam into the air and does not generate that kind of noise.

For these reasons we do feel that the Magmamax process, or a process of that kind, offers great possibilities for the development of many of geothermal resources in recreation areas and areas that we want to preserve for public pleasure. It, also, offers the possibility of utilizing resources which could not otherwise be economically developed.

Magma feels very strongly that the original estimates of geothermal energy resources and their ability to meet our future power needs may be exceeded dramatically if developers of geothermal power utilize the Magmamax type of generation, or a similar process. If this is the case, then we are concerned with something more than a toy or an insignificant resource. I think we are concerned with a resource of tremendous magnitude. Certainly other areas of the world are very concerned about geothermal energy, and they are moving rapidly to develop these resources; I would say, faster than we are.

I would like to touch upon another matter which has to do with the development of geothermal resources in the Western United States. After that, I want to make some specific proposals to utilize the tremendous impetus which this wonderful conference has generated. The thing I would like to touch on now is a matter of law which relates to the ownership of the geothermal resources. That is, the question of whether or not mineral reservations by the federal government or by any state contained in any grant or sale or to homesteaders reserve to the federal government, or in the case of a state, reserve to the state, all minerals, included within that reservation of geothermal resources. In other words, if the State of Washington sold land in which it owned the full title of minerals and the land and reserved the mineral resources, the owner of that land did not get those resources and those resources are available for development. Many property owners will be surprised if that turns out to be the case, especially if they have built homes, if they have developed, and if they have built structures, and spent money developing these lands. They may find that somebody can go in and drill a well and utilize that well for steam purposes.

I had requested that Congress quitclaim those rights by legislation, but they did not agree. They preferred to write into the new Federal Geothermal Bill a directive to the Attorney General to litigate the point. I am sure that the matter will be determined very rapidly.

It is estimated that approximately 35 million acres of land have been granted over the years by the federal government to homestead claimants, states, railroads and others, reserving to the federal government all mineral rights. Many of the lands granted to the states contain mineral reservations to the federal government. Many of those lands are either owned by the state or have been conveyed by the state to others. I know that is the case in California, and I am sure it is true in Oregon, Washington and other western states.

The question of whether or not geothermal resources are embraced within this reservation is, therefore, critical with respect to millions of acres of land, and that important point will have to be resolved. If the mineral reservation did not include geothermal resources, geothermal steam and perhaps the minerals which may be contained in geothermal steam, they belong to the owners of fee title. If they were embraced in the reservation, then we are going to have some very serious problems untangling an awful lot of titles in determining who has the right to develop that resource.

We, at The Geysers, deliberately, and with the knowledge of the Department of the Interior, drilled a well on one such property, and that well is going to be hooked up to one of the next power plants which is scheduled to go on line within the next few months. That will project the lawsuit which will determine whether the federal government retained the ownership to the steam or the person who owns the land, the surface and other emoluments of land ownership owns the geothermal steam.

If it is determined that the government retained the ownership of the steam, then the next question is what happens to the right of those of us who have filed mining claims on thousands of acres of government land for the development of geothermal steam. If the government owned it as a reserved mineral, obviously it is a mineral subject to location, since it was not a mineral embraced within any of the mineral leasing acts; and if the mineral is not subject to leasing, it is subject to location. So that will have to be resolved.

The Department of the Interior is fully aware of the problem, and it was for that reason that in the early part of 1967 it withdrew from entry, for any purpose, all lands throughout the western United States which had the slightest potential for development of geothermal resources.

In order to develop geothermal energy economically and in an order that conforms to the public interest, we must concern ourselves with several key factors. One, the source of energy, either pure dry steam or superheated hot water, cannot now be economically utilized because much of the heat energy present in the water is lost. Two, the generation of power and the facilities utilized must conform to natural environmental requirements. Three, the enterprise must return a reasonable profit within a reasonable time to interest persons in entering the field. Four, financial funding for developing this valuable resource must be provided. Five, we must have the support of the public and agencies, federal, state and local. And very importantly, most importantly, there must be free, open and ready communication between the public, industry and public agencies to discuss all matters of mutual concern.

As a matter of fact, almost everything involved in the development of geothermal power is of mutual concern and public concern. Public agencies must overcome an unfortunately all too prevalent attitude that private industry has no concern for the public interest and that somehow discussing problems of mutual concern on an open and honest basis is not possible and that to recognize and act upon a legitimate business concern is a betrayal of the public trust.

Those of us who have had to deal with public agencies have all too often run into that attitude which makes the proper and intelligent resolution of a problem almost impossible. I would say that it has been my experience that this charge which I have just made is definitely not applicable to the Department of Natural Resources of this State of Washington, the Resources Agency of the State of California, particularly the Division of Oil and Gas of California, whose representative, David Anderson, is attending here and who has been very helpful to industry and very understanding, and incidentially, very much in the public interest, or to the Oregon Department of Geology and Mineral Industries. It certainly is not applicable to the coordinator for geothermal energy for the Department of the Interior, Reid Stone, who just preceded me. He has been most cooperative and most understanding and his industrial background has helped a great deal.

We must bear in mind that it is in this country that geothermal energy has been developed by private industry using private capital. We have demonstrated that geothermal power can be inexpensive, dependable and available for development in extensive areas of the western United States without government subsidy. There is no longer any doubt that the interest in developing geothermal energy is widespread. The attendance at this conference attests to that and points up the need for continuing dialogue and cooperation and better utilization of capabilities and technology already developed.

Mr. Cole and his able staff are to be commended for providing this opportunity for such dialogue, and I would like to propose at this time that we are ready to take the next step, and that step is to establish a Western Geothermal Energy Council—a council composed of representatives of the industry, of technical organizations related to the industry, public agencies directly involved, and representatives of public groups concerned with preservation and improvement of the environment. The Council should have representatives of all of these groups and should meet periodically to discuss matters of mutual concern. It might even be that we might prevail upon Mr. Cole to take on the task of calling the first such meeting soon.

I would like to suggest also that it might be possible for a number of public and private power agencies in the Northwest to combine to select a promising site and to undertake the drilling of one or more wells sufficient to supply a 9 to 10 megawatt (that is, a 9,000 to 10,000 kilowatt) power plant of the Magmamax type. I am not boosting Magmamax here, because I am prepared to offer it without compensation for that test. Magma will contribute the hundreds of thousands of dollars of engineering that have been expended to date to prove that we are willing to utilize our technology at least as fast as those in the foreign countries want to utilize it.

The Republic of Turkey has asked permission to utilize Magmamax, and we have given them permission; and in El Salvador and eleswhere they are seriously considering it. We should have it here. It seems to me that the Northwest is as good a place to start as any. This plan would make possible the immediate development of geothermal energy in the Northwest and spread the costs so that it would require a small, readily manageable amount from each participant. This plan has the additional advantage of reducing the risk of failure. If dry superheated steam is found in the drilling, proven generating facilities of The Geysers type can be used if they so choose; in other words, you will be able to generate power. If, as is very likely the case, superheated water is found, or wet steam, which is not manageable as the steam at The Geysers, then a system such as the Magmamax process can be utilized.

All component parts for proceeding rapidly with the development of geothermal energy in the Northwest are at hand. What is required is cooperation, organization, application of technology and the availability of funds; and if the requirements for funds is spread widely and nobody tries to be the hero or hog the show, it can be done and it can be done rapidly, and it can be done properly.

The geothermal resources of the United States are in the West, and if an abundance of power is developed here, we can help alleviate the power problem of the East. This is not a new role for the West. We have been supplying many of the vital materials needed in the eastern part of our country for many years; for example, the superb aircraft manufactured by the great Boeing facilities, the wood products of the Weyerhaeuser enterprises and other well known members of the forest products industry. Someday soon the geothermal resources of the West will help light homes of the middle and eastern United States, as well as the West; and who knows, the mineral resources of geothermal waters may someday furnish a substantial portion of the minerals and metals required by our growing and vital country.