IDAHO GEOTHERMAL DEVELOPMENT PROJECTS

ANNUAL REPORT FOR 1976

GL07201

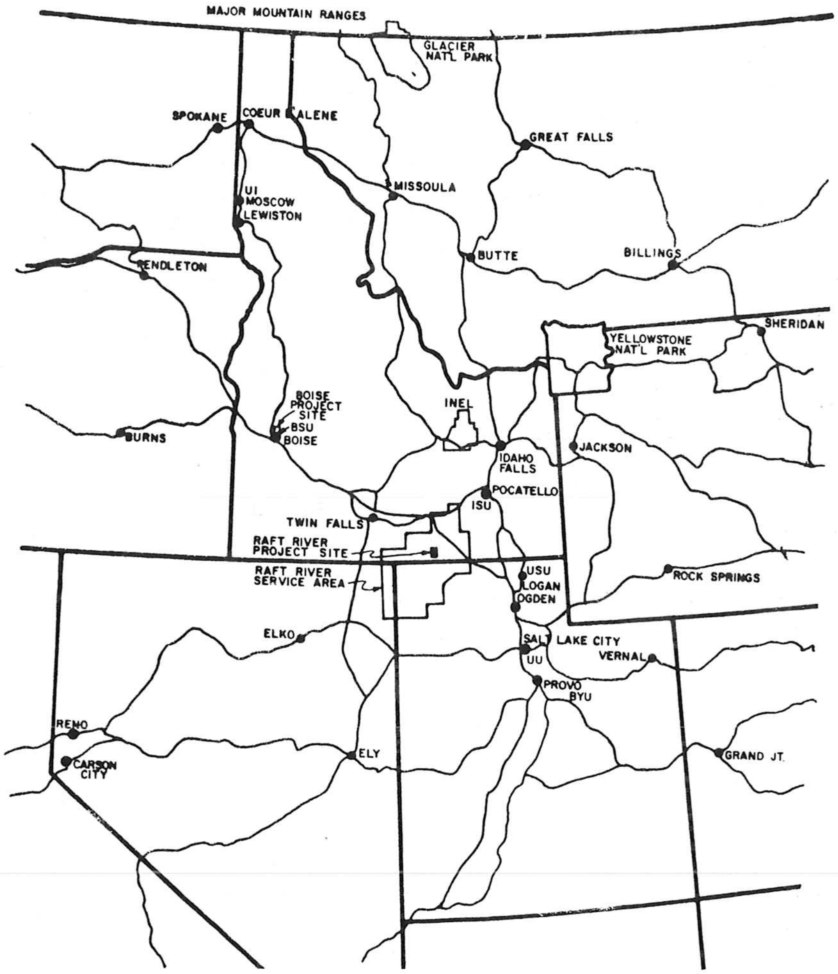
IDAHO NATIONAL ENGINEERING LABORATORY

OPERATED BY

EG&G - IDAHO, INC.

FOR THE

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION



The Geothermal Program at the Idaho National Engineering Laboratory (INEL) has been operating since 1973 as a major research and development effort toward creating an industry that can contribute significantly toward satisfying the energy needs of the Western states. It is believed that geothermal energy can only have a significant impact if means are found to economically use the moderate to low temperature waters, below 150°F (302°C). As the program has continued to develop, it appears these resources are more abundant than once thought, and may be generally available at modest depths throughout most of the area from the Rockies westward.

The year 1976 saw a number of significant advances in the INEL program. Principal success has been that of the wells that have been drilled. A third successful well in Raft River was completed in the spring, to 6000 ft, striking a 149°C (300°F) reservoir, at less cost than either of the other two wells, despite being drilled in a formation of lower productivity. This well employed a special multiple channel drilling technique, which in retrospect was necessary to make the well useful for production of fluids. Two successful wells of shallow depth (1200 ft) were also finished in Boise this summer, both producing artesian flows of the predicted temperature, 75°C (167°F).

The success in tapping both the Raft River and Boise geothermal reservoirs was followed by an extensive reservoir monitoring program. There now is no question that both reservoirs are adequate to do the jobs originally intended for these pilot programs. At Raft River, the near term goal is to produce approximately 15 MW of electricity using several advanced schemes that should significantly reduce the costs of generating electricity. The first 5 MW module was in the final design stage at the end of 1976. The unit will require 2,000 gallons per minute of geothermal water, will transfer 40 MW of heat, and will be capable of taking advantage of the extremes in mountain plateau temperatures so as to get the most efficiency from the plant. Test samples of heat exchangers have been on test for a significant portion of 1976, and have shown significantly better performance over this time than had been expected. Such performance is a much needed benefit for these low salinity, moderate temperature geothermal fluids compared to the hotter fluids with their higher dissolved solids content.

By-product uses of the Raft River geothermal water received season long testing for irrigation of crops and for fish culture. Both results were highly encouraging. The geothermally irrigated crops showed no difference in growth or mineral balance compared to those grown on river water. A test for several years is needed to determine if minerals will accumulate in the soils and adversely affect crops. The fish growing experiments showed an unanticipated benefit. The fish were free of disease, because the geothermal water was free of disease organisms.

In Boise, the success of the two shallow wells and some design innovations lead to the conclusion that providing geothermal space heat to the capitol and other state-owned buildings could be a major economic success if double or triple the number of buildings could be served. The huge capital investment needed in geothermal pipelines needs to be effectively utilized throughout as much of the year as possible. This can be accomplished best by using fossil fuel as an "emergency" peaking, for only a minor fuel cost annually, allowing the pipeline for geothermal fluid to serve those additional buildings. This conclusion underscores one of the principal issues concerning geothermal energy development--that different policies, different approaches, and different techniques may be needed than are now common for fossil fuel systems.

Jay F. Kunze

Jay F. Kunze,
Manager Geothermal Programs
EG&G Idaho, Inc.

FROM THE IDAHO GEOTHERMAL DEVELOPMENT

PROGRAM

THE SIGNIFICANT TECHNICAL DEVELOPMENTS OF 1976

THE YEAR 1976 AND GEOTHERMAL ENERGY FOR THE NORTHWEST

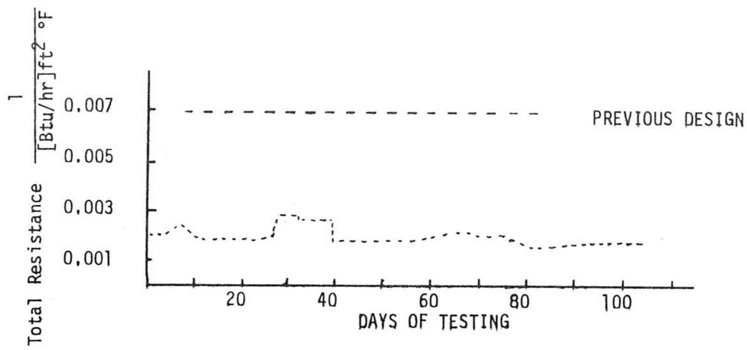
For centuries, geothermal energy has been known to exist. Its first major modern use began with the generation of electricity in 1904 in Lardarello, Italy, midway between Pisa and Rome. That area and the Geysers area, near Santa Rosa, California, each generate approximately 500,000 kW of electric energy produced by steam from deep within the earth. The source of the steam from each of these fields is only a guess, today, and the chance of finding many more such fields is slim. But, hot water reservoirs seem to be very abundant. These are being harnessed in New Zealand, Mexico, and Japan for the generation of electricity and for heating of buildings, processing of chemicals and wood products. In Iceland, the entire capital city of Reykjavik of 100,000 people, plus half of the other 120,000 residents of the country, receive their heat from geothermal reservoirs. Hungary has over 400 geothermal wells supplying space heat, and the Soviet Union and France have several dozen wells used for heating purposes.

As noteworthy as these world-wide developments are, the important question now, in the United States, is the contribution that geothermal energy might make to help alleviate the worsening crisis of scarce and expensive gas and oil. The well drilling success of the Idaho Programs has lead to optimism that perhaps throughout the West, from the Cascades and Sierras to the Rockies, geothermal energy might be very abundant, perhaps could supply 30% of the energy needs of the West. Space heating and some process heat from the energy within the earth might be extensively possible and not just in Klamath Falls and Boise. Electricity, at costs to compete with coal and nuclear, hopefully will soon be possible from the more moderate temperature geothermal waters, about 300^{o}F, that appear relatively common in the West.

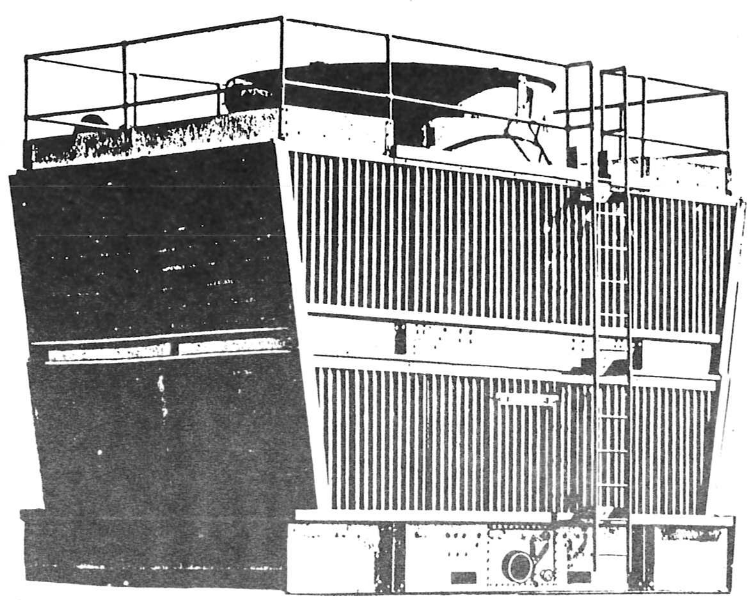
The economics, relative to the competing energy forms, is the key to near term geothermal utilization. Improved economics will, in part, depend on improved technology, better components, innovative systems and combinations specifically developed for economical use of geothermal energy. As of December 1976, it appears that a 30% improvement in the economics of using 300^{o}F geothermal waters for generating electricity in the Northwest would make this use competitive with coal and nuclear energy. As research proceeds, the needed improvements will hopefully develop, many of which are unpredictable in advance. The use of the heat directly for space or process heat appears to be technically feasible and economically attractive today, with only institutional and legal problems impeding its eventual widespread use.

The year 1976 saw several such significant developments, the products of research and development at the Idaho National Engineering Laboratory. The following pages describe some of these.

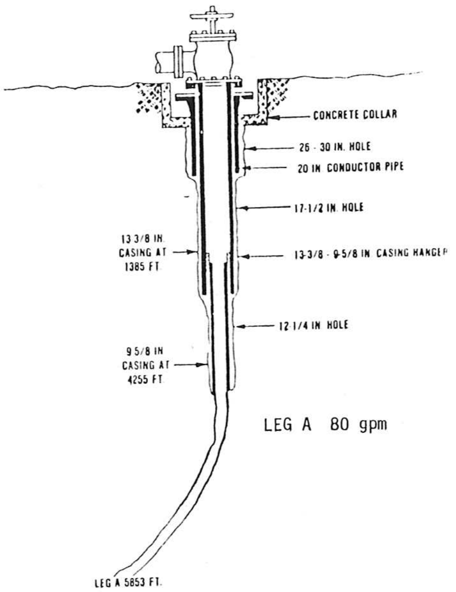
	DEVELOPMENT	COMMENTS	SIGNIFICANCE
1.	DEPOSITION ON HEAT EXCHANGER TUBING WAS NEGLIGIBLE.	AFTER 2200 HOURS IN CONTROLLED EXPERIMENT WITH 2000 PPM. LONGER TESTS PLANNED, SOME WITH 4000 PPM WATER.	TUBING LENGTH IN HEAT EXCHANGERS CAN BE REDUCED 20 TO 30%.

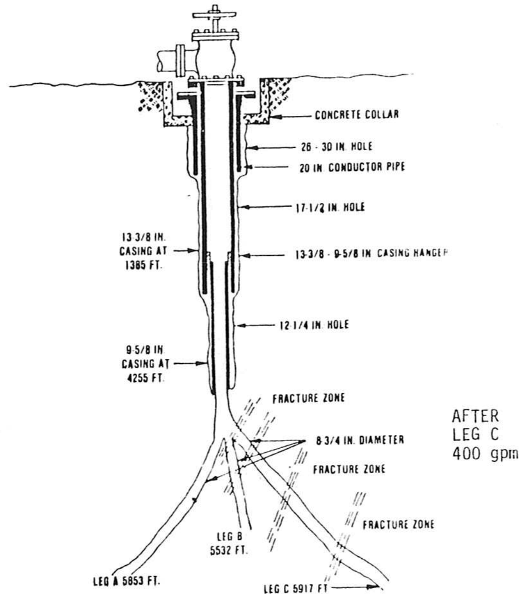


	DEVELOPMENT	COMMENTS	SIGNIFICANCE
2.	GEOTHERMAL MAKEUP WATER FOR POWER PLANT COOLING TOWER.	TESTS UNDERWAY WITH COOLING TOWER AND HEAT EXCHANGER COMPONENT MATERIALS IN CHEMICALLY TREATED GEOTHERMAL WATER.	PRELIMINARY RESULTS INDICATE GEOTHERMAL WATER CAN BE CHEMICALLY TREATED AT REASONABLE COST.

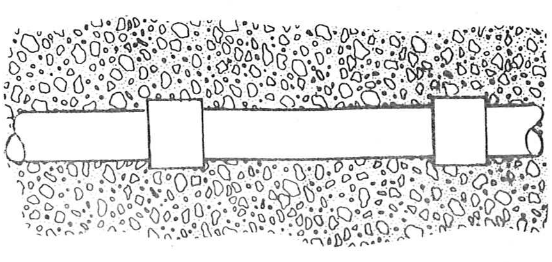


DEVELOPMENT	COMMENTS	SIGNIFICANCE
3. MULTIPLE LEGS IN BAREFOOT SECTION TO ENHANCE PRODUCTION AT MINOR INCREASE IN COST.	FOR RRGE #3, PRODUCTION ENHANCED 3 TO 5 TIMES FOR 20% INCREASE IN COST. FOR HOMOGENEOUS PERMEABILITY, A 50% INCREASE IN PRODUCTION FOR 20% COST INCREASE IS THE LIKELY RESULT.	ALL FUTURE WATER DOMINATED PRODUCTION WELLS SHOULD BE DRILLED FOR MULTIPLE LEGS.

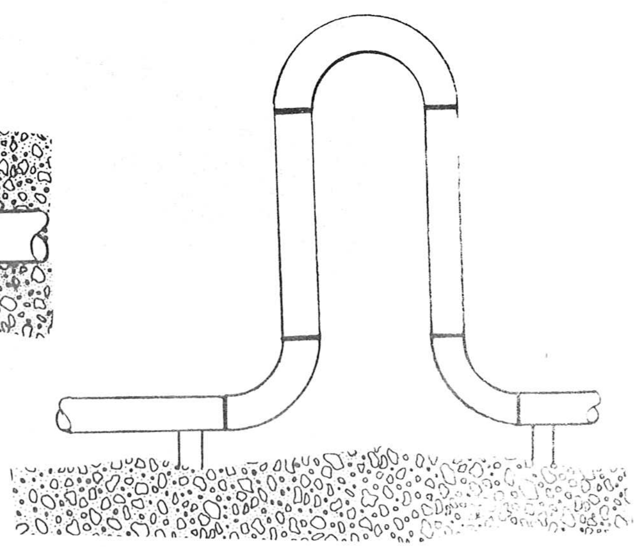




DEVELOPMENT	COMMENTS	SIGNIFICANCE
4. TRANSITE PIPE USED SUCCESSFULLY.	SEVERAL BREAKS EXPERIENCED, ALL FINE CRACKS APPARENTLY FROM THERMAL SHOCK. IN GENERAL, PERFORMS WELL, ESPECIALLY DURING ROUTINE STEADY STATE.	55% COST SAVINGS COMPARED TO STEEL PIPE. NEXT SIZE SMALLER PIPE CAN BE USED BECAUSE OF REDUCED PRESSURE LOSS IN TRANSITE PIPE



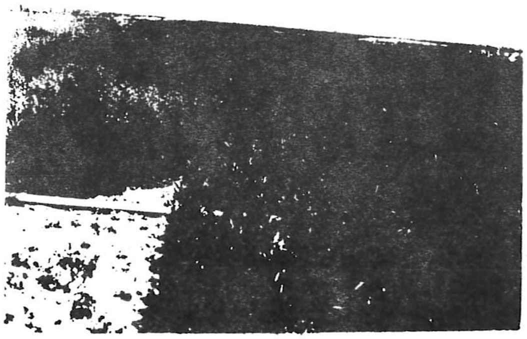
TRANSITE PIPE



WELDED STEEL PIPE

DEVELOPMENT	COMMENTS	SIGNIFICANCE
5. AGRICULTURE IRRIGATION WITH GEOTHERMAL WATER SUCCESSFUL THE FIRST YEAR.	NO DIFFERENCE IN MINERAL UPTAKE COMPARED TO CONTROL CROPS. LONG TERM BUILDUP IN SOIL WILL BE MONITORED FOR AT LEAST 3 YEARS.	A POSSIBLE BY-PRODUCT USE FOR IRRIGATION, ESPECIALLY VALUABLE IN WATER POOR AREAS.

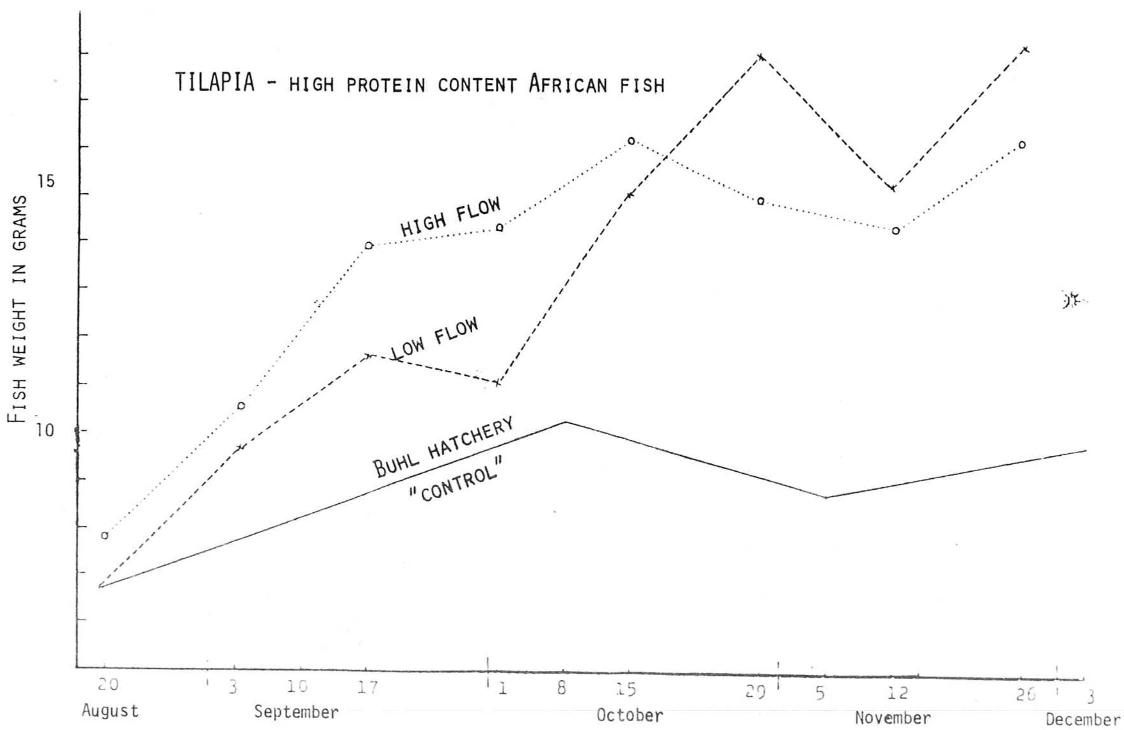
12 ACRES TOTAL OF GRASSES, WHEAT, BARLEY, OATS, ALFALFA PLUS SOME POTATOES, BEETS, SPINACH LETTUCE, SQUASH



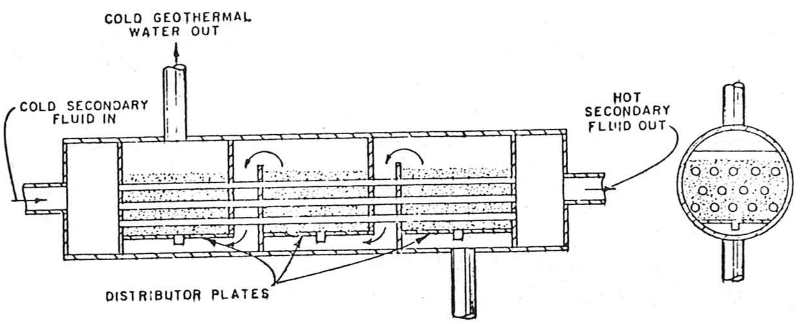
BARLEY AND WHEAT
7-20-76

WHEAT
7-31-76

DEVELOPMENT	COMMENTS	SIGNIFICANCE
6. FISH RAISING UNUSUALLY DISEASE RESISTANT.	FASTER GROWTH, VIRTUALLY ZERO DISEASE MORTALITY OF CATFISH, PERCH, AND TILAPIA.	GEOTHERMAL WATER APPEARS TO OFFER MAJOR ADVANTAGES FOR FISH CULTURE -- POSSIBLE BY-PRODUCT USE FROM POWER PLANTS.

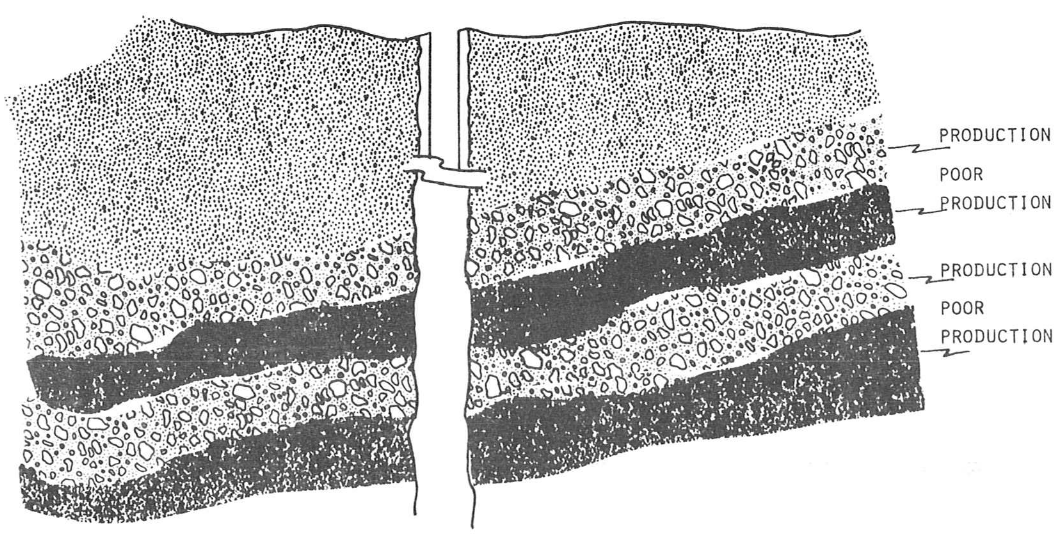


DEVELOPMENT	COMMENTS	SIGNIFICANCE
7. FLUIDIZED BED HEAT EXCHANGER HEAT TRANSFER COEFFICIENT MEASURED WITH GEOTHERMAL FLUID.	NO FOULING ON TUBES. BUT EXPERIMENTS TO DECREASE NUMBER OF STAGES AND SIZE OF PRESSURE VESSELS IS CONTINUING.	GEOTHERMAL APPLICATION GIVES 30% LESS TUBING LENGTH THAN STANDARD HEAT EXCHANGER, PROBABLY MAKING OVERALL COSTS SIMILAR. NO FOULING UNDER MOST ADVERSE CONDITIONS MAKES THE FLUIDIZED BED A CANDIDATE FOR ALL BUT THE MOST BENIGN GEOTHERMAL FLUIDS.

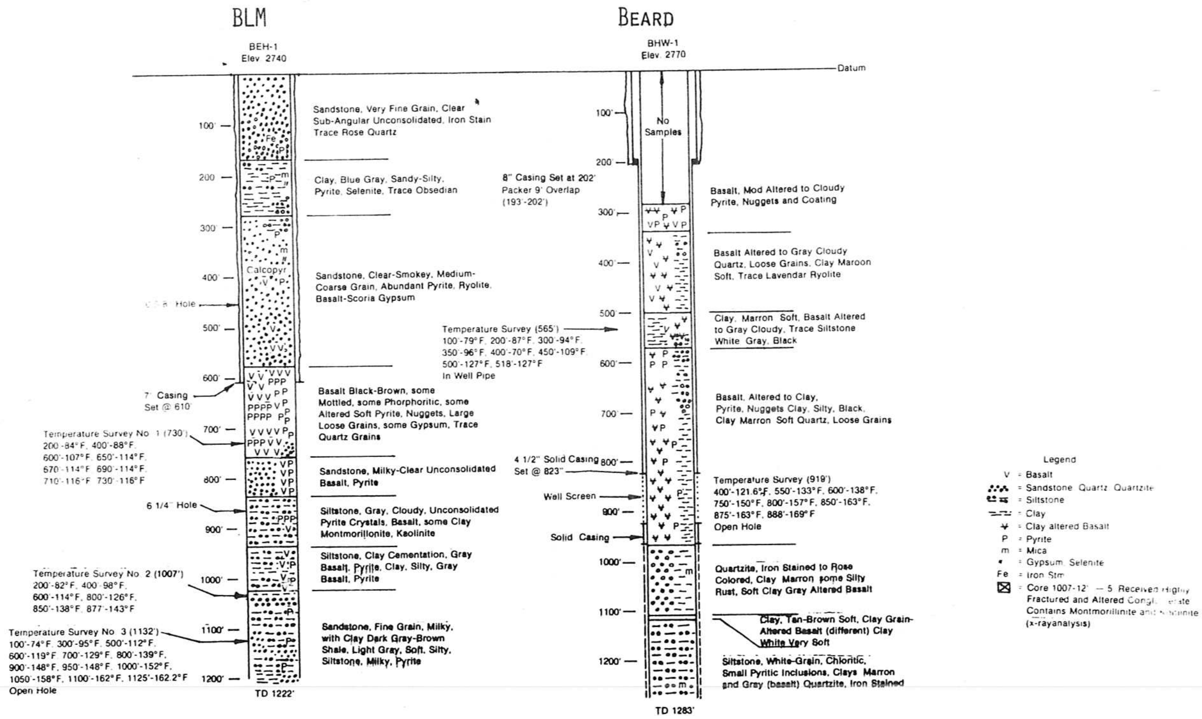


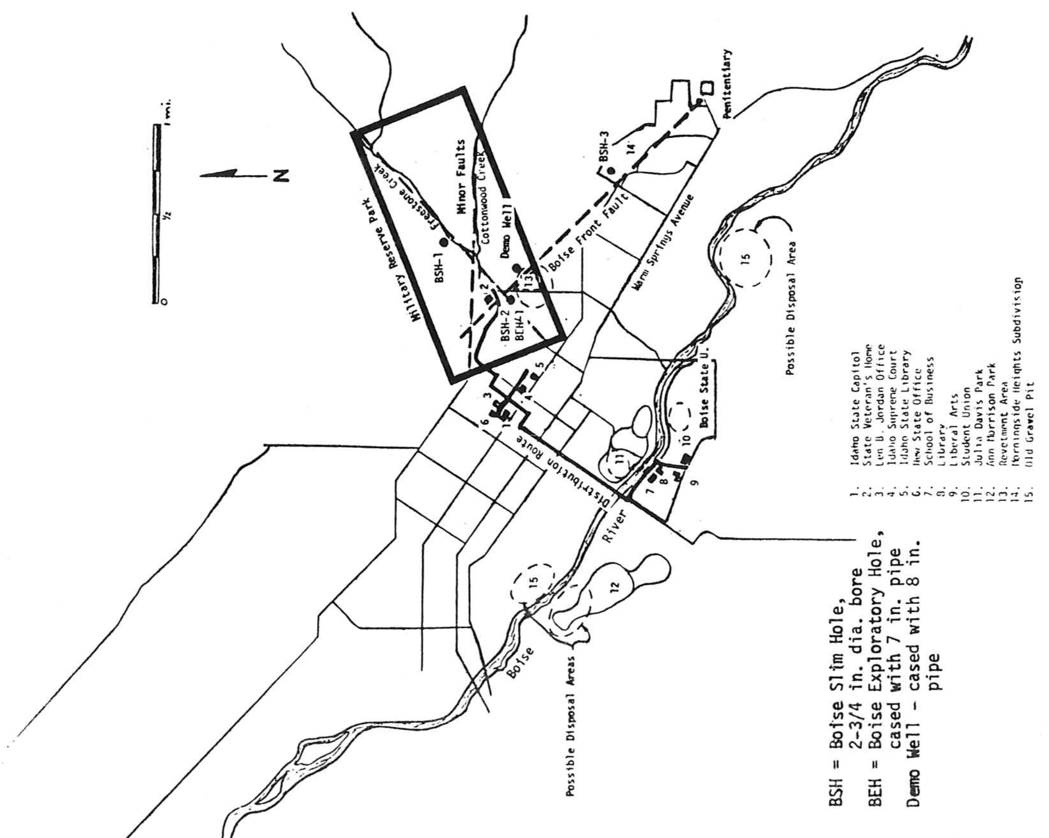
Liquid Fluidized Bed

DEVELOPMENT	COMMENTS	SIGNIFICANCE
8. REINJECTION EXPERIMENTS IN RAFT RIVER #2 WELL GAVE UNEXPECTED INFORMATION ON PRODUCING STRATA, POROSITY, AND THERMAL CYCLING.	PRODUCTION ZONES AND STRATIGRAPHY OF THE RESERVOIR WERE MACROSCOPICALLY INTEGRATED BY THIS EXPERIMENT.	PROVIDED A TOOL FOR OBTAINING INFORMATION ON PRODUCING ZONE, INFORMATION PREVIOUSLY ONLY VERY CRUDELY INFERRED FROM A VARIETY OF LOGGING METHODS.

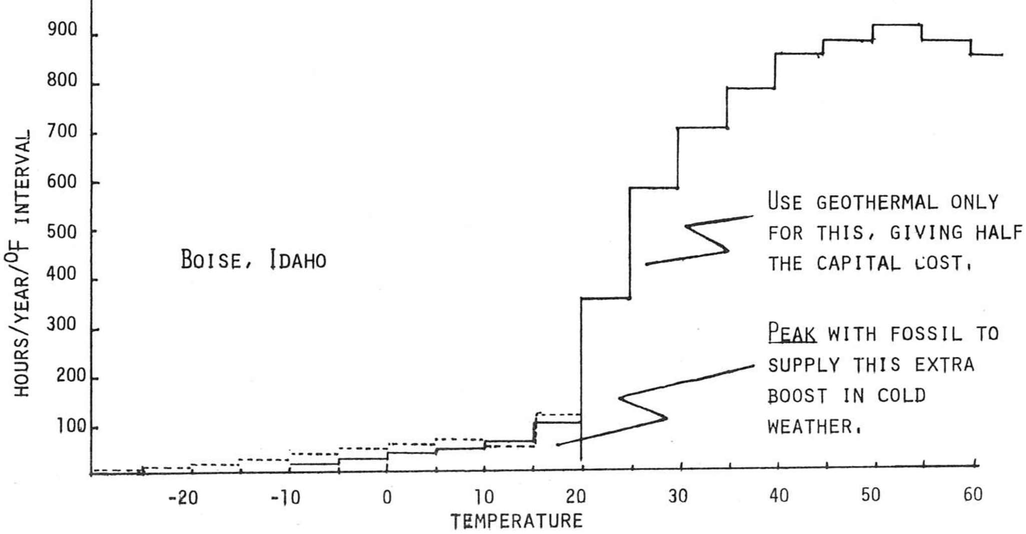


DEVELOPMENT	COMMENTS	SIGNIFICANCE
9. BOISE WELLS.	TWO OUT OF TWO SUCCESSFULLY TAPPED RESERVOIRS AT "SHALLOW" (1000 FT) DEPTH.	TWO MAJOR SUCCESSES, DRILLED ONLY WITH SURFACE GEOLOGY INFORMATION AS A GUIDE, AT VERY LOW COST.

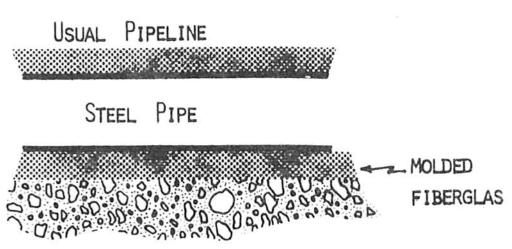




DEVELOPMENT	COMMENTS	SIGNIFICANCE
10. ECONOMIC ADVANTAGE OF FOSSIL PEAKING FOR SPACE HEATING GEOTHERMAL SYSTEMS.	DESIGNING FOR TWICE THE LOAD HENCE TO ONLY HALF THE NORMAL DESIGN TEMPERATURE, WITH FOSSIL PEAKING FOR THE COLDER DAYS, LEAVES FOSSIL SUPPLYING ONLY 6% OF THE ENERGY REQUIREMENTS, CUTS GEOTHERMAL UNIT CAPITAL COSTS IN HALF.	OVERALL ECONOMICS OF GEOTHERMAL HEATING IMPROVED BY ABOUT 35%.

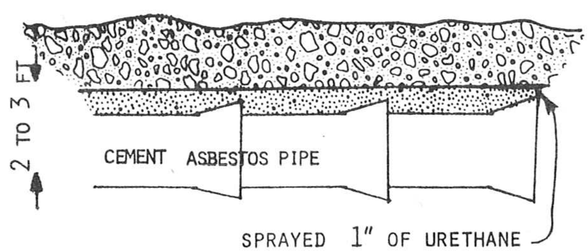


DEVELOPMENT	COMMENT	SIGNIFICANCE
11. CAPABILITY AND ECONOMIC SAVING IN USE OF URETHANE FOR 300°F GEOTHERMAL PIPING.	DEMONSTRATED AT RAFT RIVER ON 290°F PIPES. CONSIDERED NOT PRACTICAL PREVIOUSLY, BUT ADHERES WELL AND IS FIRE RESISTANT.	80% COST SAVINGS COMPARED TO MOLDED FIBERGLAS. $1000 FOR 600 FT OF PIPES AND VALVES INSULATED WITH URETHANE. $8000 FOR FIBERGLAS.



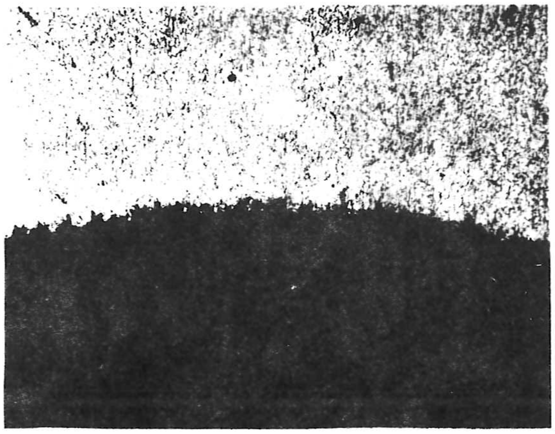
$60/FT TOTAL COST

RAFT RIVER PIPELINE

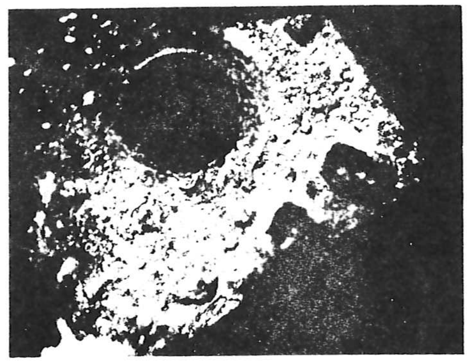


$20/FT TOTAL COST

DEVELOPMENT	COMMENTS	SIGNIFICANCE
12. Corrosion results obtained on power plant component materials	After 2200 hours in controlled experiments, with 2000 ppm water.	Data gathered for this period of time on 30 different metals.



Corrosion pits in carbon steel tubing used in geothermal water service. Magnification about 400X. No cleaning or scrubbing during test. Corrosion appears to be catalized by deposition on surface. Periodic scrubbing should reduce corrosion significantly.



Tubercles formed on low carbon steel corrosion coupon exposed to aerated geothermal water for about 7 weeks. No magnification. Compare with picture to right with unareated water in which corrosion could barely be detected without magnification.

The success of the program to date has been the result of the active cooperation of the Raft River Rural Electric Cooperative, the State of Idaho, the U.S. Bureau of Land Management, the U.S. Geological Survey, and some 60 member utilities of the Northwest Public Power Association. Several universities in the region have been supported in research for which they have special capability. Of particular concern is the development of geothermal energy in a manner that will give full consideration for the desire to minimize the impact on the environment. The INEL has been working closely with universities, the U.S. Fish and Wildlife Service, and several other national laboratories so as to make geothermal one of the most environmentally acceptable forms of energy.

For further information, please contact the Geothermal Program Office

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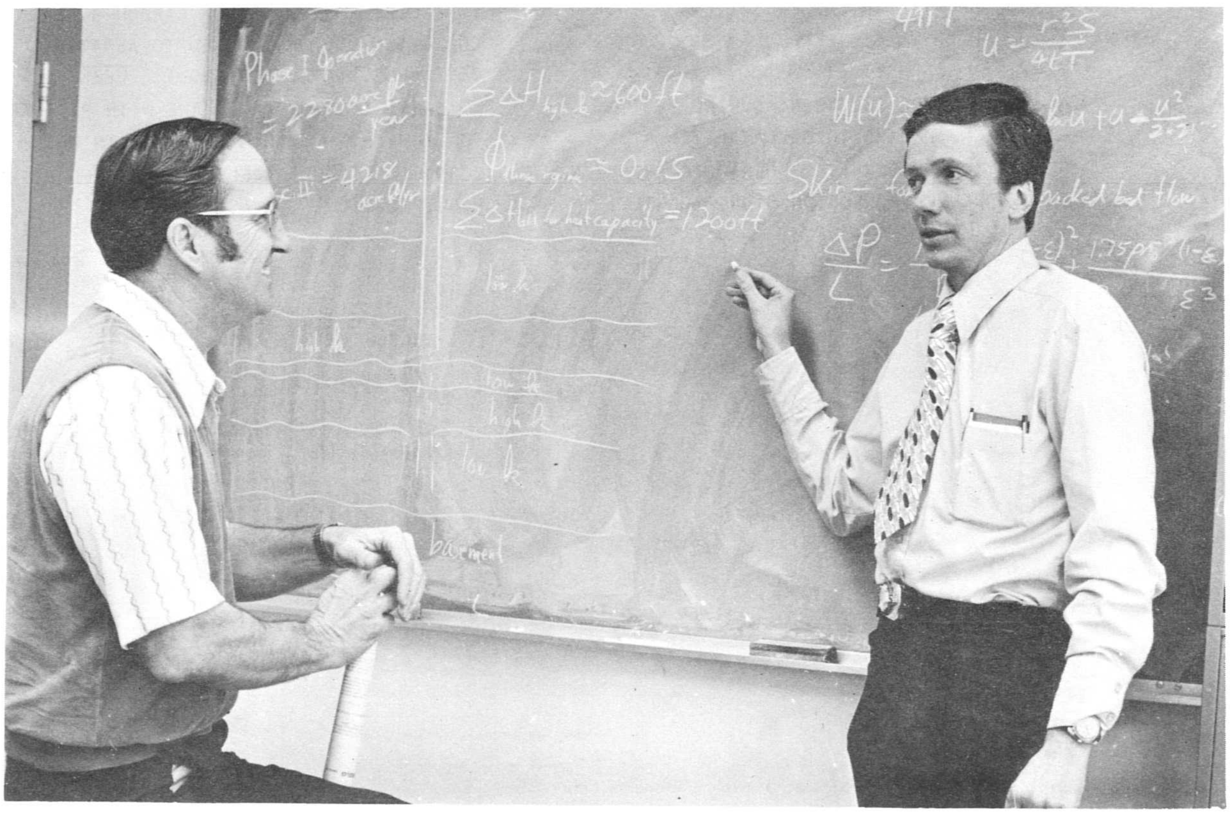
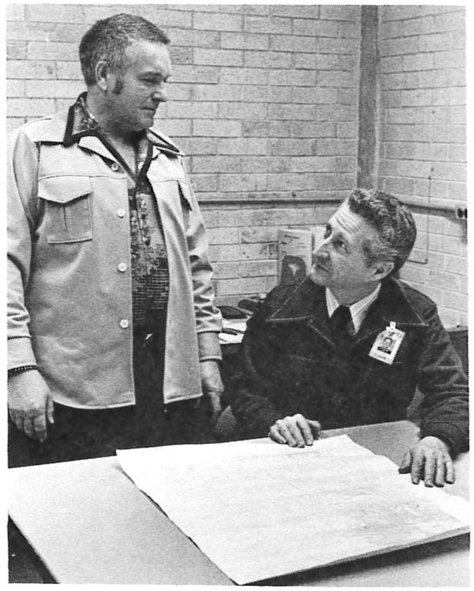
P. O. Box 1625
Idaho Falls, ID 83401
(208-522-6640, Ext. 1781)

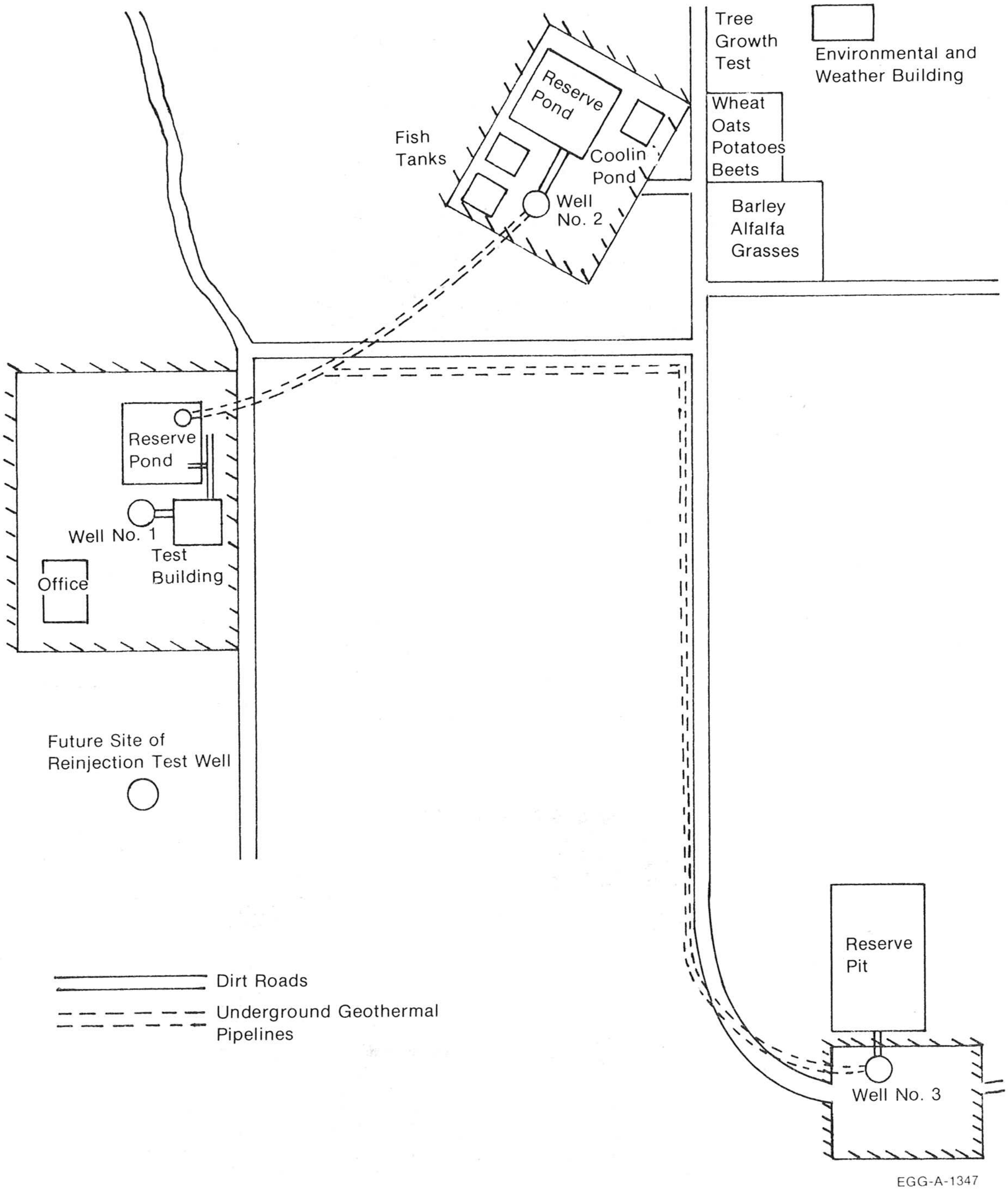


John Griffith, ERDA-Idaho Geothermal Office Director, and Dr. Jay Kunze, Manager of Geothermal Programs for EG&G Idaho, Inc. discuss the interpretation of present reservoir data in terms of the understanding of the producing zones with the well bore.



Field Operations Manager, Lowell Miller, and Environmental Control Manager, Winston Hickman, review the selection of sites for the sensitive seismic (earthquake) recorders that are installed near both the Raft River and Boise geothermal reservoirs. These detectors will sense earth tremors only 1/100 as strong as those that people can feel, and are being used to detect motion of the earth that might be occurring in or near the reservoir.

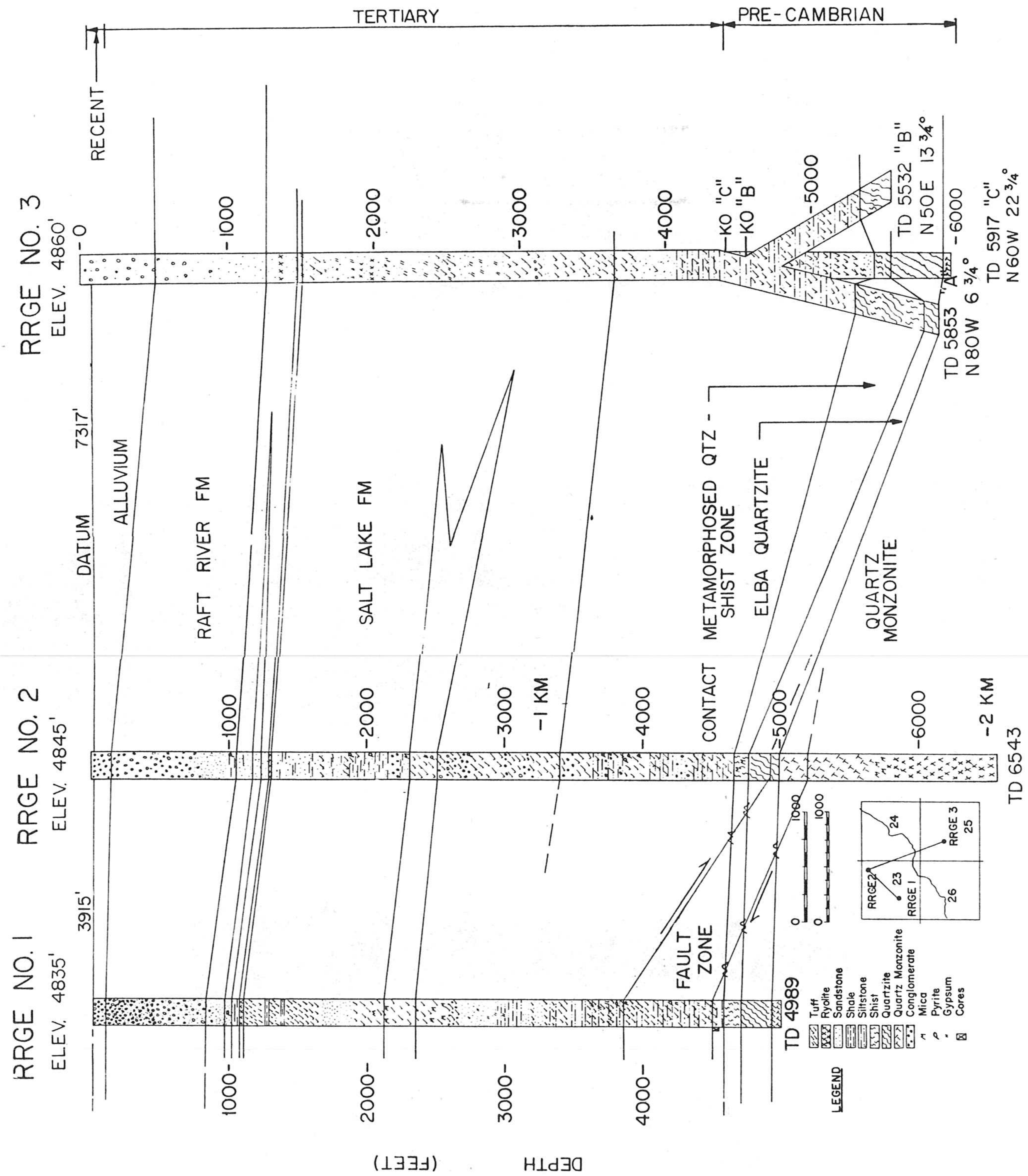
The electric power plant design is under the direction of Judson Whitbeck, who is shown consulting with reservoir engineering geologist Roger Stoker, concerning the integration of the well field for both production and re-injection, and the most appropriate location for the pilot plant.



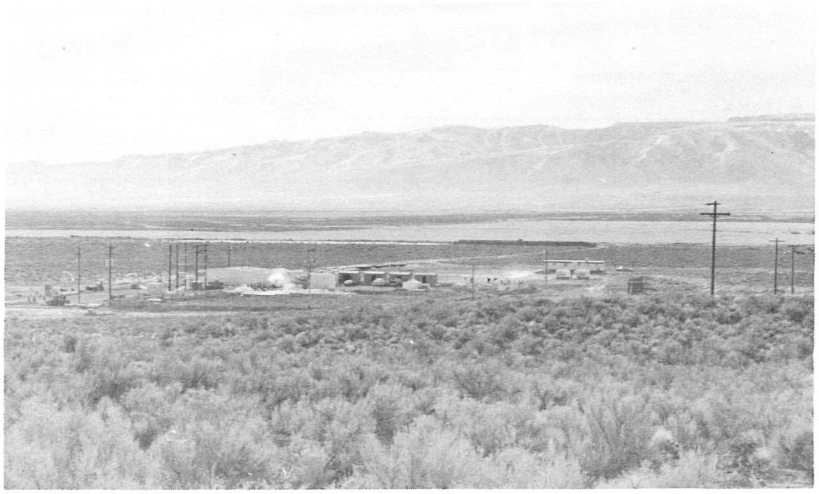
The Raft River Geothermal Test Site, 12 Miles South and 4 Miles West of Malta, Idaho

The distances between the wells are:

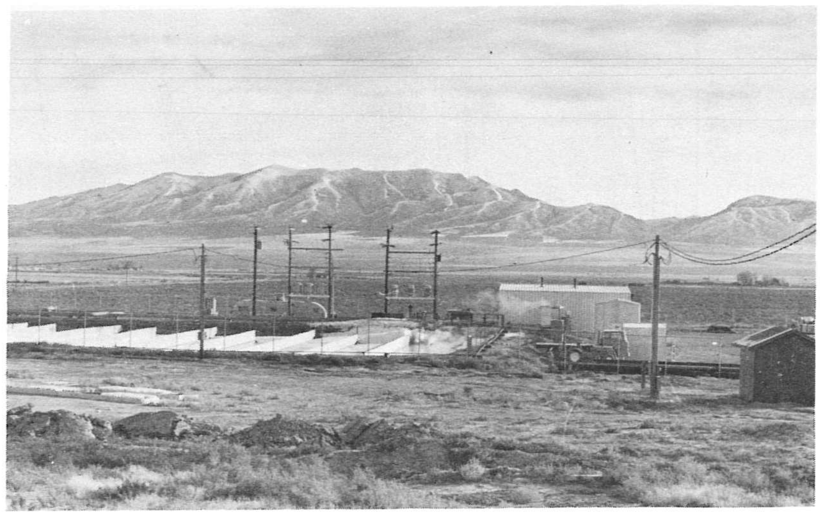
RRGE-1 to RRGE-2	4000 ft
RRGE-1 to RRGE-3	5900 ft
RRGE-2 to RRGE-3	6900 ft

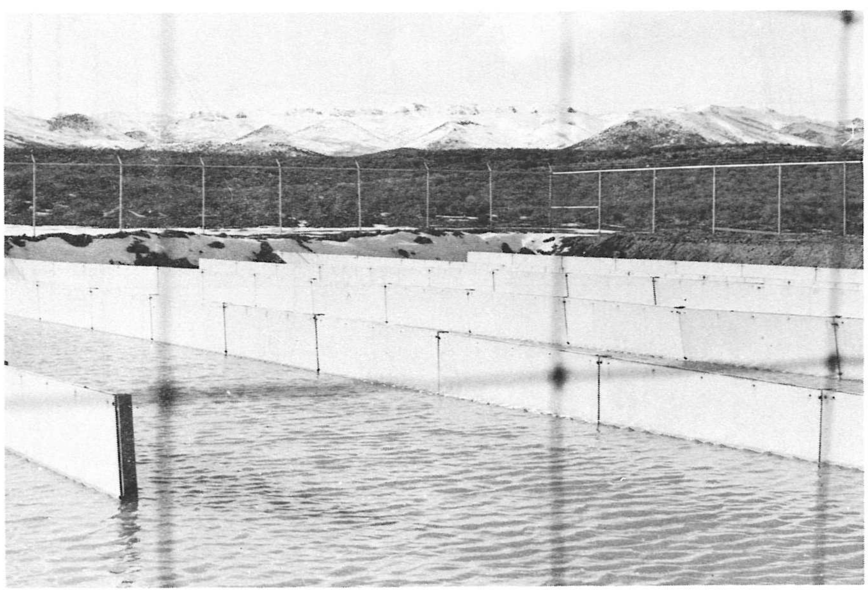


The three present hot wells at Raft River



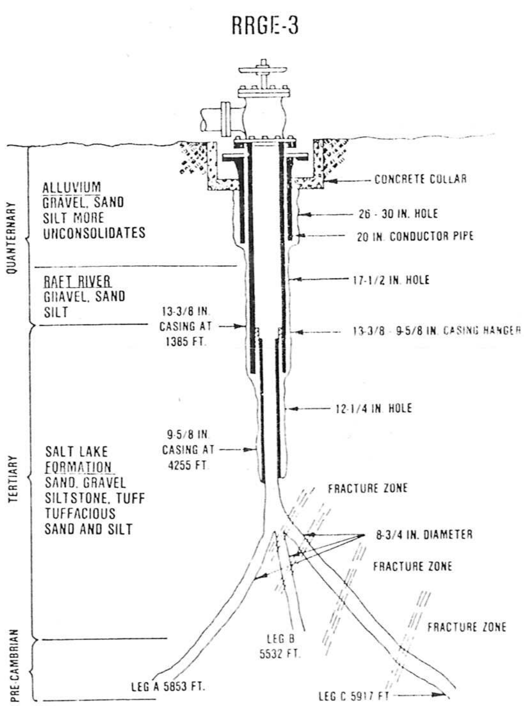
The operation's office is at site No. 1 (RRGE-1). The No. 1 well has been used for most of the year to supply test fluids for engineering experiments and agricultural tests.



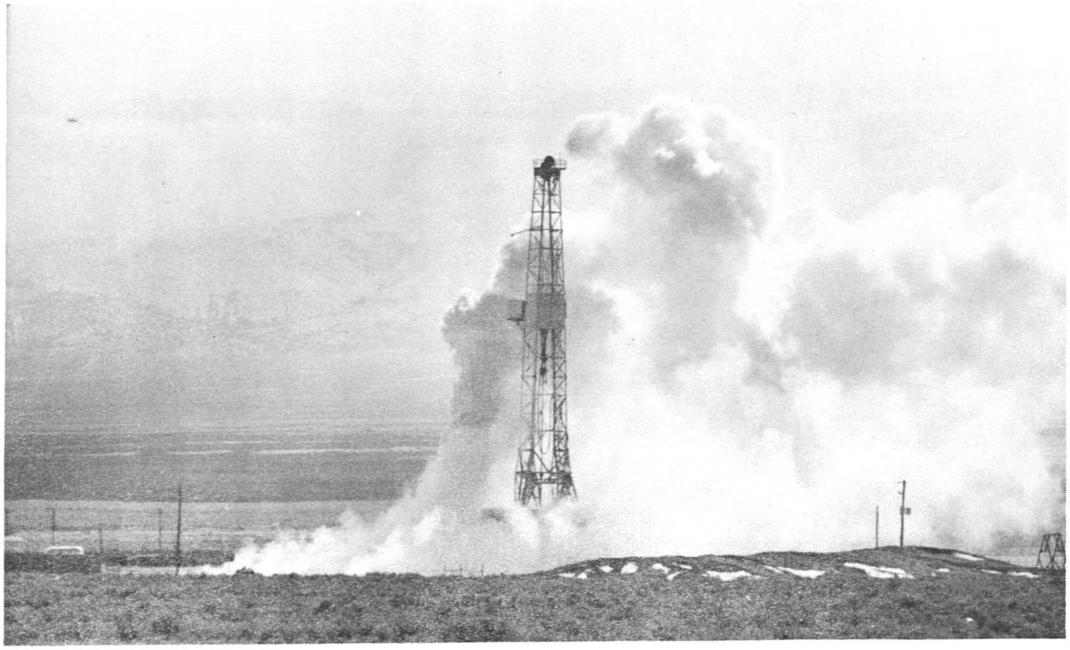


Each well has a large reservoir pond adjacent, to hold water for cooling and evaporation, eventually to be disposed of by re-injection or for use in crop irrigation experiments.

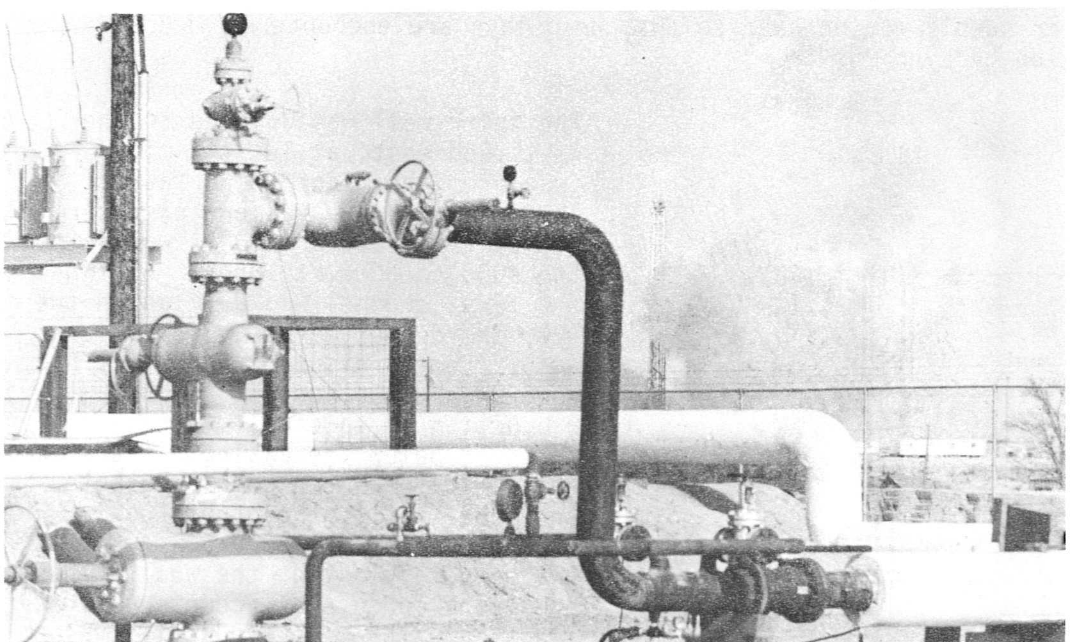
The drilling of geothermal wells presented two challenges. First is the problem of knowing where the resource is encountered by the drill bit, since the cold drilling fluid looks the same when it comes back to the surface as geothermal water that it encounters. All of the INEL drilling has been done in the expected resource region with water, not mud, as the drilling fluid. Though all the wells have been thoroughly logged using the standard oil well techniques, to date only sensitive and accurate temperature logs have been of real value in determining the production zones. Secondly, is the question of the nature of the producing zones. It is ideal to have a core of such regions, but these must be cut ahead of the regular drilling. Nevertheless, a useful complement of cores were obtained, some apparently did come from production zones, are shown being examined by Geologist Susan Prestwich. Keeping tools in supply and on hand so that no delays are encountered is given attention by Lynn Martin.



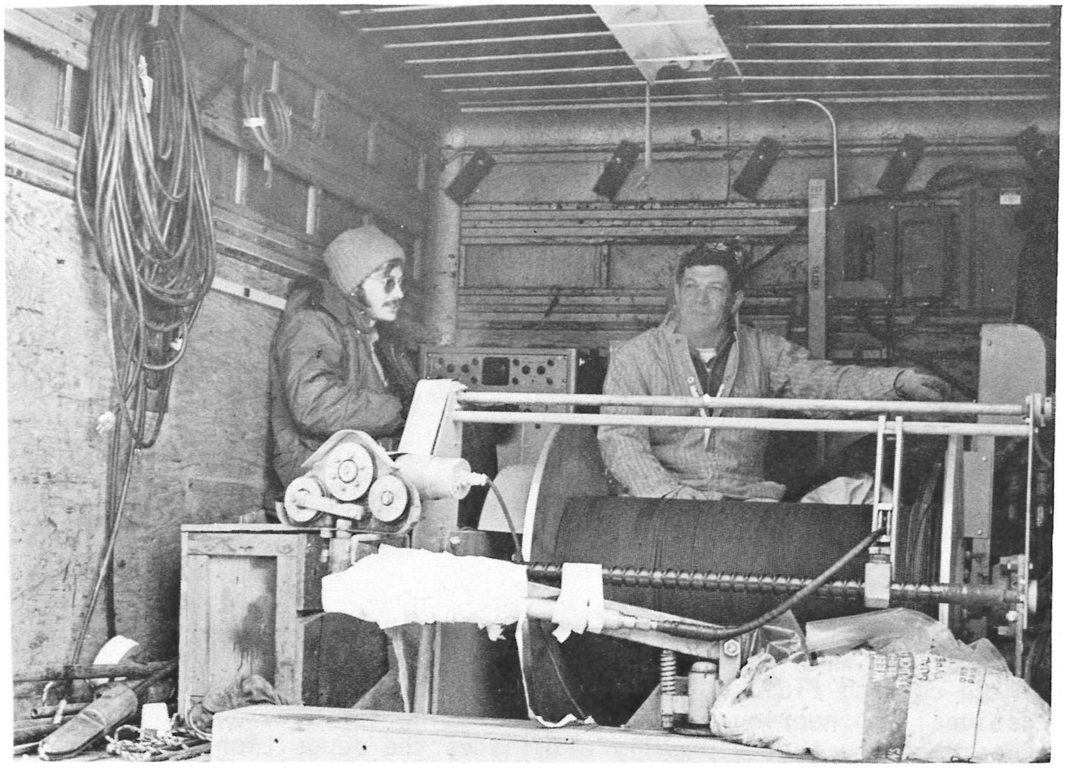
The third well was drilled to the south and east, at least a mile away from the major known faults. The well was an excellent producer of low temperature (230°F) water from the 2000 to 3000 ft level. But when the first channel was drilled in the 4200 and deeper layers, production was extremely disappointing. It had, however, been planned to enhance the production of this well with extra channels below the casing, if the early production had been good. Despite the poor result, the other two channels were drilled, adding 20% to the total cost of the well. These additional channels encountered fractions, and the well productivity increased about a factor of 500%. a most pleasant surprise. It is now believed that such outstanding advantages from multiple channelling might occur in many locations where the rock is producing water primarily through fractures and not through rock voids.



The second hot well was deepened in the spring of 1976, from 6000 ft to 6500 ft. The entire drilling operation penetrated basement rock, quartz monzanite. An occasional fracture was encountered, but neither the temperature nor flow were noticeably increased by the 500 ft of drilling.

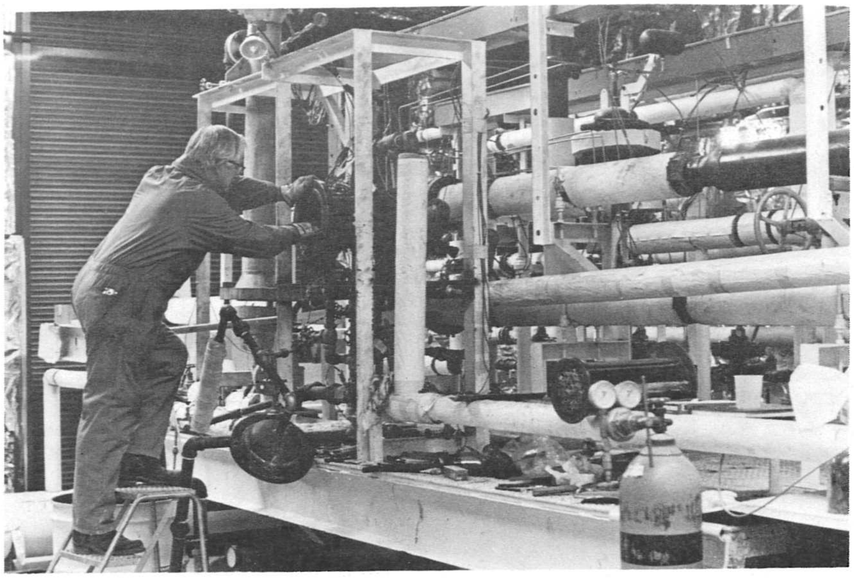


The completed wells are equipped with control valves, piping, and eventually pumps to supply fluid to various engineering, agricultural, and hydrological tests.

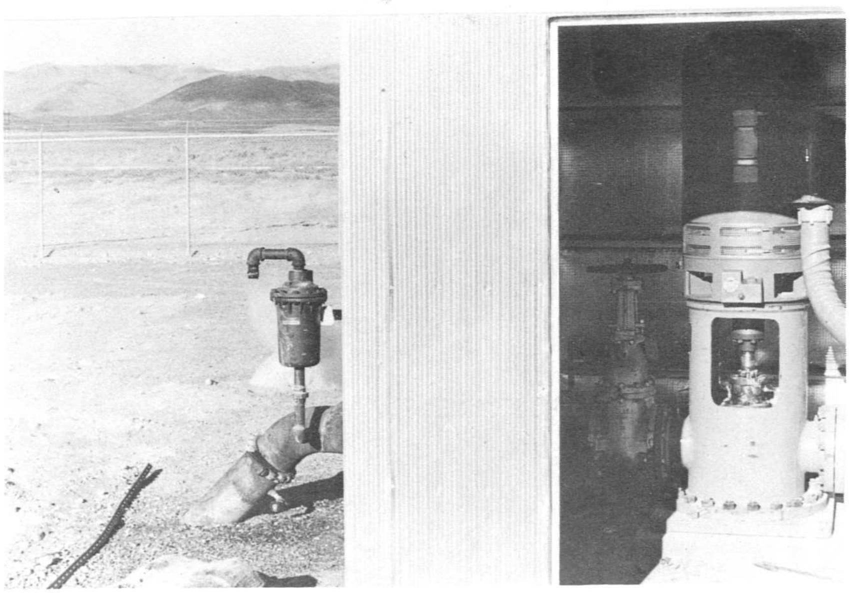


What goes on deep inside a geothermal well is moniotred by electronic instruments lowered on an electronic cable into the well. Pressure, temperature, sonic velocity, well diameter, and differences in flow into the well are measured with this equipment. Dennis Goldman, Hydrologist and Don Suckling, Engineer are shown at the electronic and winch controls.

Delivering the geothermal fluids from the well to the power plant needs to be done with minimum of temperature loss, and preferably with least cost for the pipeline. Cement-asbestos pipe is being used experimentally, buried about 2-1/2 ft, while all exposed pipelines are using spray-on insulation. Both result in significant savings compared to welded steel pipe insulated with fibreglas. Dean Fredrickson checks the temperature at the downstream end of the pipeline.

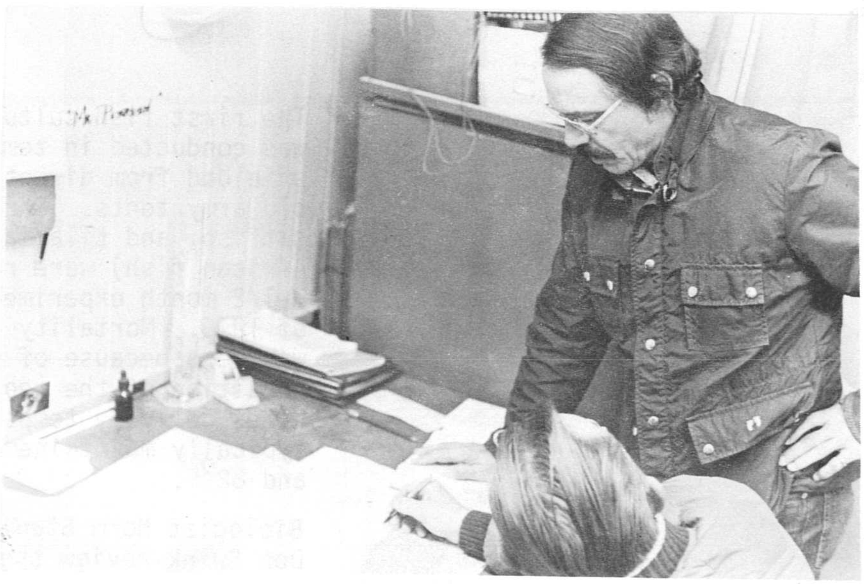


Materials and heat exchanger testing is performed inside the main test building on a system with considerable flexibility for supplying both geothermal and cooling fluids. The Allied Chemical Corporation group at Idaho National Engineering Laboratory is testing a fluidized bed heat exchanger (shown) that virtually eliminates the deposition problem. University of Utah is conducting tests on a direct contact heat exchanger that will directly mix the organic fluid and geothermal or cooling water. The advantage is that the miles and miles of tubing for conventional heat exchangers could be eliminated. The conventional, so-called tube-in-shell heat exchangers showed good outstanding performance in the tests conducted to date, continuing to transfer heat at a much higher rate than expected.



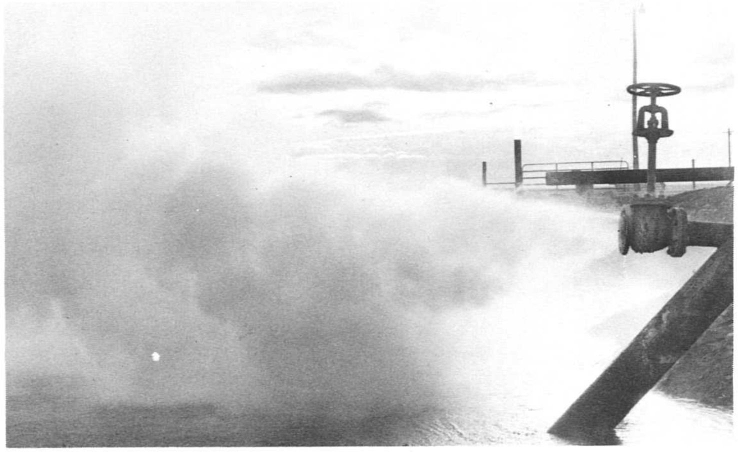
Large pumps, 300 to 500 horsepower each are used on the wells. On the right is a re-injection pump, housed inside a small metal shed. Pumps on the producing wells are generally mounted so that their impellers are 600 to 1000 ft below the surface. The three wells appear to be capable of supplying about 3000 gallons per minute of geothermal water when pumped, but only 1000 gallons per minute under artesian flow conditions without a pump.

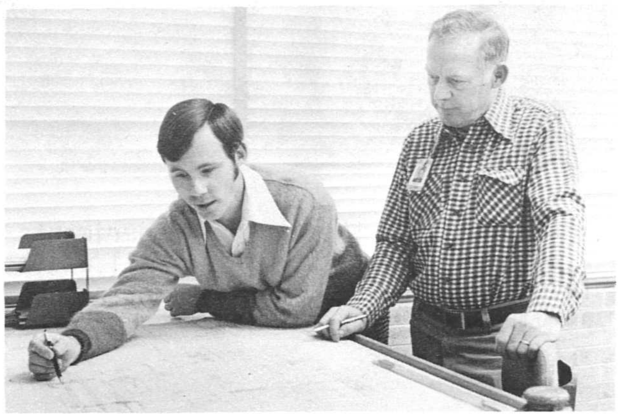
Pipelines and utilities for the various experiments and the field quarters are a major site activity. The fall weather of 1976 was particularly favorable for accomplishing the needed work. Ross Jones trenches for an electrical conduit.



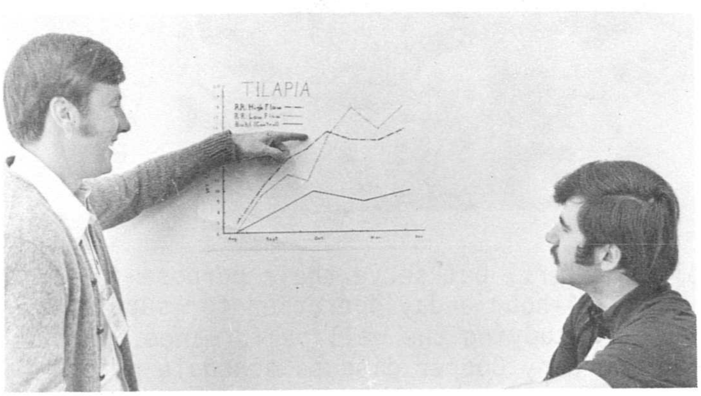
Field offices are set up in old trailers, but serve their purpose for carrying out the seven day a week, 24-hour a day operation for supplying geothermal fluids for tests and for studying the well performance. Site Shift Supervisors, Ken Peterson and Gary Cooper discuss schedule prior to a shift change.

Keeping hot fluids flowing from the artesian pressure wells is an around-the-clock monitoring job. Well repairs are difficult and dangerous, since two of the three wells cannot be "killed" with cold water. Engineers have designed a clever valve and shut-off arrangement that can be triggered at, for instance, the 1000 ft deep level in a well with a simple wire-line unit run by a winch. Jim Neitzel and Ray Sanders were the designers of the valve.





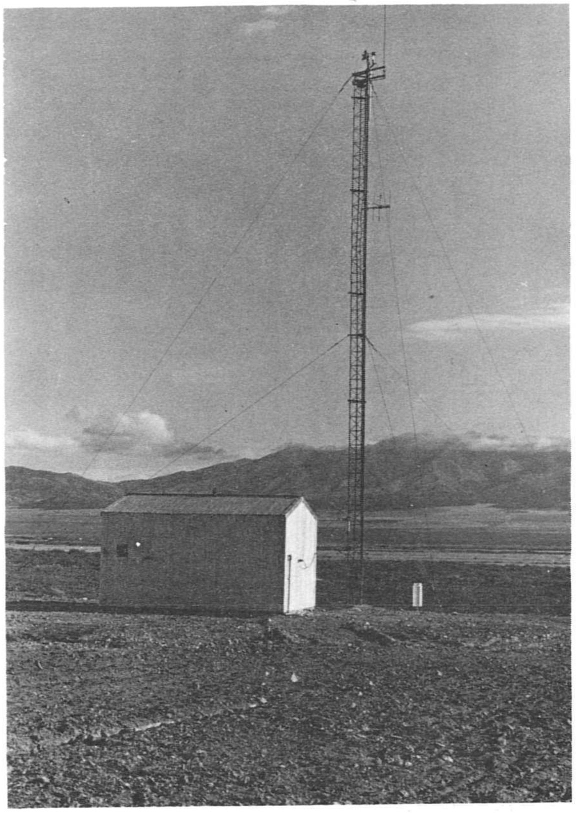
The first fish culture experiment was conducted in temporary tanks shielded from direct sunlight by old army tents. Shrimp, perch, catfish, and tilapia (a warm water African fish) were raised during a 3-1/2 month experiment in the fall of 1976. Mortality from disease was zero because of the germ-free condition of the geothermal water. Water delivery temperatures were typically maintained between $72^{\circ}F$ and $82^{\circ}F$.



Biologist Norm Stanley and Chemist Don Swink review the growth chart that shows both the high and low flow Raft River geothermal water gave faster growth rate than the control fish in a hatchery at Buhl.

Twelve acres of test plots were planted in various grains, grasses, and vegetables that are common garden products in the Raft River area. Half were irrigated with river water, half with cooled geothermal water at about 90°F. Both crops were essentially identical. It was theorized that the amount of minerals in the geothermally irrigated crops would be excessive, but the geothermal crops developed as low a mineral content as the new irrigated crops. The experiment will continue for the next several years to determine if buildup of minerals occur in the soils. Shown in the field are Steve Metzger, who is hoping to stimulate similar uses of geothermal water elsewhere, and Geologist Wendy Bierlein.

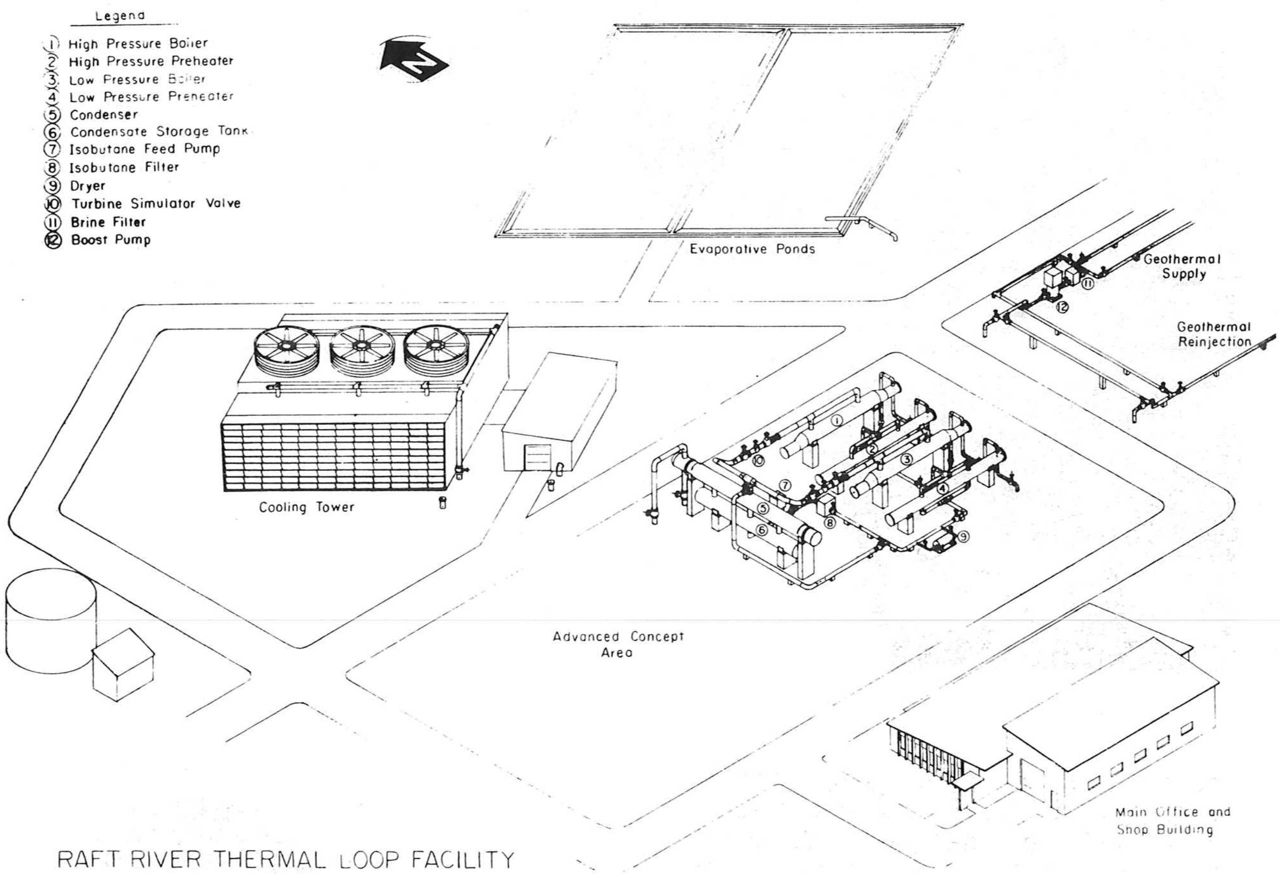
The crops were sampled for both yield and subject to thorough chemical analysis for all minerals that might be of concern. Dick Schmitt who directed the experiment examines some of the grain with environmental engineer, Sue Spencer.



A special environmental building and site has been established downwind from the Raft River wells. Not only is meteorology, but seismicity (earthquakes), subsidence (settling of the ground), air quality and water quality of wells and the river are routinely monitored. The plant and animal life has been thoroughly tabulated, for later comparisons.

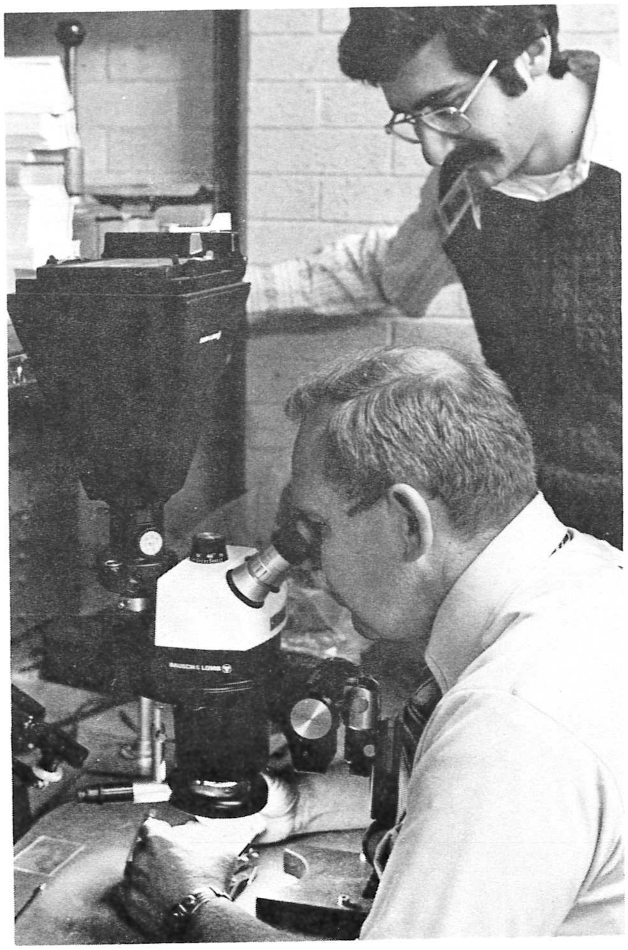
The numerous organizations participating or cooperating are shown in the matrix chart below, with reference to all the environmental activities being conducted.

	Air	Water	Physiography	Biological Environment	Human Environment	Integrated Program
Idaho National Engineering Lab.	X	X	X	X	X	X
Energy Research & Development Admin. Idaho Operations Office	X					X
U.S. Environmental Protection Agency		X				X
U.S. Fish & Wildlife Service				X		
U.S. Soil Conservation Service			X			
National Oceanic & Atmospheric Adm.	X					
U.S. Bureau of Land Management				X		X
U.S. Geological Survey		X	X			
U.S. Bureau of Reclamation		X				
Idaho Dept. of Water Resources		X				
Idaho Bureau of Mines & Geology		X				
Idaho Dept. of Fish and Game				X		
Idaho Dept. of Health & Welfare	X	X				X
Battelle Human Affairs Research Cnt.					X	
Battelle NW		X				
Univ. of Utah Research Institute	X			X		X
University of Utah		X	X	X		
Idaho State University				X	X	
University of Idaho				X		
Brigham Young University				X		X
University of California - Berkeley			X			
Colorado School of Mines			X			
Utah State University		X	X	X		
Private Consultants		X	X	X		X
Service Companies	X	X				



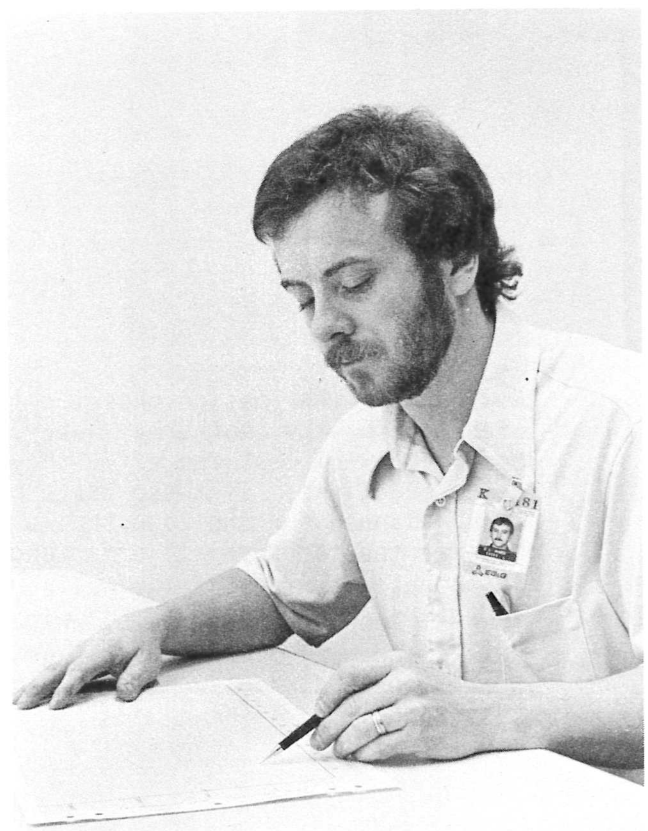
RAFT RIVER THERMAL LOOP FACILITY

Now in the final design phase, this thermal loop will exchange 40 Megawatts of heat from the geothermal water, discharging the heat to the atmosphere. Operation will test the efficiency and durability of equipment to perform these functions. If these tests prove successful, a turbine-generator, being planned for the loop, should generate at least 5 MW of electricity. Despite the poor overall efficiency, 12-1/2%, it should be noted that there is no cost for fuel if the wells can be kept producing indefinitely. The thermal loop will be "fueled" with 1900 gallons/minute of 290°F geothermal water, and will discharge this water at 140°F. After extracting some additional heat, non-electrical uses, the used geothermal water will be injected back into the ground.

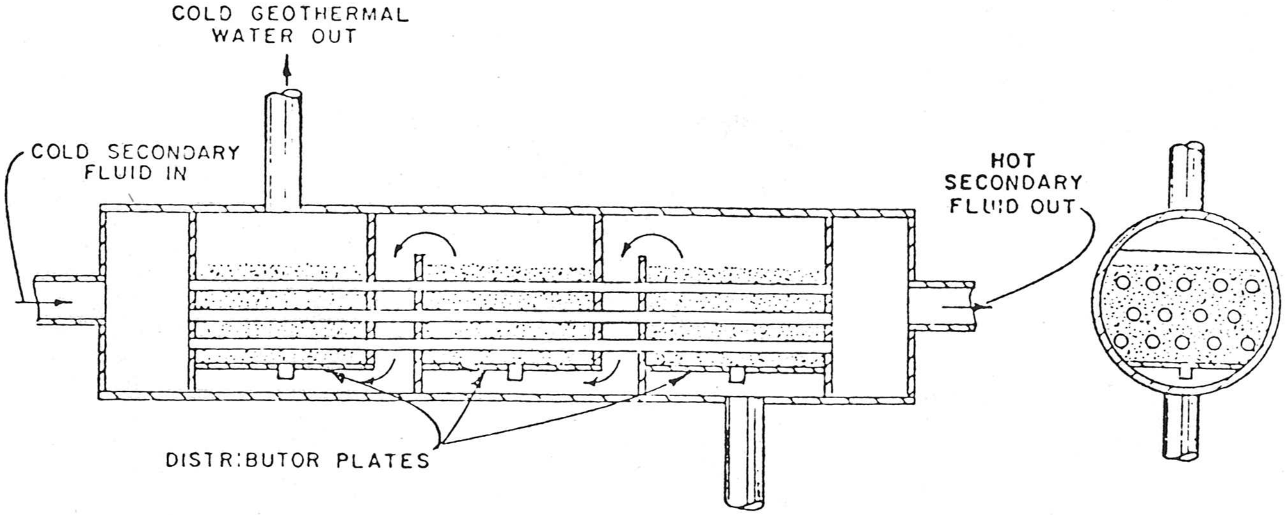


A variety of materials have been subject to long exposures to the geothermal water. A 2,400 hour controlled test was completed in December, 1976, on candidate materials out of which the power plant components will be made. Carbon steels have been of most interest, because their corrosion rate appears to be acceptably small, yet it is one of the strongest and least expensive metals.

Dr. Dick Miller, metallurgist, and plant designer Roger Piscitella are shown examining one of the test samples.

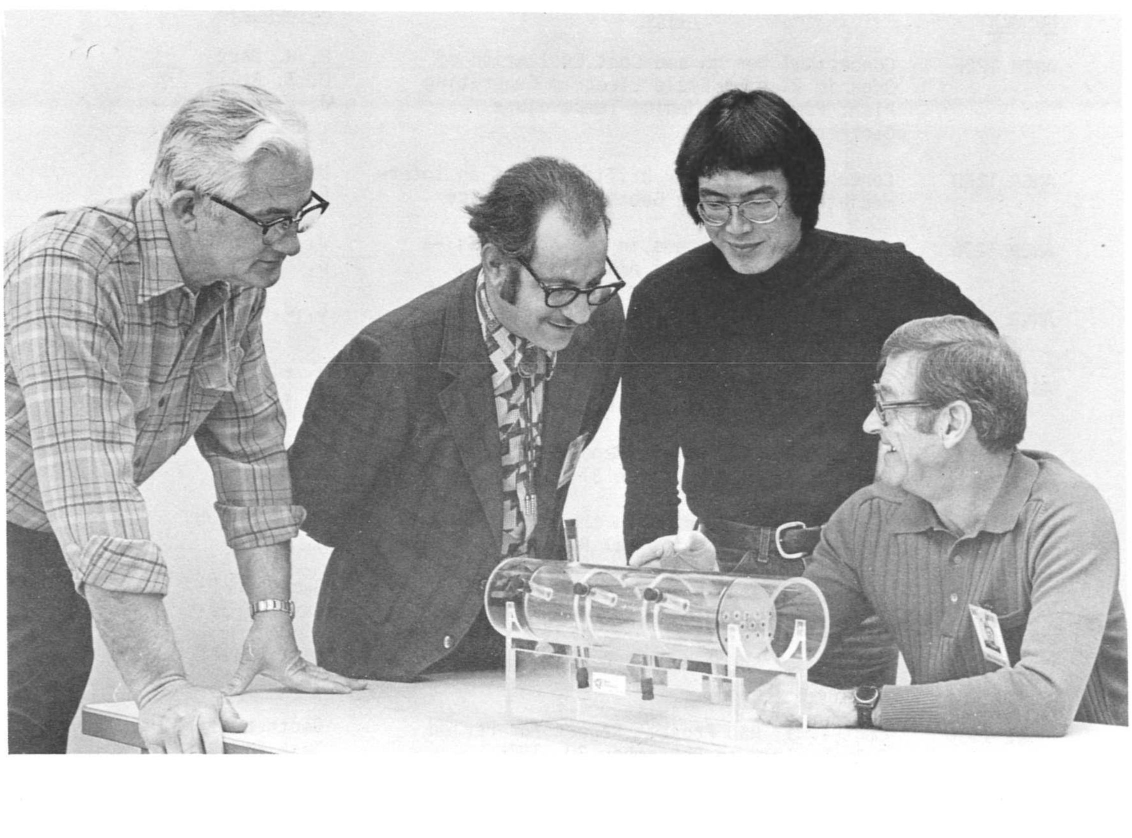


The fouling of heat exchanger tubing occurs as the geothermal water is cooled and the minerals in the water precipitate out on the tubing. This reduces the amount of heat that can be transferred, and correspondingly reduces the amount of electricity that can be generated. The geothermal waters from moderate temperature reservoirs characteristically have very low amounts of dissolved minerals. In the case of Raft River, considered typical of the moderate temperature waters, the dissolved solids are only 2000 to 4000 parts per million by weight (2 to 4 grams per liter of water). Fouling rates were predicted for this water, but the tests run to date have shown fouling much less than predicted. Greg Mines who is responsible for this phase of the test is most encouraged by these results. If these results hold for many months and years, it means smaller and hence less expensive heat exchangers will do the job of the larger ones presently designed.



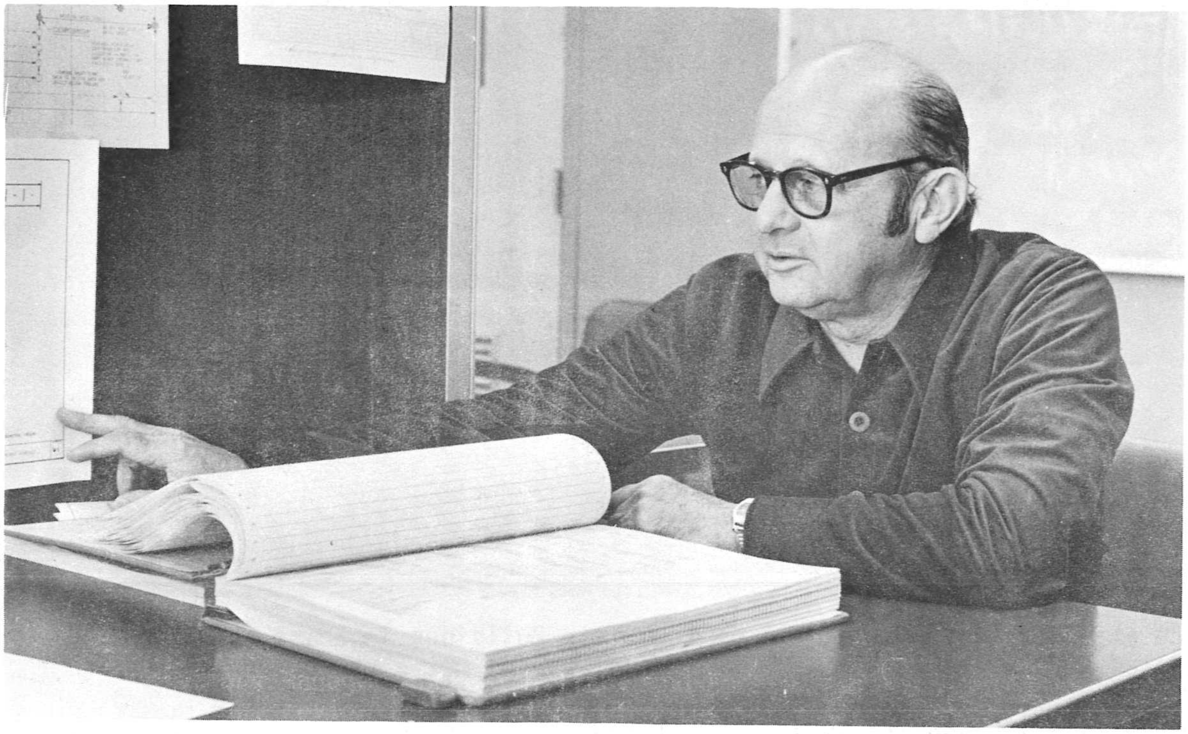
Liquid Fluidized Bed - Horizontal, Three-Stage Arrangement

The concept of using sand particles inside a heat exchanger saw several applications prior to its introduction into geothermal engineering. One use is for high temperature calcining of nuclear wastes into an unleachable aluminum oxide pellet. Another is for cleaner and more efficient combustion of otherwise difficult-to-burn fuels. But for geothermal applications, it was not the unusually high heat transfer coefficient that was the most attractive, but the fact that the sand bed prevented chemical scale from depositing on the heat exchanger tubes. Velocities of the geothermal water in the bed are only about 4 inches/second and Chemists Dick McAtee and Dr. Tony Allen, chemical engineers Sam Fukuda and Earl Grimmett now face the task of taking this concept that works so well and reduce its size and hence its cost.

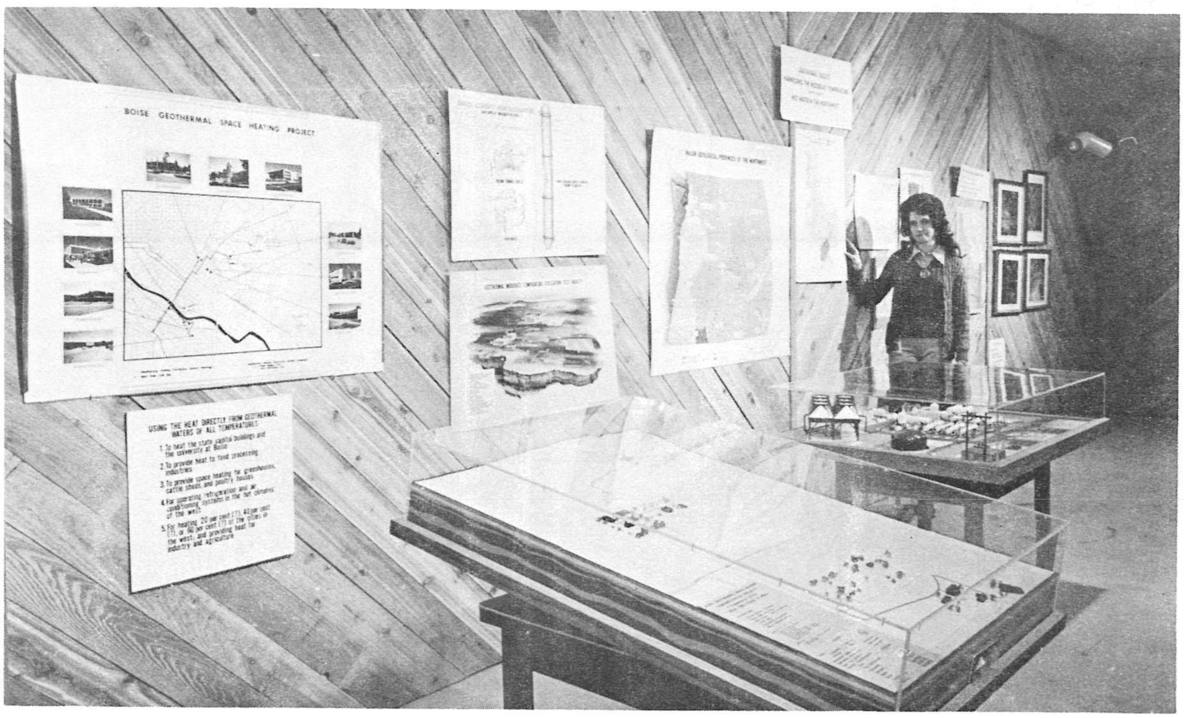


As new techniques are developed and discoveries occur, it is important that all those interested in geothermal energy have access to the technology. Therefore, reports of various types are a major product of the INEL Geothermal Program. The typing and secretarial staff of Carol Sandberg, Nancy Nicholson, Anna Wickersheim, and Barbara Kirkham are key to assuring that others outside the organization review up-to-date information. Some of the most recent reports are:

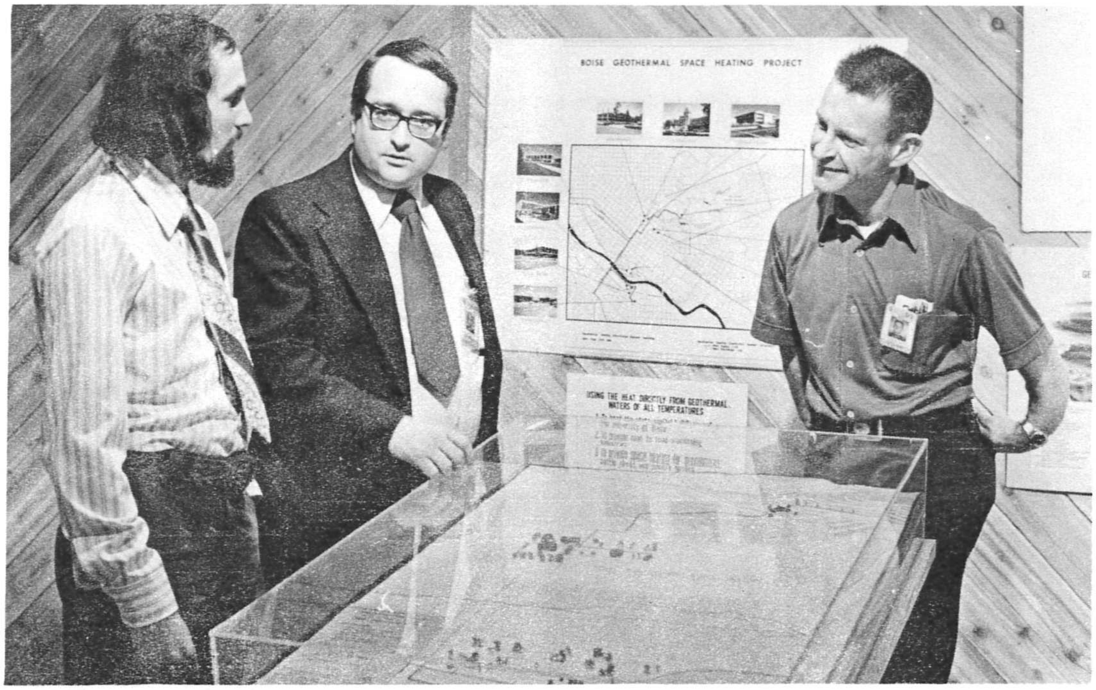
REPORT NUMBER	TITLE	AUTHOR(S)
ANCR 1226	Conceptual Design and Cost Evaluation of Organic Rankine Cycle Electric Generating Plant Powered by Medium Temperature Geothermal Water	R. H. Dart D. T. Neill J. F. Whitbeck
ANCR 1260	Conceptual Study for Utilization of an Intermediate Temperature Geothermal Resource	D. G. Swink R. J. Schultz
ANCR 1276	Space Heating Systems in the Northwest -- Energy Usage and Cost Analysis	J. G. Keller J. F. Kunze
ANCR 1295	Geothermal Steam Plant Modeling and Power Tradeoff Studies	C. J. Shaffer
ANCR 1318	A Plan for Developing Moderate Temperature/ Low Salinity Geothermal Resources	J. F. Kunze J. F. Whitbeck
ANCR 1319	Geothermal R&D Project Report for Period January 1, 1976 to March 31, 1976	Geothermal Task Force
ANCR 1342	Corrosion Engineering in the Utilization of the Raft River Geothermal Resource	R. L. Miller
TREE 1008	Geothermal R&D Project Report for Period April 1, 1976 to June 30, 1976	Geothermal Task Force
TREE 1023	Geothermal Shell and Tube Heat Exchanger Augmentation	D. T. Neill
TREE 1030	Geothermal R&D Project Report for Period July 1, 1976 to September 30, 1976	Geothermal Task Force



Assistant Program Manager, Dale Gilliard, keeps a close watch on schedules and budget to assure that the program is making timely progress.

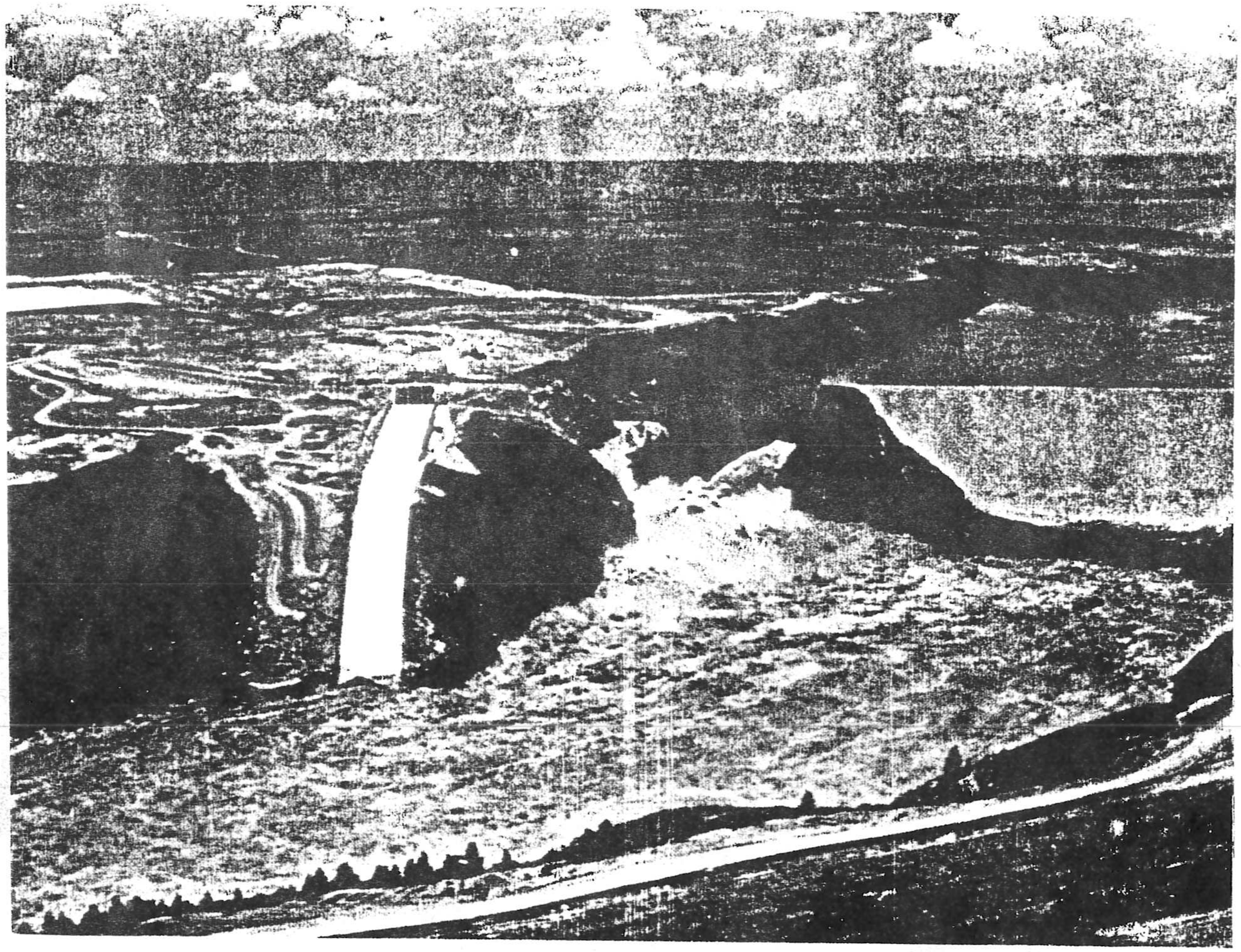


Public information of the potentials of geothermal energy included setting up several temporary exhibits in several distant cities in addition to the exhibit at Idaho Falls' new Science Experience Center, visited by nearly 20,000 people since its opening on July 4, 1976. RoseMarie Peterson, Staff Administrative Assistant, may be contacted for those who may wish to have exhibits set up for special events.



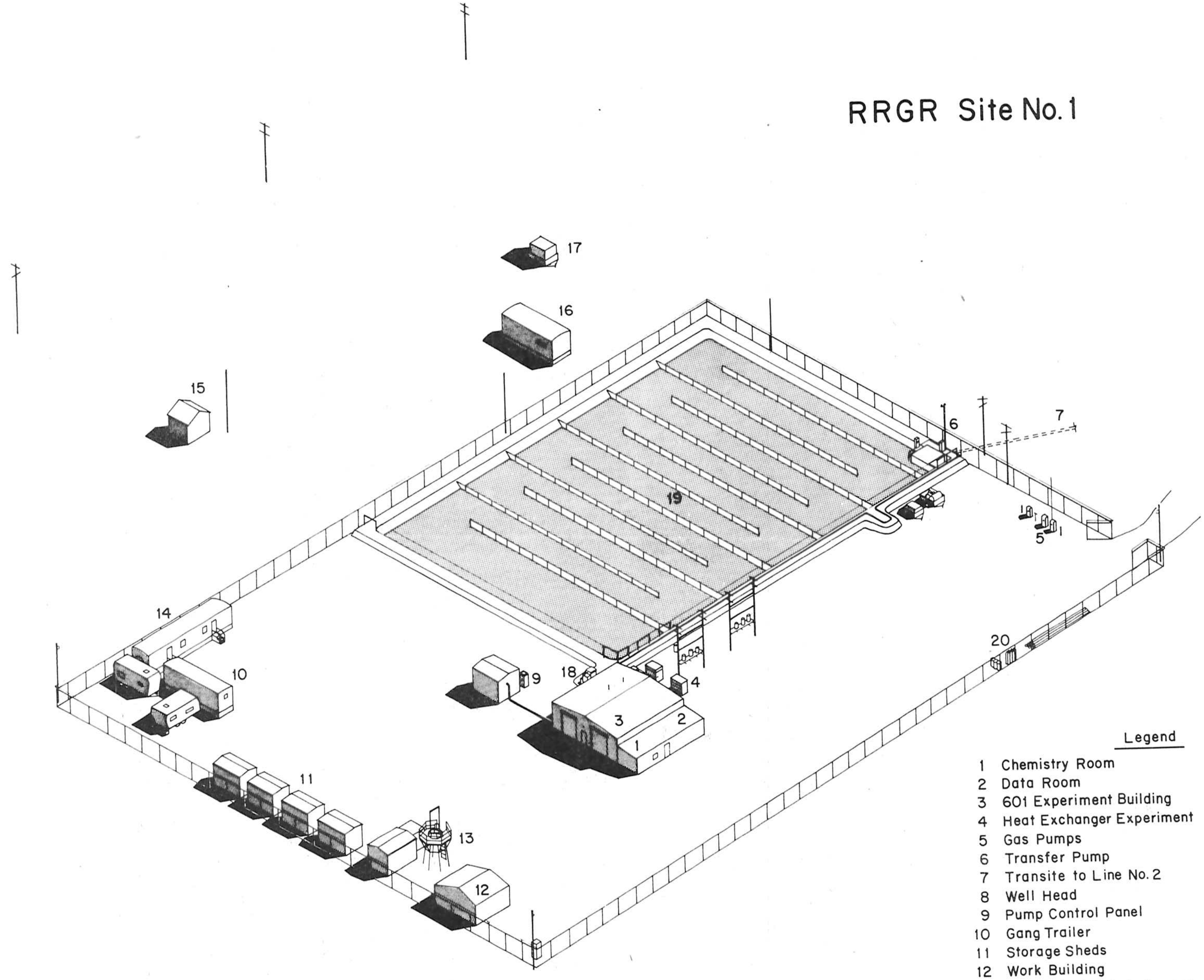
The attempts to show that all of the State Buildings in Boise could be heated very economically with geothermal energy met with considerable technical success. Two test wells were both successful, and were relatively inexpensive, only 1200 ft deep. The engineering design for delivering the fluid and heating the buildings uses a small amount of oil heat to provide the boost on the coldest days, and thus allowing twice as many buildings to be served by geothermal heat. Engineers Joe Keller, Loyd Donovan, and Ivar Engen are shown with a scale model of the Boise system.

The concept of using an organic fluid to drive the turbine has its major attractiveness when used in an area with cool climate and low annual mean temperatures, such as all of the mountainous Northwest. These low temperatures make it possible to operate the turbine at high efficiency. Mechanical Engineer Bob Dart discusses the advantages of this concept with Jim Hurley, who is examining the economics of the various power cycles applied to a variety of climates.



On June 5, 1976, the recently completed Teton Dam, nearly filled to its 305 ft height, disasterously broke just before noon. Flood waters engulfed the Upper Snake River Valley. Eight billion gallons of water rushed by and through the small town of Sugar City, population 800. Two thirds of the houses were destroyed or required major rebuilding. The sewer and water line systems were wrecked. The task of rebuilding Sugar City means completely new heating systems for the buildings and homes. Is this the time to consider a central geothermal distribution system? Is the geothermal water close enough, and not too deep to justify the investment for such a small town? These are questions that are presently being addressed. Sugar City lies near the edge of the Snake River Plain, but perhaps not quite so close that the faults at the plain boundary can be tapped and the water piped inexpensively to the town. At what depth might it be found under Sugar City? Boosting of lukewarm water with a heat pump appears to be economical, so perhaps moderate depth wells might be adequate. INEL is currently exploring these various possibilities.

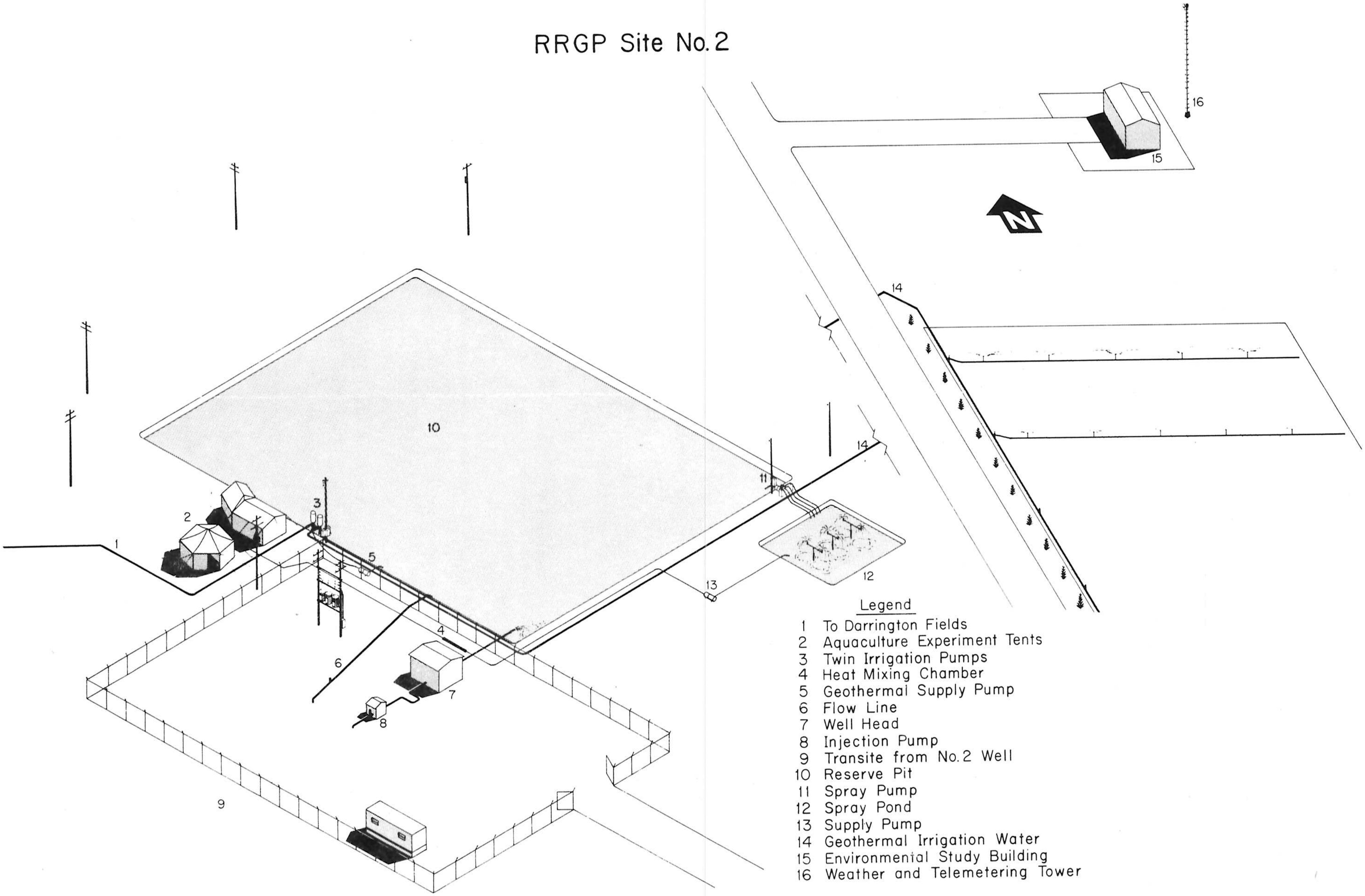
RRGR Site No. 1



Legend

1 Chemistry Room
2 Data Room
3 601 Experiment Building
4 Heat Exchanger Experiment
5 Gas Pumps
6 Transfer Pump
7 Transite to Line No. 2
8 Well Head
9 Pump Control Panel
10 Gang Trailer
11 Storage Sheds
12 Work Building
13 Atmospheric Study Camera
14 Office Trailer
15 Domestic Well House
16 Univ. of Utah Control Trailer
17 Pentane Experiment
18 Cooling Tower Experiment
19 Cooling Pond
20 Bottle Gas Rack

RRGP Site No. 2



Legend

1 To Darrington Fields
2 Aquaculture Experiment Tents
3 Twin Irrigation Pumps
4 Heat Mixing Chamber
5 Geothermal Supply Pump
6 Flow Line
7 Well Head
8 Injection Pump
9 Transite from No. 2 Well
10 Reserve Pit
11 Spray Pump
12 Spray Pond
13 Supply Pump
14 Geothermal Irrigation Water
15 Environmental Study Building
16 Weather and Telemetering Tower

THE CHARACTERISTICS OF THE WELLS

RAFT RIVER

RRGE #1 - Completed in March 1975, 5000 ft deep

Solids in water:	1700 mg/liter
Artesian Pressure:	50 psig cold 175 psig hot
Reservoir Temperature:	297°F (147°C)
Flow Experience:	400 gallons per minute for many days with artesian pressure only. 870 gallons per minute for 4 days with a pump, drawing down 375 ft below ground level
Predicted after 10 years of operation:	1100 gallons per minute with 900 ft drawdown below ground level

RRGE #2 - Completed in June 1975, 6500 ft deep

Solids in water:	1800 mg/liter
Artesian Pressure:	60 psig cold 165 psig hot
Reservoir Temperature:	298°F (148°C)
Flow Experience:	500 gallons per minute for several days with artesian pressure only
Predicted after 10 years of operation:	1500 gallons per minute with 900 ft drawdown below ground level

RRGE #3 - Completed in June 1976, 5917 ft deep

Solids in Water:	4600 mg/liter
Artesian Pressure:	40 psig cold 140 psig hot
Reservoir Temperature:	301°F (149°C)
Flow Experience:	400 gallons per minute for a day under artesian pressure (291°F at surface)
Predicted after 10 years of operation:	500 gallons per minute with 1000 ft of drawdown below ground level

BOISE

Test Well #1 (Beard) - Completed August 1976, 1283 ft deep

Artesian Pressure:	11 psig hot
Reservoir Temperature:	172°F
Artesian Flow Experience:	195 gallons per minute for 1/2 day

Test Well #2 (BLM) - Completed September 1976, 1222 ft deep

Artesian Pressure:	9 psig hot
Reservoir Temperature:	>164°F
Artesian Flow Experience:	Minimal to date, briefly at 50 gallons per minute

Both Boise wells have dissolved solids of less than 300 mg/liter

RAFT RIVER FLOW OF GEOTHERMAL FLUIDS (GALLONS)

MONTH	RRGE-1	RRGE-2 PRODUCTION	RRGE-2 REINJECTION	RRGE-3
1975				
February	8,000,000	--	--	--
March	1,000,000	--	--	--
April	400,000	--	--	--
May	0	100,000	--	--
June	0	500,000	--	--
July	0	3,400,000	--	--
August	0	1,900,000	--	--
September	0	9,000,000	--	--
October	0	10,000,000	--	--
November	0	3,000,000	--	--
December	1,800,000	1,000,000	2,000,000	--
1976				
January	2,000,000	1,300,000	1,600,000	--
February	5,400,000	1,000,000	4,200,000	--
March	500,000	1,000,000	2,700,000	--
April	0	0	0	--
May	0	0	0	--
June	0	0	0	1,690,000
July	1,300,000	1,000,000	20,000	0
August	12,300,000	5,500,000	0	0
September	8,600,000	7,200,000	0	0
October	7,000,000	1,000,000	0	0
November	6,000,000	1,000,000	16,000	80,000
December	5,000,000	750,000	0	1,240,000
1977				
January	2,600,000	600,000	0	1,240,000

IDAHO GEOTHERMAL DEVELOPMENT PROGRAM

EG&G IDAHO, INC.

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Dr. F. H. Tingey, Assistant Manager

Dr. J. F. Kunze, Manager of Geothermal Programs
S. D. Gilliard, Assistant Manager
R. M. Peterson, Administrative Assist.

L. G. Miller, Field Operations Manager
R. C. Stoker, Chief Geologist
D. Goldman, Chief Hydrologist
S. J. Prestwich, Drilling Geologist
Raft River Site Supervisors
R. S. Hope
C. G. Cooper
K. E. Peterson
R. W. Gould, Manufacturing Engineering Supervisor
D. H. Suckling, Engineer
R. D. Sanders, Design Engineer
J. W. Neitzel, Design Engineer

J. F. Whitbeck, Electric Project Manager
R. R. Piscitella, Design Engineer
Dr. R. L. Miller, Metallurgist
G. L. Mines, Test Engineer
R. H. Dart, Test Engineer
Dr. C. A. Allen, Chemist (Allied Chemical Co.)
R. E. McAtee, Chemist (Allied Chemical Co.)
A. F. Fanous, Engineer
O. Fukuda, Chemical Engineer

W. W. Hickman, Systems and Environmental Manager
S. G. Spencer, Environmental Engineer
N. E. Stanley, Biologist
L. F. Martin, Physicist

Dr. W. Darrell Gertsch, Direct Use Manager
J. G. Keller, Physicist
R. C. Schmitt, Engineer
L. E. Donovan, Space Heating Engineer
D. G. Swink, Chemical Engineer (Allied Chemical Co.)
I. A. Engen, Engineer
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J. V. Hurley, Loan Guarantee Review

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Dr. C. W. Bills, Assistant Manager Technical

J. L. Griffith Director Geothermal Energy Office
W. R. Knowles, Sr. Project Engineer
Dr. D. H. Hoggan, Water Resource Engineer

RAFT RIVER GEOTHERMAL DEVELOPMENT CORPORATION, Wholly Owned Subsidiary of Raft River Rural Electric Cooperative

G. F. Gardner, General Manager
E. C. Schlender, Geothermal Executive Vice President

Board of Director Members for Geothermal
John Pierce
Wallace Spencer
Al Kempton

LIASON WITH STATE OF IDAHO

Idaho Department of Water Resources

R. K. Higginson, Director
A. K. Dunn, Asst. Director
J. C. Mitchell, Geochemist

THE FUTURE AT THE RAFT RIVER PROJECT

What research needs to be done before there is assurance of generating electricity economically from the geothermal reservoir?

What are the near term plans? (Over the next two years).

ELECTRICITY

Thermal loop, possibly with a turbine generator to make 5,000 kW, to be operating at least by Christmas 1979. This unit will use the present three wells, with operating pumps, and will dispose of the water in reinjection wells yet to be drilled.

This initial concept, when applied to a commercial power plant, will make electricity at a cost about 30% higher than that from new nuclear plants. (Note, for comparison, solar costs are about 500% higher than these.)

What is being done to reduce cost? The following experiments will be continued for at least two more years.

1. Experiments to increase power production efficiency by using cooler discharge conditions for the turbine--
   i.e., 80^{o}F on summer nights
   35^{o}F on cold winter days
   by using cooling ponds for coolant storage, dry cooling towers, and other generally untested concepts.
2. Tests to develop better and cheaper heat exchangers and condensers.
3. Reinjection practice, putting the used, and cooled geothermal water back in the ground to maintain the pressure in the reservoir. A reinjection well will be drilled in the spring of 1977.
4. Heat removal with reduced consumptive use of water
5. Continued experiments on direct uses of geothermal water in:
   a. agriculture - for irrigation and soil warming
   b. forestry - for biomass production enhancement
   c. fish culture - maintain a flowing warm water environment for maximum portein production

DIRECT HEAT USES

Space heating if water is above 100^{o}F (preferably above 120^{o}F)

Process heat - depends on use and temperature; i.e.,

Potato processing	350^{o}F
Sugar beet processing	220^{o}F
Food canning and processing	212^{o}F
Pastuerizing	170^{o}F
Vitamin manufacture	140^{o}F

Economics of Direct Heat Uses

Geothermal hot water energy in Raft River, Bridge area, is currently about 1/2 as expensive as natural gas, 1/3 as expensive as oil, if it can be fully utilized. Herein lies the problem--so much energy from such an expensive deep well that neither the commercial or agricultural base presently exists to use it. Can such a base develop in the near term? This is a question being explored by INEL, the Raft River Rural Electric Coop., and a Salt Lake City geological research company, under an ERDA contract.

WHAT ARE THE PROSPECTS FOR THE ENTIRE NORTHWEST

(Idaho, Northern Utah, and Nevada, Eastern Washington and Oregon, and the parts of Montana, Wyoming, and Colorado in the Rocky Mountain Region)

The Raft River area appears to be typical of geothermal conditions in this region. Raft River has a 300°F reservoir, with certain characteristics of porosity, permeability, and temperature vs depth.

Other reservoirs will differ. Some will be hotter, most cooler; some more productive, some less. It is hoped that the experience at Raft River will add an element of confidence to what can or cannot be done economically with these other reservoirs, for both generating electricity and for using the heat directly.

What could happen? - within 10 years - Twenty areas similar to Raft River could be identified throughout the Northwest; i.e., one out of every six utilities in the area would identify a successful geothermal reservoir in that time. Twenty power plants, each 50 MW, would be built, for a total investment of $900 million dollars, bring 1000 MW of power to the Northwest at prices competitive with coal and nuclear power.