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REVIEW OF KERR-McGEE APPLICATION FOR AMENDMENT TO LICENSE NO. 40-8027, DOCKET NO. 40-8027 TO PERMIT SUBSURFACE STORAGE OF CERTAIN LIQUIDS AT KERR-McGEE's SEQUOYAH FACILITY

by

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Energy Commission

June, 1972

LETTER OF TRANSMITTAL

In the letter of transmittal the modifications and additions to the previous application are briefly described.

Significant modifications to the original application include:

1. Reduction of the volume proposed for injection from 120gpm to 19gpm during the first five years.
2. More thorough consideration of possible alternatives to subsurface injection than had previously been given. This consideration led to the conclusion that there are no immediate practical alternatives to storage for the 19gpm raffinate waste stream.
3. The listing of additional provisions for monitoring of the injection well and an additional program for monitoring of the surface water and shallow ground water.
4. Statements reflecting a stronger belief in the safety of subsurface injection based on additional geologic and geohydrologic investigations.

Some conclusions reached as a result of the additional studies are:

a. There are five permeable and porous layers in the Arbuckle Formation into which the wastewater will flow. The total porous volume of these layers is at least 3.6×10^{10} gallons;
b. There is no effective communication between the five layers;
c. Hydrologic boundaries that occur in the near vicinity of the injection well are impermeable boundaries and leaky faults or fracture zones do not exist within the area analyzed;
d. The predicted distance to which the injected fluids will move within five years ranges from 140 to 900 feet from the well bore within the five layers;
e. The well-head injection pressure will increase only 200psi over the first five years.

ANALYSIS OF REVISED
APPLICATION AND EXHIBITS

Geologic and Hydrologic Considerations

The basic regional geologic and hydrologic findings that were presented in the original (1970) application have not been changed. The extensive program of well testing and analysis that was carried out for Kerr-McGee has provided new information concerning the proposed injection horizon (Arbuckle Formation) and its probable response to wastewater injection. The Oklahoma Geological Survey has also provided some useful geologic information.

The data that have been obtained from the well testing program are factual and provide a means of determining the nature of the Arbuckle Formation, and for predicting the results of long-term wastewater injection. However, the analysis of the nature of the Arbuckle Formation and the development of a predictive model allows for considerable latitude, depending on the assumptions and conclusions of the individuals performing the analysis. Because of the extremely complex nature of the geologic and hydrologic system involved, it is not possible for me to perform an independent analysis of the problem in the depth of that performed by Kerr-McGee Corporation and its consultants. Therefore, I have tried to evaluate the report on its logic and consistency and by making simple calculations to test the validity of the more sophisticated procedures used by Kerr-McGee and its consultants.

I will accept, as a working hypothesis, the conclusion that five permeable zones are present at the depths indicated and with the porosities and permeabilities listed. This conclusion is reasonably consistent with log analysis data provided by the Oklahoma Geological Survey and the conclusion is relatively conservative in nature and much less favorable to Kerr-McGee than the assumptions used in the 1970 application. I do believe that layers 4 and 5 are not continuous thick zones of high porosity as might be suggested by the application, but about 60 foot intervals containing thin one to 10 foot porous layers. The probability of such thin layers being widespread is less than that for thicker layers.

The conclusions concerning the extent of the five permeable layers, the nature and location of hydrologic boundaries, the rate of pressure buildup and the distance of

wastewater travel are based on the studies by H. J. Gruy and Associates.

The basis for the methods used by H. J. Gruy and Associates for determining the first three items listed above is well established, but the three dimensional analysis of geohydrologic problems by the finite difference method is a relatively recent development. It is my opinion that the validity of the technique used for analysing such a complex system as exists in this case has not been demonstrated with field examples and, therefore, remains to be tested. I would not be easily convinced that such a model is capable of defining, with the precision indicated in Exhibit A, the nature and performance of the injection horizons. However, even if the results listed in Appendix A can not be relied upon to the precision indicated, some important conclusions can be made from the Gruy study.

The well test data seem to definitely show that the lateral extent of the permeable layers is restricted by faulting or pinch-out of the permeable zones and that vertical leakage does not occur. The report describes two lateral barriers at 1,164 feet in layer 5, and a barrier at no closer than 30,000 feet for layers 3 and 4. The investigators also apparently believed it necessary to have boundaries at the distances shown in the report for the x-y dimensions of all the layers. The necessity for assuming that all of the layers were completely bounded by lateral permeability barriers is not clear. It appears to me that it was necessary to introduce them in order to obtain a mathematical model that would produce a result to match the actual test information. This fact in itself casts doubt upon the realism of the model, because the presence of such an extensive set of lateral barriers is not substantiated by any geologic evidence that is presented. The geologic structural map for the top of the Arbuckle Formation shows two faults that could act as lateral barriers, one at about one mile southeast of the well and one about six miles northwest of the well. No fault is shown as close as 1,164 feet, nor are any geologic structural features present northeast or southwest of the well that could act as barriers. Although the actual presence of such an extensive set of hydrologic boundaries is extremely unlikely, the assumption that they exist leads to a conservative answer (high pressure) in predicting pressure buildup results. The test data indicate that good vertical confinement does exist in the immediate area of the well.

On the other hand, from the discussion presented by Gruy and Associates, I would not rely upon the results of

the computer model to disprove the possibility of leakage through fault zones such as the ones shown on the structural geologic map.

No reasoning or calculations are shown to substantiate the figures for distance of wastewater travel. As discussed in my review of the original application, it is generally considered impossible to make any meaningful estimate of the direction and distance of fluid travel for formations such as the Arbuckle.

In summary, I believe that it is probable that permeable zones exist in the Arbuckle Formation with the general characteristics listed in the application. The presence of the extensive number of lateral permeability barriers proposed by Gruy and Associates is not supported by geologic evidence presented, but the assumption that they exist leads to a conservatively high value for rate of injection pressure buildup. Good vertical confinement appears to exist in the immediate vicinity of the well. However, I do not believe that the Gruy analysis adequately shows that the known major faults are barriers to fluid movement. The figures for distance of wastewater movement are not substantiated and should not be regarded as reliable.

One of the studies provided by the Oklahoma Geological Survey is a photogeologic map of the Kerr-McGee plant and the surrounding area. The map shows the surface traces of the major faults to be located essentially as shown in the Kerr-McGee application, but it also shows some possible additional faults inferred from photogeologic evidence. Of particular interest are two inferred faults that trend northwest-southeast, perpendicular to the Carlile School fault and which, if extended, would pass very close to the Kerr-McGee well (see attached xerox copy of a part of the map). Such fault zones, if they exist, could provide selective avenues for lateral and/or vertical movement of wastewater. They could also be barriers as might be suggested by the reservoir studies previously discussed. No direct evidence is presently available to either prove or disprove the existence of the inferred faults. However, it is common for earth fractures to occur in such sets, and their existence would not be surprising.

Wastewater Characteristics and Preinjection Treatment Program

The application requests permission to inject wastewater, which would have widely varying composition, but would be primarily an inorganic nitrate solution composed

of one molar free nitric acid and up to 0.5lb/gal of suspended solids, traces of natural uranium, other metals, tributyl phosphate, and hexane.

I have been bothered by the fact that a specific analysis or analyses of the wastewater stream has not been provided, together with a total description of all of the chemical components present or likely to be present and their ranges of concentration. This is probably already in the AEC files, but I believe that it is important to know all of the chemicals proposed for injection, including nonradioactive ones, since it is possible that some toxic metals could also be present. Another item that has not been presented is a toxilogical evaluation of the wastewater in varying dilution ranges, since it is the toxicity to humans that is of principal concern. Probably this would not be necessary for the radioactive elements, but what about the others?

The application discusses the radiological aspects of the well, but the discussion is incomplete, because it does not include an evaluation of the fate of the Ra-226, which seems to me to be the most objectionable radioactive component.

The proposed wastewater pretreatment program includes solvent extraction of tributyl phosphate and storage in a holding tank prior to injection. Neutralization of the very acid wastewater is discussed in page 4 of the letter, but not included in page IV-2 of the application. I believe neutralization would be a very useful step to minimize the corrosion potential. If it is also stated in the letter (p.-4) that neutralized raffinate that is presently being held in storage would be mixed with new waste prior to injection and the resulting product settled to remove precipitated impurities. Again, this step is not discussed in the application portion. The discussion in Appendix G is not consistent with either the letter or the application.

Well Location and Design

Evidence is presented relative to the location and depth of shallow core holes, water wells, and oil and gas test wells in the vicinity of the injection well. The closest deep test is the Leonard #1 Smith, located about two miles east of the Kerr-McGee well on the opposite side of the Carlile School fault. Although a show of gas was encountered in the Leonard #1 Smith, commercial amounts of gas were not present, and the hole was plugged.

Because of its distance from the injection well and the fact that it has been plugged, the abandoned well could not be considered to be a migration path for escape of injected wastewater.

The core holes and water wells are all shallow and do not completely penetrate the Pennsylvanian age rocks. These shallow wells are separated from the Arbuckle Formation by more than 1,000 feet of intervening deposits of shale, siltstone, sandstone, and limestone, which provide an effective barrier to direct vertical migration in the absence of unplugged deep wells or a permeable fault zone.

The well design appears satisfactory. If the wastewater is not neutralized, the corrosion potential will be so great that any unprotected surface or defect in the plastic coating on metal surfaces will undoubtly result in rapid deterioration of the particular system component.

It is not planned to use filters. If the wastewater is not neutralized, then filters are probably unnecessary, since the nitric acid will continuously react with the formation. If the wastewater is neutralized, then the use of filters might be advantageous to prevent loss of permeability due to plugging by suspended solids.

The well monitoring devices are discussed in Exhibit H. Most of the available monitoring devices and procedures are proposed for incorporation with the well. Some devices are already in place, others would be added if the license applicacion is approved.

Well head injection and casing-tubing annulus pressure indicators are proposed for inclusion, with automatic transmission of signals to the control room. It is not stated that an automatic shut-down and alarm switches would be incorporated with these monitors. Provision should be made for automatic shut down of the well, if predetermined pressure limitations are exceeded. A schedule of pressure limitations, based on Kerr-McGee's own predicted pressure buildup curves, should be used. Each of the critical monitoring elements should be duplicated, so that malfunction of a sensor or gauge can be detected should it occur.

In the application it is proposed that quarterly reports be presented to the Commission for evaluation. I suggest that, if the well is licensed, monthly reports be required during the first year, with a requirement for immediate notification of the Commission in the event of any deviation from what are agreed as normal operating conditions. A specific format should be established for the content of the monthly reports, prior to initiation of operation of the well.

In addition to the well monitoring program proposed by Kerr-McGee Corporation, a periodic inspection of the surface and subsurface well facilities should be scheduled if the well is licensed. Inspection of all surface facilities and monitoring and recording devices should be required several times daily, and evidenced in a log. Inspection of the down-hole equipment should be scheduled, probably semi-annually. The injection tubing can be inspected with an appropriate down hole device, or it could be pulled and inspected. In any case, an acceptable procedure should be established to provide for the pulling of tubing and for work-over or testing of the well. This could be a problem, since the radioactive fluid in the well will backflow to the surface when the well-head is opened. The fluid pressure in the Arbuckle Formation is already sufficient to cause artesian flow, and it will be increased during injection.

The integrity of the packer and tubing could also be periodically checked by reducing the casing-tubing annulus pressure to below that in the injection tubing, then circulating out the annulus fluid and monitoring it for radioactivity.

The application (p.-9) mentions a periodic pressure fall-off test program, but does not specify its nature or frequency. The details of the proposed program should be specified.

Surface and Shallow Subsurface Monitoring Procedures

An extensive prog for sampling of surface waters and shallow wells is prog in Exhibit I of the application. It is proposed that weekly samples be collected and monthly analyses performed for each of the sampling locations. The reason for the weekly sampling with only monthly analysis is not explained.

The proposed monitoring program is an additional safeguard, which should be incorporated, but I would judge it to be of minimal value in evaluating the safety of the injection program. If leakage from the Arbuckle Formation to the surface or near surface should occur it would not be likely to develop and be observed for many years, and by that time, an environmental hazard would have been established that would be difficult or perhaps even impossible to reverse.

CONCLUSIONS

The interpretation of the regional geologic and hydrologic conditions as described in the original Kerr-McGee Corporation application of 1970 has not been changed in the revised application. Thus, the comments that were transmitted to Mr. Harmon in my letter dated May 7, 1970, still apply.

The significance of my original comments has, however, been modified by new information presented in the revised application and provided by the Oklahoma Geological Survey. From study of the additional information, I have formulated the following conclusions:

1. The Arbuckle Formation has several discreet permeable zones with an aggregate thickness of about 116 feet. Most of the injected wastewater will enter these zones.
2. It appears that the zones are not extensively interconnected. They are apparently well confined vertically and vertical escape of injected wastewater near the well would be unlikely.
3. The permeable zones seem to be very restricted in lateral extent, but analysis of the nature and location of the lateral boundaries as described in Exhibit A does not correlate with known geologic features, and for this and other reasons is considered unreliable.
4. The rate of pressure buildup as predicted in Exhibit A is much more rapid than would be expected, but is still small.
5. The predicted distance of wastewater migration is not considered reliable. I believe it to be impossible to make an acceptable estimate because of the geologic nature of the Arbuckle Formation.
6. It has not been reliably determined whether the major known fault systems are barriers to fluid movement or conduits for such movement. Although this was attempted, the complexity of the problem causes the analysis to be questionable in my opinion.
7. A photogeologic study provided by the Oklahoma Geological Survey shows two

inferred faults that are perpendicular to the Carlile School fault and which, if extended, would pass very close to the Kerr-McGee well. The significance of these faults is not known, nor is their existence proven. However, the occurence of such additional faults would not be surprising.

8. The description of the wastewater chemistry, toxicity, and the pretreatment program is incomplete and inconsistent. More specific observations are contained in the analysis section.
9. There is no known hazard of escape of wastewater from the Arbuckle Formation through other abandoned deep wells.
10. The well design appears satisfactory, but if the wastewater is not neutralized before injection, the corrosion potential is extremely high.
11. Filters may be desirable if the wastewater is neutralized before injection.
12. The well monitoring program proposed by Kerr-McGee contains many of the necessary features, but various additional requirements are suggested in the discussion of the well location and design.
13. The surface and shallow subsurface monitoring program proposed by Kerr-McGee should be adopted, if the well is licensed. However, if leakage from the Arbuckle Formation to the surface or near surface should occur, it would not be observable for many years and would be difficult or impossible to reverse when it was discovered.

POSSIBLE ENVIRONMENTAL IMPACTS OF WASTEWATER INJECTION

In any case where wastewater is injected into the subsurface, the minimal impact will be an increase in underground fluid pressure and displacement of native fluids by the wastewater. In any case, the projected increase in pressure, over a five year period, is too small to cause any direct damage by fracturing of the reservoir rocks. No matter how small, an increase in reservoir pressure will lead to modification of the natural fluid-flow patterns and, as suggested in the reviews of the original application, could stimulate escape of natural brines into other formations and perhaps ultimately to the surface through fracture systems. There would probably be no way to resolve an argument concerning the relative likelihood of escape of brines to the surface. However, since the total volume of wastewater to be injected over a five year period is now only 50 million gallons, the potential impact is small, even if injection did cause an equal volume of natural formation water to flow into surface or shallow ground waters.

A relatively more serious question is the ultimate fate of the injected wastewater. Reservoir studies by Kerr-McGee Corporation and its consultants indicate that it is unlikely that injected wastewater would escape vertically from the Arbuckle Formation in the immediate vicinity of the well. This conclusion appears reasonable.

It is estimated in the application that injected wastewater would not travel more than 900 feet from the well during five years. I do not believe that any accurate estimate of the rate and direction of wastewater movement can be made in this case. Therefore, an impact would be the introduction into the subsurface of a radioactive wastewater whose ultimate location can not be reliably predicted.

There do not appear to be any natural resources other than fresh water and the underground space itself that could be damaged by the injected wastewater.

Available evidence suggests that escape of the injected wastewater to the surface or near surface would be unlikely in a few years or even in a few tens of years. However, the ultimate movement of the wastewater to a totally unanticipated location cannot be ruled out completely because of the geologic complexity of the area in question.

Other unanticipated environmental impacts could occur as a result of accidents or engineering failure of some component of the disposal system. The possibility of such unanticipated impacts is very small if the proper precautions are taken in system construction and monitoring.

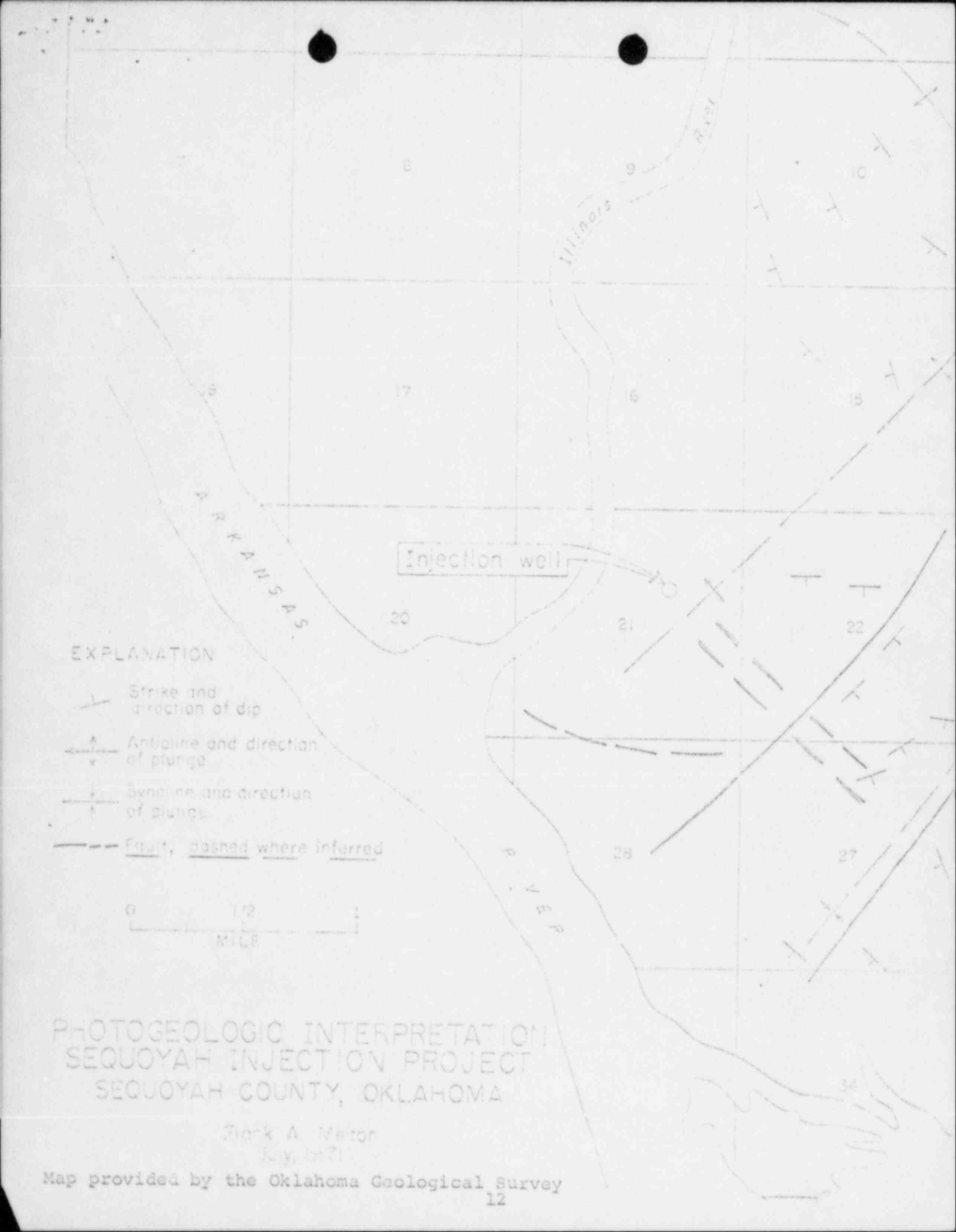
RECOMMENDATIONS

The geologic and engineering aspects and the possible environmental impacts of the proposed wastewater injection well have been discussed.

I believe that the decision concerning the proposed well depends on:

1. The Atomic Energy Commission's judgement concerning the relative merits and disadvantages of the other alternative disposal methods available in comparison with subsurface injection.
2. The relative benefits of subsurface injection to the public in comparison with the possible environmental impacts that have been outlined.

I recommend that, if the well is licensed, the monitoring procedures be modified as outlined in the body of this review.



Map provided by the Oklahoma Geological Survey

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C. R. Buchanan	ACTION NECESSARY ☐ NO ACTION NECESSARY ☐	CONCURRENCE ☐ COMMENT ☐	DATE ANSWERED: BY:
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June 16, 1972

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Mr. Cecil R. Buchanan
Materials Branch
Directorate of Licensing
United States Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Buchanan:

I am in the process of reviewing the application for amendment of Kerr McGees Corporation's license No. SUB-1010, which was sent to me by Mr. Malaro on June 2.

Some time age, Dr. Charles J. Mankin, Director of the Oklahoma Geological Survey at Norman, Oklahoma, advised me that his agency was involved in some supplementary surface and subsurface geological studies of the Kerr McGee plant site in connection with the proposed injection well. I recently called Dr. Mankin to determine if these studies were carried out. Some investigations were performed, and Dr. Mankin will make the reports available to me.

I wanted to advise you of these developments, because it is my opinion that I should review the work done by the Oklahoma Geological Survey as well as that supplied by Kerr McGee. This will lengthen the time that will be required for the review, but I still estimate that I will be able to complete the review before the end of June.

Sincerely yours,

Don Warner

Don L. Warner
Associate Professor
Geological Engineering

DLW/ps

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Ltr. in response to our ltr. of 6-2-72 commenting on Kerr McGee's application for an amendment .

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