SUMMARY TECHNICAL EVALUATION REPORT

1. Contractor: Northwest Geothermal Corporation

2. SCAP No: DE-SC07-80ID12139

3. Description: This project will provide a heating system in the central business district of Lakeview, Oregon.

4. Summary of Review:

   A. Environmental:

   (1) The proposer must provide DOE proof of permission to dispose of testing fluids into a storm culvert. Permits must also be secured for injecting spent geothermal fluids utilizing an injection well. To protect the human environment, while drilling in a town, the drill site must be securely fenced.

   (2) During well tests, the water will be disposed of via an intermittent stream into a marsh. The proposer assumes that the water quality will not be worse than the water that naturally drains into the basin from other hot springs (probably a reasonable assumption). The proposer should present, in further detail, what effect the increased volume of geothermal fluids will have on the intermittent stream and more importantly on the marsh.

   (3) Environmental considerations should probably include effect on all aquatic life and not only fish life.

   (4) Irrigation use patterns of the region are known to affect the water supply of existing geothermal wells. Operation of the proposal production well may result in a decrease in production of other nearby geothermal springs and may result in further groundwater interference. The potential for these impacts must be explored in greater detail and contingency plans for dealing with these problems must be developed.

(5) Expended geothermal fluids will be injected below a clay bed which apparently separates the domestic water supply from other water sources. If this clay formation is impermeable throughout the basin, then injection may be acceptable. The water quality of the receiving zone should be a factor in the determination.

(6) If the quality of the geothermal fluids is similar to that of the swimming pool well, the only constituent of concern is boron (and then it is only of concern if the water were used for irrigation). If the quality is similar to that of the Barry Ranch Hot Springs, arsenic, fluoride, & total dissolved solids concentrations could restrict fluid disposal. Northwest Geothermal should maintain some contingency in their program until the water quality of the production well can be determined.

(7) Land and water permits along with other applicable environmental laws are not discussed in the proposal. Northwest Geothermal Corp. has experience in working with both the city and state so most potential problems should be anticipated. However, a discussion of these aspects should be presented in greater detail.

(8) The drill site is located in a city park, therefore, drilling operations could present a significant social concern. The proposer addresses this well and drilling activity will be scheduled around public use of the area. It is stated in the proposal text that drilling will only be conducted during the day, however the work schedule is based on a 24 hour/day operation. This should be clarified along with the potential for noise disturbance of nearby residents.

(9) Local wells should be monitored during injection testing to determine if the extent of the clay bed which separates lower from upper aquifers is great enough to prevent containimation. Site preparation requirements are not clearly specified. Mud tanks are mentioned in the statement of work (pg. 38) and mud pits are discussed on pg. 53. This should be clarified.

B. Resource/Exploration

(1) Nine of the ten thermal wells presented in the proposal are on the downthrown side of the range front fault, while just one is on the upthrown side. We recommend that the proposer consider drilling on the downthrown side as opposed to the currently proposed site on the upthrown side; this is imperative if intersecting the range front fault at 3,000' is the target.

(2) We feel it is very optimistic of the proposer to expect to produce 1000 g.p.m. from one well, especially with a pump at 500' (piii). The production will, most likely, be less and drawdown will likely dictate that the pump be placed one to two hundred feet deeper. (The cost share reflects 560 gpm, which we feel is reasonable.)

(3) In that there are two PRDA's outstanding in the Lakeview, OR, area, and the data therein will directly affect the decision to site the proposed well, that data must be provided to DOE prior to the drill site selection decision point. Page 46 of the proposal (vol. 1) indicates NGC is currently drilling geothermal wells in Lakeview. Data from these must be part of the data package leading to the production well site selection. A detailed exploration program has already been carried out by DOGAMI through a DOE contract. Their results should be made available for our review.

(4) There has been considerable geothermal drilling activity in the Lakeview area, notably by Phillips, who possibly would release information on the productivity of the geothermal reservoirs below a depth of 2,000 ft. Data from the referenced 1973 Gulf Oil Co. test (5440') must be acquired and incorporated into the well site selection considerations.

(5) We feel the mercury survey suggested in the Proposal Evaluation Summary is needless, as it merely indicates a leaky fault. (Our earlier input to DOE.)

(6) What is needed most (and must be presented to DOE's satisfaction prior to drill site selection) is a detailed, accurate structural geology map, which will show the fault trace and dip.

(7) It is recommended that the proposers consider a dipole-dipole resistivity survey to aid in their exploration for the best well site.

(8) It is recommended that the proposers have a hydrologist evaluate the likelihood of cold water mixing in a 3000' deep target reservoir.

(9) The proposer should be asked to consider drilling near Hunter Hot Springs (2 miles to the northwest) which would be much closer to the industrial park. (Editor's note: There is some question as to past DOE work on an industrial park in Lakeview, whether it is north or south of Lakeview, or whether it is this project.)

(10) Page 1 of Vol. 1 states that the swimming pool well, located near the proposed drilling site, produced 250 gpm with 320 ft of drawdown (specific capacity 0.78 gpm/foot of drawdown). This test was apparently run in 1938 when the well had a depth of 2,380 ft. NGC subsequently rehabilitated the well to a depth of 1,820 ft. In its present configuration, the well now produces water with temperatures from 92 to 100°F. However, the present specific capacity of the well is not clearly stated. This information would be useful in evaluating the productivity of the proposed production well.

C. <u>Drilling - Production Well</u>

(1) The drilling program proposes fluid rotary drilling, presumably with bentonite, to the total depth. Drilling a 17 1/2-inch hole with a 5 1/2 inch drill pipe and a 500°gpm mud pump, will provide ascending velocity of about 50 feet per minute. To obtain the optimum drilling rate, it will probably be necessary to increase the viscosity of the drilling fluid, which in turn increases the carrying capacity of the mud and the potential to circulate drill cuttings. These problems could perhaps be reduced by use of a shaker and large volume mud tanks. Mud tanks are proposed in place of pits to prevent disturbance of the park site. Normal pit or tank size is usually 1-1/2 times the volume of the hole to be drilled. This means over 2,700 cubic feet tank capacity would be required. Since this is probably not practical, tanks with special clean-out features should be utilized in conjunction with the shale shaker.

(2) Drilling of the 12-1/2-inch hole between 1,200 and 3,000 ft will apparently be accomplished by using bentonite drilling fluid. The proposed 500 gpm circulation rate provides an ascending velocity of 102 feet per minute. This circulation rate may be adequate, but the proposer should anticipate the potential problem of baking bentonite wall cake at the elevated temperatures in the lower reaches of the hole. The proposer should consider using a temperature-stable mud (such as sepiolite) or drilling the 12-1/4-inch hole with air. Air circulation requirements would be about 2,000 cfm to maintain an ideal ascending velocity of 3,000 ft per minute. Air pressure requirements are unknown since the static levels and water densities are not presented. The ascending velocity required for air drilling could be reduced if temperature-stable drilling foam additives could be used.

(3) Drilling of cement plugs are proposed at various stages in the drilling program. To prevent a possible contamination of the mud with cement cuttings, consideration should be given to wasting those cuttings and the fluid used during said drilling.

(7) With reference to item 6, page 54, it is recommended that all lost circulation problems be solved prior to running the surface casing, otherwise the cement job will not be successful.

(8) Numerous references are made regarding the use of 1-in. tubing at the surface for remedial cementing of the casing. This procedure is not recommended in geothermal or other wells subject to temperature cycling. Every effort should be made to establish surface returns during the primary cementing. If such cannot be obtained, it is not necessarily a problem. Squeeze cementing could be in order depending on the difficulties and the presence of trouble-some zones, and this is generally the preferred remedial operation.

(9) If delineation of a cement top proves necessary, an acoustic device will be preferable to the density log, for reasons of speed and reliability.

(10) Proposer should, preparatory to cementing the 13-3/8' casing, pump a substantial water flush ahead of the cement. The cement should be preceded and followed by standard Halliburton cementing plugs. We feel that 25% excess cement is minimal. An excess of about 35% should be considered unless information attained during the drilling of the hole dictates otherwise.

(11) The need for the open hole packer described on page 55 is questionable.

(12) In addition to circulating the drilling mud out of the hole with polyphosphate solution, development of the well screen by high velocity jetting with the phosphate solution, and air-lift pumping should also be planned.

(13) Development and stimulation of the producing zone should be planned.

(14) The proposer intends to drill the injection well without blowout prevention equipment, for the surface production hole to 1,200 ft. The use of proper BOPE should be considered mandatory in both cases. Further, regarding safety, the use of an H_2S detector with 0-10 ppm full scale sensitivity is recommended for the production well. The well is in a residential area and is going deeper than previous tests, where the proposer himself states that records have been less than reliable.

(15) The injection well drilling plan proposes 17-1/2-inch hole to 600 feet and cementing in the string of 13-3/8-inch casing. This work could be accomplished economically by an experienced water well contractor. Therefore, we suggest using A-53 plain end 12-inch (49.56 lbs/ft) or 14-inch (54.57 lbs/ft) standard seamless pipe, instead of 13-3/8-inch field tubing. The proposal does not address anticipated problems, if any, while drilling through the clay zone.

(16) What are technical specifications of the injection well 8-5/8-inch casing string? From cost estimate information, it appears to be line pipe instead of oil field casing. Since the injection well may be subjected to high injection pressures, oil field type casing may be warranted.

(17) The proposer should be questioned regarding his injection well and the need to gravel pack. Depending upon rock competency, this may not be required. His gravel pack procedure has several flaws:

(a) The 1-1/2 inch gravel feed pipes will not fit in the annulus between the 13-3/8 inch and 8-5/8 inch casings.

(b) There is no need to use 800 ft of 8-5/8 inch pipe, nor to cement it. About 250 ft of slotted liner will suffice, hung at 550 ft. A cement job would serve only to plug or impair the gravel pack, thus defeating its purpose.

(18) Provided the proposer can justify the need to gravel pack, future submittals regarding this procedure should be reviewed carefully.

(19) Well screen specified for the completion should be manufactured to provide extra column and collapse strength and made of 304 or, 304 ELC stainless steel for corrosion resistance and resistance to future treatment with acid stimulants.

(20) Chemical analyses should also be made of the injection fluid and compared to the analysis of the natural ground water in the injection zone. Mixing of these two waters will induce build-up of incrustants near the well bore and will eventually reduce the injection rate. Injection rate and head should be monitored throughout the life of the well to provide a timely redevelopment schedule. The proposer also indicated the desire to allow the spent geothermal water to free fall or cascade into the well. This procedure is not recommended because resulting chemical changes will cause a build-up of voluminous metallic oxides on the well screen and in the gravel pack and aquifer.

D. Drilling-Logging

(1) A geolograph must be used to record drilling conditions.

(2) The proposer should identify the type of equipment and/or the commercial logging or consultant services planned for geophysical logging. Ideally, caliper logs to determine the size of the bore hole would be run following drilling of each diameter of bore hole, and prior to installing casing and cementing. This would provide a more accurate determination of the cement volume required. Resistivity logs should be multiple electrode as provided by short and long normal readings.

(3) Deviation and drift surveys are also suggested to determine any potential problems with casing alignment. Presumably, the production well will be pumped with a turbine pump (temperatures are too high for submersible pump motors), and high degree of straightness will be required for the successful operation at the anticipated pumping level.

(4) Both the production and injection wells should be logged.

E. Testing

(1) The preliminary test plan should include anticipated flow rates, test duration, instrumentation, and analysis techniques. Testing of the production well should be performed not only at a constant rate, but also at varying rates to assist in determination of well efficiency and the optimum production rate for the well.

(2) It is recommended that numerous nearby wells be instrumented for observation wells during drilling and testing of the wells; observation of the swimming pool well, alone, is not enough.

(3) The proposer also apparently intends to conduct open hole injection tests (page 45). Open hole pumping tests could cause well collapse necessitating redrill of the injection zone.

(4) The proposer's intent to collect periodic water samples during testing is excellent. This may establish the trend of the water quality once the resource is put into production. Field water quality analysis is recommended for those transitory components such as pH, and dissolved oxygen. Accurate analyses for other constituents may require stabilizing reagents. Water samples for fluoride analysis should be collected in plastic bottles. The chemical analyses of the Lakeview City Well #5 (Swimming Pool Well) appears to have abnormally high nitrate of 99.3 mg/l. This high concentration may have some relation to the geothermal resource, but such high concentrations are more generally associated with surface containimation.

F. Project Management-Personnel

(1) Page 40 states that a single contractor will be sought to drill both the production and injection well. This could save time, but generally contractors equipped to drill the production well would not have small enough equipment to drill the injection well. Extensive efforts to use a single drilling contractor's equipment might result in either too small of equipment being used on the production well or too large (and too expensive equipment) being used to drill the injection well.

(2) Geothermal production well drilling supervisory experience is minimal.

(3) The qualifications of the drilling supervisor do not indicate extensive experience in this field. Additional expertise is recommended.

(4) A hydrologist to run and analyze the pump test should be chosen and his/her qualifications submitted to DOE for review.

(5) DOE must feel secure in the proposers analytical abilities, especially in geologic matters; if they do not, appropriate consultants should be required to fill any gaps. Perhaps input from Joe Fiore would help on this point, as he has worked with NGC in the past.

(6) DOE should require that the proposers firm-up their front-end funding requirements, as a condition of the contract.

G. Project Management-Timing

(1) Since fieldwork must be completed before June 1, 1981, would a 24-hour-per-day drilling schedule be more desirable than the daylight only schedule as proposed? The 4-week period proposed for drilling and logging the 3,000 foot production well is reasonable if 24-hour-per-day drilling operations are intended, but may not sufficient if daylight only operations are intended. Similarly, the 8- to 10-day period proposed for completing the 800-foot injection is reasonable assuming 24-hour-per-day operations.

(2) Probably the most critical element of the entire project is found in the time constraints for the project. If drilling and testing is not completed by June 1, 1981, the entire project could be jeopordized. This is particularly true if the well had to be abandoned at some critical point. The DOE negotiator might consider a start date prior to March 1, 1981, or suggest that the drill site be relocated so that it would not interfere with summer activities at the swimming pool. The proposer points out that it is imperative that the work be completed by June 1, 1981 so as not to interfere with recreational activities (swimming) in the nearby municipal pool. The projected flow chart for production well drilling (page 44) is extremely optimistic. It calls for 2,900 feet of drilling in a 5 day period. Thus, over 600 feet per day of progress is expected. It is more likely that the progress will approach 200 feet per day, particularly if only daylight hours can be worked. Also, this schedule does not appear to be compatible with the time allottment (Vol. 2, page 4) wherein 16 days are provided to drill the 3,000 feet

at an average rate of 187 feet/day including the installation of casing. We estimate drilling and testing of the production well will require at least 10 weeks and could easily require at least 12 weeks. Only 13 weeks are available between March 1 and June 1, 1981. Additional time must be added to the flow chart (page 44) for well development-stimulation, and to demobilize the drilling rig and mobilize testing equipment to the site. Supervision of well testing (Vol. 2, page 4) provides only 96 hours of supervision whereas 336 hours are apparently planned. Possibly the proposer does not intend to provide supervision by NGC personnel during the entire test.

The drilling schedule for the injection well is similarly optimistic. Two days drilling time are provided to drill and case the 800-foot injection well. Even if a 24-hour work day is planned, the total drilling time would probably require at least 1 week. Additional time of 3 to 4 days should be provided for well development and demobilizing the drilling equipment and mobilization of the test equipment to the site. The total drilling and completion time for the injection well probably be on the order of 6 to 8 weeks.

H. Utilization

(1) The peak space heating loads are based on the total annual energy consumption divided by 1000 peak heating hours per year, (2.74 hours/day). This calculation yields an overestimate of the true conditions and thus of the required geothermal flow. The back ground data were insufficient to check the extent of the conservatism.

(2) Favorable overall geothermal resource utilization efficiency depends heavily on a 200,000 gpy pilot scale alcohol plant. The alcohol plant is to operate with 220°F hot water, which would be marginally feasible at best. Assuming minimal transmission losses, 250°F is the lower limit on wellhead temperature for the plant to be viable.

(3) The alcohol plant, which will use a substantial percentage of the geothermal fluid's heat, is not firmly planned. If the DOE feels this will have a major impact on the cost share, then a firm commitment to build the alcohol plant is required. The analysis of the heat load looks acceptable, but will it be cost effective to retrofit all of the 51 businesses? Should DOE require a statement of intent from some percentage of those businesses to use the district heat distribution system. DOE should request a piping diagram of the system to help understand the cascaded distribution among users with differing temperature requirements.

I. Cost Share

(1) The cost share is based on a pumping depth of 500 feet when the text states the pumping level will be greater than 600 ft. Since the pumping level is "suspected to be" deeper than 600 feet (Vol. I, page 4), the cost-share chart proposed, which is based upon a 500-foot pumping depth, is inappropriate.

(2) Allowable water quality should be raised to 1500 or 2000 ppm TDS. Proposers must inject the fluid after use anyway and this amount of dissolved material would not significantly impact their operation.

(3) The proposers will be able to sell the completion well to Lakeview, OR, even if it is a cold water well. In that DOE will be "buying" the well, proceeds of such a sale should go to DOE. This must be provided for in the contract, and as it affects the "failure" end of the cost share plan.

Temperature		Proposed % of Cost		
Less than 130°F	20	20	30	20
130° to 150°F	20	30	40	50
150° to 190°F	30	50	70	80
190° to 210°F	60	70	80	90
210°F	80	90	90	90
Flow rate	250-300	300-400	400-500	500 gpm

(4) These suggested changes reflect modification of pumping rates through more appropriate ranges. The proposer's percentage of costs have also been increased to reflect their apparent capability to use lower flows and lower temperatures.

J. Cost

(1) It may be possible to provide for a more economical production well. Specifically, the proposer should elaborate further on the need for 1200 ft of 13-3/8 in. surface casing. It is recommended that 100-400 ft of surface casing be considered, and then run a single string of 8-5/8 in. for isolation across the cooler zones.

(2) Total proposed costs for the production well drilling subcontractor, including mobilization/demobilization, are $150,000. It is my opinion that 3,000 foot production well will require 21 days of drilling rig time on a 24-hour-per-day basis with reasonable rig hourly costs of $225/hour resulting in $113,440 plus about $20,000 to $25,000 for mobilization/demobilization, or a total of $138,400. The proposer's estimate for rig costs is therefore determined reasonable.

(3) Total proposed costs for the injection well drilling subcontractor are $20,160. It is my opinion that the 800 foot injection well will require 8 days of drilling rig time on a 24-hour-per-day basis. If the same drilling subcontractor is used, then equipment hourly rates should be similar as in (9) above with only location-to-location move charges being added. Reasonable estimate is therefore 24 x $225 x 8 = $43,200 plus $2,000 for moving, or a total of $45,200. The proposer's estimate is therefore considered $25,000 understated.

(4) Page 3, Item 3: 12-1/4-inch TCI bits can be obtained for about $4,700, and not $6,400. This reduces the total item of No. 3 to $18,800 instead of $25,680.

(5) Page 3, Item 8: The $150 a foot for well screen is too high. Continuous wire-wound 304 stainless steel screen providing extra column and collapse should be obtained for about $100/foot.

(6) Direct Labor--Estimated hours for the Principal Investigator and Staff Supervisor are reasonable. The 300 hours for the Operations Supervisor may be understated since he will be involved on nearly a full-time basis a 10-week field schedule. Assuming six 10-hour days per week, then 600 hours seems justifiable.

(7) Well Testing, Travel, and Consultant estimated requirements appear reasonable.

(8) Vol. 1 Page 34 provides a $20,000 per year pumping cost. This apparently is based on 500 gpm from a pumping level of 700 feet and a power cost of 2.5¢ per KW hour. The pumping head and power costs are obvious variables. Power costs should be expected to increase which will change the P & L statement.

(9) Casing quantities are consistent with technical plan requirements. Costs for both 13-3/8 inch and 8-5/8 inch casing appear excessive. Based upon current price catalogs, 13-3/8 inch, 54.5 lb/ft, ST&C casing lists for $23 per foot and 8-5/8 inch, 32 lb/ft, ST&C lists for $14 per foot. Therefore, casing costs could reasonably be reduced by ($7/ft x 1,800 ft) + ($3/ft x 1,000 ft) = $15,600.

(10) Liner hanger costs are not included. Typical materials and service charges for 13-5/8 inch liner job are $15,000 to $18,000.

(11) Bits for drilling out cement above liner hanger and inside liner and liner shoe are not included. Add one 12-1/4 inch mill tooth bit at $1,500 and one 7-7/8 inch mill tooth bit at $750. Total addition cost is $2,250.

(12) Cement costs are normally a major cost element in a drilling project estimate and should be clarified instead of being lumped in with "bits, pipe, mud, and cement."

(13) Rental equipment costs such as BOPE and stabilizers should be clarified in the cost estimate.

(14) The wellhead completion equipment and downhole pump costs should be clarified in the cost estimate.

(15) An estimate for site restoration should be provided.

(16) The allowances made for transporation of materials (pipe, bits, mud, etc.) should be included in the cost estimate.

K. Recommendations

(1) Permits must be obtained for fluid injection.

(2) A contingency plan should be developed to deal with potential interference effects on local wells and springs.

(3) A data package must be submitted to DOE prior to well siting. This should include the following:

(a) Data from the existing PRDA, the DOE contract with DOGAMI, and the wells currently being drilled by NGC.

(b) Data from the referenced Gulf Oil Co. test.

(c) Data from drilling being done by Phillips.

(d) A detailed structural geology map.

(4) The preliminary test program should be updated to include anticipated flow rates, test duration, instrumentation, and analysis techniques.

(5) Qualified consultants are needed, an environmental consultant and, drilling engineer, and hydrologist should be chosen and their qualifications submitted to DOE for approval.

(6) The time schedule for drilling both the production and injection wells is extremely tight and should be revised.

(7) The cost share should be changed to reflect and pumping depth greater than 600 feet.

(8) The drilling costs should be updated and reflect the details requested on cement, casing, bits, site restoration, etc.

(9) A firm commitment to build the proposed alcohol plant and to retrofit the downtown businesses to use geothermal energy should be obtained.

(10) The required temperature of 220°F may not be high enough to use in the alcohol plant where 250°F is estimated as the lowest useable temperature.