United States Department of the Interior
WM DOCKET CONTROL CENTER
GEOLOGICAL SURVEY
RESTON, VA. 22092

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In Reply Refer To:
EGS-Mail Stop 410

October 10, 1983

WM Record File 1061

WM Project 16
Docket No. ✓
PDR ✓
LPDR ✓

Distribution:
HM | RJohnson
DM |
(Return to WM, 623-SS) 15

Mr. Jeff O. Neff
NWTS Program Office
Department of Energy
505 King Avenue
Columbus, Ohio 43201

Dear Jeff:

The enclosed review document satisfies our agreement and obligation to the Department of Energy (DOE) for review and evaluation of salt-site hydrologic modeling under Interagency Agreement No. DE-AI97-79ET44611. The U.S. Geological Survey (USGS) has made every reasonable effort to provide an independent, objective, technical review of the DOE-contractor hydrologic models, their input data, and the model results. These models and results address conditions at specific locations in Louisiana, Mississippi, Texas, and Utah in which either salt domes or deposits of bedded salt are being considered as potential hosts for repositories for high-level radioactive waste. The principal objectives of our review were to check for technical flaws, to determine the adequacy of the model codes of their application and of their results to represent actual field conditions, and to enable credible interpretations of ground-water flow systems and predictions of radionuclide transport.

In the course of these reviews, the following criteria were generally applied:

1. Appropriate differential equations of flow and solute transport must be solved by the models.

2. Appropriate numerical solutions schemes should be used in the models.

3. Input parameter data must be realistic.

4. Imposed boundary conditions must be realistic.

5. Assumptions, approximations, and errors should be within acceptable limits, and should cause the output to err on the conservative side.

6. Model should be thoroughly documented and its accuracy previously demonstrated on several real and hypothetical programs, and problems with known analytical solutions.

00114

7. The models should adequately simulate known past and present conditions in the system being modeled before being applied to future projections.

8. The model should maintain an accurate mass balance of water, (generally less than 1 percent error), and a mass balance of dissolved constituents for nuclide transport simulations, (generally less than 5 percent error).

Our review document includes three distinct but related reviews as follows:

1. Review of INTERA and ERTEC ground-water flow models of the Gulf Coast Salt Domes, Louisiana and Mississippi by G. N. Ryals.

2. Hydrologic Review for the Palo Duro-Dalhart Basins, Texas, and the Paradox Basin, Utah, by J. W. Mercer.

3. Review of DOE Contractor's ground-water hydrologic modeling of four salt sites for disposal of high-level radioactive waste by K. L. Kipp.

After you have had time to study these reviews, you might decide that a 1-day meeting to discuss our comments would be beneficial. If such a meeting is desirable, please give me a call and we will plan a time that is mutually agreeable. Also, if you have any questions, please contact me.

Sincerely yours,

Jack

John B. Robertson
Chief,
Office of Hazardous Waste Hydrology

Enclosure

Copy To:

C. Cooley, DOE
W. Bennett, DOE
C. Kingsburg, DOE
C. George, DOE
T. Baillieul, DOE
H. Miller, NRC
M. Bell, NRC
P. Cohen, USGS
G. Bennett, USGS

ENCLOSURE

REVIEW OF INTERA AND ERTEC GROUND-WATER FLOW MODELS OF THE GULF COAST SALT DOMES, LOUISIANA AND MISSISSIPPI

by
Gary N. Ryals
U. S. Geological Survey

General Comments

The INTERA and ERTEC modeling efforts represent a necessary first step in developing detailed predictive computer models and conceptual models of the Louisiana and Mississippi study areas. However, whether or not these first efforts are worthy of publication may need to be evaluated by DOE. The very preliminary nature of the modeling exercises presented in the INTERA and ERTEC reports would not normally be considered publishable by the U.S. Geological Survey (USGS) because of the confusion and misunderstanding that can be generated. The authors of the INTERA and ERTEC modeling reports state that the models are preliminary and that it is evident that several more years of development possibly could be necessary. As additional data are gathered and the computer models change, conflicts with older models may become apparent.

A possible flaw in approach by INTERA was detected during review of the INTERA models and during comparison of the approaches presented by INTERA and ERTEC. During the presentations in Columbus, Ohio, INTERA stated that they are relying strictly on published data for the development of their models. This is evident by the lack of new (but currently available) information developed and presented in the modeling reports. ERTEC, on the other hand, is developing regional maps to supplement published reports. The main source of data for Louisiana and Mississsippi for INTERA has been two area characterization reports (ONWI, 1982a and 1982b), which present the results of the area characterization phase of the overall ONWI program. The reports present detailed information for approximately 1,350 square miles of study area in Louisiana and approximately 1,440 square miles of study area in Mississippi. However, the INTERA regional models involve more than 9,660 square miles in Mississippi and 12,000 square miles in Louisiana. How can INTERA adequately conceptualize and model the regional geohydrology if the level of data is not uniform throughout the modeled area?

The model-generated travel times and flux rates presented in the modeling reports were not reviewed. becaise at this stage of development, the models are very simplistic, and more work is required to fully understand the flow system. Thus, we believe it is premature to calculate realistic travel times. This is another item that could lead to confusion and misunderstanding in the future as more modeling reports are published.

An important issue that will need to be addressed by ERTEC and INTERA will be the approach of modeling multiphase (oil, gas, and water) aquifers. Known model codes commonly used in hydrologic investigations, including the ERTEC and INTERA model codes, cannot simulate multiphase systems. However, the petroleum industry may have model codes that can simulate multiphase systems. The area characterization reports for Louisiana and Mississippi, which focus on a limited area compared to the regional models, report oil and gas production from aquifers included in the ERTEC and

INTERA models. Specific units that have oil and gas production and are included in the INTERA and ERTEC models of the Mississippi study area are the Wilcox Group, Cockfield Formation, and Kosciusko (Sparta) Formation. In Louisiana, the Austin Group has oil and gas production and is included in the INTERA model for Louisiana. The issue of modeling a multiphase aquifer was raised in a report by Ryals (1982, p. 14) for the Austin Group in Louisiana. To provide confidence in the modeling results, the issue must be resolved.

Specific Comments on INTERA's Louisiana Model

INTERA (1983a) is the principal report reviewed for evaluating INTERA's model of the Louisiana study area. Overall, the report is well written. But, many of the figures were impossible to read. Fortunately, copies of the source reports were available from which the figures were taken. Since many people do not have these reports more effort should be taken to reproduce the illustrations clearly. The following are specific technical comments.

1.--Pumpage from the Sparta aquifer was not adequately modeled by INTERA. Data on pumpage from the aquifer have been gathered by the USGS in detail since about 1960. Estimates have been made for the period 1900-60. INTERA included pumpages for 1975 of 30 million gallons per day at Monroe, LA., and El Dorado, AR., and of 20 million gallons per day at Magnolia, AR. In 1975, total ground-water use for Quachita Parish, where Monroe is located, was about 19 million gallons per day from all ground-water sources (Cardwell and Walter, 1979). Pumpage from the Sparta in 1975 for northern Louisiana was about 65 million gallons per day. It is obvious that pumpage from the Sparta was not evaluated in sufficient detail by INTERA. In addition to the pumpage data, the USGS is monitoring many observation wells in the Sparta and has constructed potentiometric surface maps periodically. Because of the relatively large amount of pumpage and potentiometric data available for the Sparta, calibration of aquifer parameters such as transmissivity in ground-water flow is enhanced. Thus, model output for the INTERA model is suspect because of the large amount of data for the Sparta which was omitted.

2.--Recharge to the Sparta through the outcrop was reported as 7.2×10^{-10} m/s (about 0.9 inches/year). We believe that this figure is too low for the Sparta, the actual recharge is probably 3 to 6 inches per year.

3.--Throughout the modeling report, the Quachita River is described as a regional discharge boundary for the Sparta and other Tertiary units. We believe the axis of the Mississippi embayment is more likely to be the regional discharge boundary. The Tertiary units discharge water to the overlying Mississippi alluvial deposits. This concept is discussed in Ryals (1982), Hosman (1978), and Payne (1968, 1970, 1972, and 1975).

4.--Injection stress was not input to the INTERA model. However, the injection stress is as important as the withdrawal stress in developing a complete concept of ground-water flow. Of the modeled units, the Austin and Wilcox Groups contain injection wells. ONWI (1982) reports 1,510 operating brine-disposal wells in Louisiana in 1976 and 57 active industrial-waste disposal wells in the State in 1978. An evaluation of the injection wells in the study area must be made in order to adequately model the area.

5.--The Nacatoch Sand aquifer was not input to the model. Because the Nacatoch aquifer occurs only in the northwestern part of the study area, the aquifer was incorporated into the confining layer between the Wilcox Group and Austin Group. This could be acceptable on a regional scale. However, local models are planned around Vacherie dome in which the Nacatoch will be an important unit. By incorporating the Nacatoch into the regional model at this time, hydrologic concepts of the relationship of the Wilcox, Midway, Navarro, Taylor, and Austin Groups can be developed and data deficiencies can be determined.

6.--Temperature is an important input to the regional model. Smith and others (1981) present a study of geothermal gradients and include northern Louisiana in which a geothermal anomaly was found. INTERA should evaluate the report and modify the model if necessary.

Specific Comments on INTERA's Mississippi Models

INTERA (1983b) is the principal report reviewed to evaluate INTERA's models of the Mississippi study area. In addition, input data (INTERA, 1983 written communication) for regional simulation B described in the modeling report was reviewed. Overall, the report is well written and boundary conditions, parameter values, and most assumptions seem reasonable. This report, as with the Louisiana modeling report, contained many illegible figures. The following are specific technical comments.

1.--One of the most important inputs to a model is hydraulic stress; for example the withdrawal and/or injection of water by wells. INTERA states that ground-water withdrawal is not significant enough to affect the regional potentiometric surfaces of the aquifers. We disagree with that conclusion because the regional model presented in the report includes the updip parts of some of the aquifers where pumpage may be significant. Bentley (1983) states that cones of depression are located at Hattiesburg and Purvis because of large withdrawal. Withdrawal wells may be an important aspect in the regional model and probably are an important aspect in the local model around Richton dome. The necessary proof or justification to exclude pumpage from the models was not presented in the report.

Injection was addressed by INTERA in an incomplete manner. In one simulation, an injection well was present in the Sparta Formation. ONWI (1983b) indicates that there are numerous injection wells in the characterization study area and probably many more in the regional model area. Potentiometric surface maps of units with injection wells presented in the report are not true representations because the injection cones are not presented. The injection of water is an important aspect in modeling the Mississippi study area and must be addressed in detail.

INTERA's model results are questionable because the stresses have not been fully evaluated and potentiometric maps are incomplete. The maps and stresses are necessary to develop concepts as well as to develop models of the area. Confidence cannot be placed in model results such as travel times until the maps are completed and the stresses are evaluated.

2.--Figure 2-20, as presented in the report, is somewhat confusing. The figure is from ONWI (1982b) and presents potentiometric surface maps for selected elevations. This figure is referred to in the discussion of the ground-water flow regime in the principal hydrogeologic units. Specifically, the figure is referred to in the discussion of the Wilcox, Sparta-Cook Mountain-Cockfield, and Catahoula. At any one elevation, the map may represent several units; therefore, developing concepts may be difficult. The report would be more meaningful and the reader would be able to evaluate model results if potentiometric surface maps were presented for individual hydrogeologic units.

Specific Comments on ERTEC's Mississippi Model

ERTEC (1982b and 1983a) are the two principal reports reviewed to evaluate ERTEC's model of the Mississippi study area. No printouts of input data for the model were received. The reports are well written and concise and there is excellent utilization of available data. One omission in the reports is figures depicting potentiometric surfaces, both measured and model generated. These figures would add support to statements made in the report. There is an excellent attempt to model injection and withdrawal stresses in the model. There are 115 injection wells input to the model. Because of a lack of injection data, each well was assumed to input the same amount of water. Plans should be developed to obtain as much information as possible from the operators of the injection wells to define the injection stress.

Concluding Remarks

Overall, the concepts and models presented by ERTEC and INTERA seem reasonable at this stage of development. The most serious problems are with INTERA's treatment of hydraulic stress to the aquifer systems and with using the Quachita River as a major regional discharge boundary in Louisiana. Comparing ERTEC's and INTERA's approaches in Mississippi, ERTEC's approach seems to be more systematic and representative. There are differences in approach by INTERA and ERTEC and in the interpretation of model results. We agree with the following statement comparing ERTEC's and INTERA's models in INTERA's modeling report for Mississippi: "Given the sparsity of data, the numerous conceptualizations and modeling options available, and thus the professional judgment required, it is not surprising that differences in approach and consequently conclusions have arisen." Numerous assumptions or qualifications might be added to the statement.

The differences in INTERA's and ERTEC's models and the numerous conceptualizations and assumptions required for the models reveal the need for additional data collection. Additional test drilling probably would be required to obtain the data.

An evaluation should be made to assess the issue of simulating multiphase systems as soon as possible. If this is a serious problem, a considerable amount of time may be required to adapt or develop an adequate model.

Selected References

Bentley, C. B., 1983, Preliminary report of the geohydrology near Cypress Creek and Richton salt domes, Mississippi: U.S. Geological Survey Water-Resources Investigations Report 83-__, [In review].

Cardwell, G. T., and Walter, W. H., 1979, Pumpage of water in Louisiana, 1975: Louisiana Department of Transportation and Development, Office of Public Works Water Resources Special Report 2, 15 p.

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Hosman, R. L., 1978, Geohydrology of the northern Louisiana salt-dome basin pertinent to the storage of radioactive wastes--A progress report: Baton Rouge, Louisiana, U.S. Geological Survey Water-Resources Investigations 78-104, 27 p.

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Office of Nuclear Waste Isolation, 1982a, Gulf Coast salt domes, geologic area characterization report, north Louisiana study area, volume IV: ONWI 119, Battelle Memorial Institute, Columbus, Ohio, 396 p.

_____ 1982b, Gulf Coast salt domes, geologic area characterization report, Mississippi study area, volume VI: ONWI 120, Battelle Memorial Institute, Columbus, Ohio, 451 p.

Payne, J. N., 1968, Hydrologic significance of the lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas: U.S. Geological Survey Professional Paper 569-A, 17 p.

_____ 1970, Geohydrologic significance of lithofacies of the Cockfield Formation of Louisiana and Mississippi and of the Yegua Formation of Texas: U.S. Geological Survey Professional Paper 569-B, 14 p.

_______ 1972 [1973], Hydrologic significance of lithofacies of the Cane River Formation or equivalents of Arkansas, Louisiana, Mississippi, and Texas: U.S. Geological Survey Professional Paper 569-C, 17 p.

_______ 1975 [1976], Geohydrologic significance of lithofacies of the Carrizo Sand of Arkansas, Louisiana, and Texas and the Meridian Sand of Mississippi: U.S. Geological Survey Professional Paper 569-D, 11 p.

Ryals, G. N., 1982, Regional geohydrology of the northern Louisiana salt-dome basin, part I, conceptual model and data needs: U.S. Geological Survey Open-File Report 82-343, 23 p.

Smith, Douglas L., Dees, William T., and Harrelson, Danny W., 1981, Geothermal conditions and their implications for basement tectonics in the gulf coast margin: Gulf Coast Association of Geological Societies Transactions, v. 31, pp. 181-190.

HYDROLOGIC REVIEW FOR THE PALO DURO - DALHART BASINS, TEXAS AND THE PARADOX BASIN, UTAH

by
Jerry W. Mercer
U. S. Geological Survey

This review concerns specifically a technical evaluation of the procedures, test methods, and results obtained by DOE contractors at the proposed salt sites in the Palo Duro - Dalhart Basins, Texas, and the Paradox Basin, Utah. The review also includes some general comments concerning the model boundary conditions and data input parameters. Each regional area is discussed separately with concluding remarks that may be applicable to both sites.

Palo Duro and Dalhart Basins, Texas

After reviewing the field activity plans (often referred to as engineering scopes of work-ESSOW) prepared by Stone and Webster (SWEC) for two of the test wells drilled in the Palo Duro Basin, several concerns come to mind. The activity plans reviewed, particularly for geophysical logging and drill-stem tests, were for the Harman #1 well (dated August 11, 1982), and the J. Friemel #1 well (dated April 12, 1983). The following comments are intended to be suggestions to help make the data collected more defensible.

No reference is made for establishing a set of procedures for the actual logging operation. Calibrations and descriptions of services are covered; however, no specific directions to the logging contractor are included. The logging contractor is a service company and should be told what is needed; not the reverse. Specifically, prior to logging, a meeting should be held between the logging contractor and a qualified logging representative from SWEC detailing not only the logs needed, but the specific details on the zones of interest

and the logging scales to be used. In addition, the qualified representative should be in the logging unit during initial runs and make appropriate changes with the logging engineer as needed. This will provide backup for the QA audit and assure that the best possible logs are obtained. An example of this type of documentation, attachment 1, as used at the WIPP site, as well as a log check-off sheet, attachment 2, to assure that all the parameters required are on the logs before the logging contractor leaves the site are provided. Some of this may be done, but it should be documented in the field activity plan.

Another comment is related to the field activity plan for drill-stem testing (DST). It is not obvious from the plan that a hydrologist is required onsite during the DST's. Reference is made only to a pretest meeting with a hydrologist. A hydrologist should be onsite to make decisions during the testing if they are required. This is the best opportunity to evaluate the test and to determine what steps will be needed for long-term testing. Again, it assures that defensible data is being collected. If this is not corrected, the field activity plans should be corrected. It may not be as important in long-term testing to have a hydrologist continually onsite. Another comment is justified relative to reliance on the contractor to provide all the DST interpretation. Again, an onsite hydrologist is necessary to check the data provided by the contractor. Complete reliance on the contractor may leave one open to criticism. Similar comments were made by Al La Sala in a memorandum to Jeff Neff, dated August 26, 1982. La Sala also commented about the necessity of confirmatory tests in conjunction with the DST's, i.e. slug injection and pulse tests. We disagree with the response by Jeff Neff in a followup memorandum dated December 1, 1982. Although oil-service companies have the expertise in looking for oil, they do not have the same level of knowledge in low-permeability rock, and their results are not always accurate and reliable. If they were, all the DST's run in the Palo Duro Basin should be accurate and reliable, which is clearly not the case. It is inappropriate to conclude that confirmatory results cannot be obtained from pulse and slug tests but can be obtained from "intrinsic permeabilities taken from geophysical logs." There have been many tests run at the WIPP site in New Mexico, in a similar environment, that confirm the validity and use of slug injection and pulse tests as confirmatory methods. Long-term tests are preferred for the best data base.

SWEC appears to be using the "state-of-the-art" for their testing equipment. Equipment being used on the J. Friemel well in June 1983 was impressive.

Another important comment concerns the classification and use of the DST data used in providing a data base from which the potentiometric surface maps were constructed and relates to the established pressure used to calculate the equivalent freshwater head in the class 1-DST data (SWEC, 1983, p. 18). Using the Horner Plot and extrapolating to an initial shut-in pressure (ISIP) is a reasonable method as long as the shut-in time is sufficient to discount the after-flow and wellbore storage effects. This is especially true in very low-permeability formations. If the actual DST charts were evaluated and plots made, then these values may be appropriate, but analyses from company records should be questioned.

Just having enough data to make a Horner Plot does not guarantee that sufficient time has elapsed to get an accurate ISIP. Pressure data should be reported and validity of the calculations should be checked in areas where anomalous pressures occur.

Another problem is in the use of the data and the screening of "bad" data when constructing the potentiometric maps. The idea that the basin has to be in hydrostatic equilibrium should be examined. Discarding data that is either underpressured or overpressured without a detailed evaluation of the DST chart should be done with care. The data may be trying to tell us something we are overlooking. There is good justification for discarding some of the underpressured data but no technical justification given for ignoring the overpressured data.

There also appear to be significant discrepancies between the two published maps for the potentiometric surface of the Wolfcamp. We understand that this has been discussed at several meetings and may have been resolved by now. If not, the data bases of the Texas Bureau of Economic Geology, (TBEG) and SWEC should be reviewed to see if the problem is in the data or in the interpretation. Of course, the differences could also be a result of different methods used for contouring. Before a defensible scenario on flow direction and rates is made, these discrepancies will have to be resolved.

Comments about the modeling effort are restricted to the implied boundary conditions and the data input to the model. It is not clear from reading the modeling report whether the variable density of the fluids between units and regionally within specified units is actually accounted for in the model. We know that the potentiometric surface data input is corrected to freshwater head, but do the actual flow and rate calculations take density in to account? INTERA (1983) seems correct in that the boundaries of the conceptual model should be extended to try and take in most probable recharge and discharge areas. The suggestion is also properly made that a new model run be made to use the most recent data base available. Again, it would help if it were a data base agreed on by both TBEG and SWEC.

Paradox Basin, Utah

Although at least two sites in the Paradox Basin are being considered, this review was concentrated in the Gibson Dome area. The review of the field test plans submitted by Woodward and Clyde for the Gibson Dome #1 and the Elk Ridge #1 have indicated some of the same problems as those of SWEC in the Texas activities. As before, these comments are intended to be suggestions to improve the defensibility of the data collected.

The problem areas identified in the field test plans refer to the procedures for geophysical logging and the DST's. If the geophysical logs are to be used for selecting zones for hydrologic testing, it would be prudent to have a qualified logging representative onsite during logging to verify that the best possible logs are acquired. The same comments as those discussed for the Palo Duro - Dalhart Basin studies are also applicable here. Reference is again made to the examples of logging instructions to the logger that are included with this memorandum. If there was a qualified logging representative onsite, it should be documented in the field plan.

Similar comments are pertinent when addressing the DST section of the field plan. Details are not available in the plan to determine if a hydrologist from Woodward and Clyde was onsite during the actual DST's. It still seems to be important to have a qualified person present to evaluate the data and make changes to the test plan if needed during the test. It is important to note that Woodward and Clyde does recognize the need for comparative testing, i. e. pulse-tests, and has incorporated them into the test plan. Al La Sala has again identified similar problems with the test plans as documented in a memorandum to Ben Bower on August 20, 1982. His evaluation of lack of specific details in the descriptions of the field activities, seems appropriate.

Review of the reports available reveal that the data base for the hydrologic evaluation of the Paradox Basin is limited. It would, therefore, appear to be difficult to make a decision on site selection based primarily on geohydrologic considerations. It seems that this limited data base has created some discrepancies in the evaluation of these data by different professionals working on the project. These problems were discussed in a hydrology meeting on the Paradox in Salt Lake City in July 1983. The differences of opinion are in determining points and amounts of recharge and discharge from the various hydrologic units as well as in flow directions from the Gibson Dome area. Other issues were discussed including hole locations for future tests and some discrepancies in the data collected at Gibson Dome #1. Again, resolution of these problems is paramount to site selection.

The modeling review, as in the case of the Texas study, concentrated on an evaluation of the data input and the boundary conditions. In the case of the Paradox study, however, the data base is inadequate to allow realistic deterministic modeling, thus restricting the use of the conceptual model. It again is not clear whether this model accounts for variability of the fluid density between and within individual hydrologic units. INTERA (1983) seems correct in that the model boundaries should be extended to include all potential recharge and discharge areas. A new model run should be made using all the new data collected as well as the data from the Gibson Dome #1 and Elk Ridge #1 test holes.

General Comments

Extensive work has been conducted in the regional site characterization for both the Paradox and Palo Duro - Dalhart Basins. It is, however, difficult to see why there has not been extensive interaction between the contractors on these salt projects and those who have completed site characterization at the WIPP site in New Mexico. After having attended meetings in Texas and Utah, we find similar problems as those encountered in New Mexico, but are unaware of an interchange of ideas and data. Site characterization problems are similar and interchange should take place as specific salt sites are selected.

References Cited

INTERA Environmental Consultants Incorporated, 1983a, First status report on regional ground-water flow modeling for the Palo Duro Basin, Texas: Revised second draft June 1983.

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LOG QUALITY REPORT

Hole Wipp Hydro H-5C Log Date 5-30-78 Current Date 5-31-78

Log ______ Run # one Engr. B.P. Bothwell

Field Print [X] Final Print [ ] Log Analyst J. D. Hudson

CHECK ALL BOXES — ACCEPTABLE YES OR UNACCEPTABLE NO
Sections not applicable to a particular service, Leave Blank.

REMARKS: Code Remarks with the proper Section Number. For Example: Remarks concerning before log calibrations would be coded B-5.

	YES	NO
A. HEADING		
1. Correct Heading Used	X	
2. Heading Data Properly Completed	X	
3. Logging Data Section Completed	X	
4. Equipment Data Section Completed	X	
5. Scale Changes Noted on Heading	Y	
6. Are all abnormal conditions explained in the remarks section	X	
B. CALIBRATIONS AND SCALES		
1. Scales Correct for Area	X	
2. Scales Labelled	X	
3. Scale Changes Labelled	X	
4. Zeroes Recorded	X	
5. Before Log Calibrations	X	
6. After Log Calibrations	X	
7. Repeat Section Recorded	X	
8. Repeat Section Acceptable	X	
C. VALIDITY OF LOG		
1. Curves Functioning Correctly	X	
2. Do Log values fall within reasonable limits	X	
3. Curves on Depth	X	
4. Logging Speed Indicated	X	
5. Logging Speed Correct	X	
D. APPEARANCE		
1. Printing or Typing Neat	X	
2. Printing or Typing Accurate	X	
3. Grid and Pen Traces	X	
4. Splices Straight and Clean	X	
5. Film Correctly Processed	X	
6. General Print Quality	X	

INSTRUCTIONS TO LOGGING COMPANY

Date May 30, 1978

Logging Company DRESSER ATLAS

Logging Engineer

Witnessed By [illegible] ...WELL
Jim D. Hudson

Log Headings:

Company Fenix & Scisson, Inc.

Well Number WIPP No. H-5c

Field NASH DRAW County EDDY State New Mexico

Location 1006.47' FNL, 134.20 FEL

Section 15 Township 22S Range 31E

Permanent Datum GROUND LEVEL Elevations: K.B. N/A

Log Measured From G.L. D.F. N/A

Drilling Measured From G.L. G.L. 3507.57

Hole Status:

	SIZE	FROM	TO		SIZE	FROM	TO
Casings	9 5/8"	0	40	Borehole	18"	0	40'
					7 7/8"	40	1025

Type Fluid in Borehole Fresh Water Gel Fluid Level Will fill hole w/mud after repeat run and before final run of each log.

Density pH

Viscosity Fluid Loss

Purpose of Logging Program, Zones of Special Interest, Critical Hole Conditions, Remarks, Etc. Purpose is to obtain stratigraphic and hydrologic data to the top of the Salado Formation. The logs will be used for stratigraphic correlation and hydrologic analysis. All logs: 200 ft. repeat section - Caliper Span 3" to 15". Gamma Ray 0-~~200~~ 150 API units. RM, RMF, RMC, measured and mud pressed. All logs recorded on same depth. Insure film dark enough to show all fast breaks on prints.

Number of Prints: Field ~~10~~ 15 Final ~~10~~ 15

PRINTS TO

Invoice To: Fenix & Scisson, Inc.
1502 W. Stevens Street
Carlsbad, New Mexico 88220

Instructions to Logging Company

Not necessary to run in this sequence

Log No. 1 Dual Laterlog w/Gamma Ray and S.P.

(a) Vertical Depth Scales 2-inches/100-feet and 5-inches/100-feet
(b) Horizontal Logging Scales Standard Dresser Atlas
(c) Logging Speed Desired 40'/min Test
(d) Interval to be Logged Total hole
(e) Zones of Special Interest Total hole GR Bottom to Casing point Resis & S.P.

(f) Special Instruction Fenix & Scisson representative will fill hole w/ mud between repeat run and final run

****

Log No. 2 Micro-Laterlog w/Gamma Ray and Caliper

(a) Vertical Depth Scales 2-inches/100-feet and 5-inches/100-feet
(b) Horizontal Logging Scales Caliper 7"-15" , 2-1000 ohms all back up
(c) Logging Speed Desired Standard
(d) Interval to be Logged 40' to T.D.
(e) Zones of Special Interest Total hole -- Bottom to Casing point

(f) Special Instruction Same as Log #1

****

Log No. 3 Acoustilog w/Gamma Ray and Caliper

(a) Vertical Depth Scales 2-inches/100-feet and 5-inches/100-feet
(b) Horizontal Logging Scales 40 to 200 Micro Sec/ft.
(c) Logging Speed Desired Standard
(d) Interval to be Logged Casing point to T.D.
(e) Zones of Special Interest Total hole

(f) Special Instruction Same as Log #1

Log No. 4 Compensated Neutron /with Gamma Ray

(a) Vertical Depth Scales 2-inches/100-feet and 5-inches/100-feet
(b) Horizontal Logging Scales GR = 15 API/CD Neutron Porosity -5 to 45%.
(c) Logging Speed Desired Standard
(d) Interval to be Logged Total hole
(e) Zones of Special Interest Total hole

(f) Special Instruction Same as Log #1

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Log No. 5 Densilog w/ Gamma Ray and Caliper

(a) Vertical Depth Scales 2-inches/100-feet and 5-inches/100-feet
(b) Horizontal Logging Scales 2.0 to 3.0 G/CC 10 or 15 API/CD TC=1
(c) Logging Speed Desired Standard
(d) Interval to be Logged Total hole
(e) Zones of Special Interest Total hole

(f) Special Instruction Same as Log #1

END of LIST

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Log No.

(a) Vertical Depth Scales 2-inches/100-feet and 5-inches/100-feet
(b) Horizontal Logging Scales
(c) Logging Speed Desired
(d) Interval to be Logged
(e) Zones of Special Interest

(f) Special Instruction

REVIEW OF DOE CONTRACTORS' GROUND-WATER HYDROLOGY MODELING OF FOUR SALT SITES FOR DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE

by
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A total of 17 reports (including first and second drafts) that were supplied, covering modeling efforts at the various sites and descriptions of the models used, were reviewed. Model documentation was provided for only the SWENT model of INTERA and the Adjoint variable sensitivity model of INTERA. The documents reviewed were the following:

Model descriptions

1. SWENT: A three-dimensional finite difference code..., ONWI-457;

2. SWENT code listing..., ONWI/E512-02900/CD02, 400--01G-01A;

3. Adjoint sensitivity theory for steady state-ground-water flow...; ONWI/82/E512-02900/TR12 410-00G-07;

Richton Dome:

4. Teubner and Tracy, Computer model selection, regional ground-water flow, Richton Dome..., ERTEC memo EW--ONWI-82-2022 (1982);

5. Status report on modeling regional ground-water flow near Richton Dome..., ERTEC;

6. Amendment to status report..., ERTEC;

7. Status report on regional and local ground-water flow modeling..., ONWI/E512-02900/TR21, 410C-00G-02 (First draft and second draft);

Vacherie Dome:

8. Status report on regional ground-water flow modeling..., ONWI/E512-02900/TR20, 410D-00G-02;

Palo Duro Basin:

9. Review of BEG deliverables..., Permian Potentiometric analysis, PNL;

10. Preliminary modeling of ground-water flow near salt dissolution zones, Texas Panhandle, Simkins & Fogg;

11. Status report on regional ground-water flow modeling..., ONWI/E512-02900/TR-13, 410A-00G-03 (First draft, second draft, revised second draft);

12. Status report on repository system assessments..., ONWI/E512-02900/TR-14;

Paradox Basin:

13. Preliminary results of computer modeling..., Woodward-Clyde PBP-WCC-ONWI-716;

14. Status report on regional ground-water flow modeling..., ONWI/E512-02900/TR-17 410B-00G-03 (first draft, second draft).

Items 4, 9, 10, and 13 are letter reports or extracts from larger documents. A report concerning the ERTEC ground-water flow model, was requested but never obtained; Tracy, Teubner, and Coddington, 1982, Documentation of a three-dimensional flow model-GRAM, ERTEC Western, Long Beach, California.

The approach used was to review each of the above reports from the standpoint of technical content only. Editorial critiques were made only on the second drafts of items 7, 11, and 14. The scope of my part of this review was confined to assessment of the ground-water flow models with respect to their appropriateness and correct usage. Some regard was paid to assessment of the interpretation of the physical systems for model application, i. e. boundary conditions selected, gridpoint design, etc. Mainly, any assumptions, numerical implementations, and approximations that might be inappropriate or questionable for the physical systems being modeled were looked for. It was virtually impossible to be able to identify any programming errors or data input errors, with the exception of the SWENT code. This code is sufficiently similar to the SWIP code that INTERA provided to the USGS that it was possible to check for the presence of errors that had been discovered in the SWIP code during the course of other work.

Critiques of the Models Used

There are some general comments that apply to all the ground-water flow modeling that was reviewed. Only steady-state ground-water flow modeling was done. No nuclide transport modeling has been done. One thermal energy model has been applied in the Palo Duro Basin at the repository scale. Only an approximate form of variable density flow modeling was done for some cases. Most of the models are three dimensional, only the INTERA SWENT code has been applied to all four sites under this review.

No known errors from the SWIP code relative to the ground-water flow portion of the SWENT code were found to be present. A phone conversation with Bob Andrews of INTERA revealed that they used the two-line successive over-relaxation solution method for solving their simulations. This is an iterative solution technique, and the termination criterion for the iterations is incorrect. At least it is not one of the generally accepted criteria (Jennings, 1977). They test on the algebraic value of the change in the elements in the solution vector rather than on the absolute value of the change. With a large number of nodes and with a near optimal over-relaxation factor, it probably turns out that positive and negative changes are encountered about equally, so testing on the positive changes only could lead to nearly the same result at convergence, but there are cases where the iterations could be prematurely terminated with a resulting low accuracy in the solution. It appears that the risk of premature termination diminishes the closer to the over-relaxation factor is to the optimum value.

The method the SWENT code uses to represent the geometry of tilted, warped, and pinched out geologic formations involves some approximations that need discussion. The coordinate system remains set with the z-axis vertical (aligned with the gravitational vector), and the x and y-axes forming a horizontal plane. The horizontal grid mesh is projected down through each stratigraphic layer. The stratigraphic layers were selected to be one cell-layer thick with the thickness of the cells adjusted to span the stratigraphic layer and the position of the cells adjusted to follow the curvature or tilt of the formation boundaries. This approach has the advantage of minimizing the number of cells (blocks) necessary to discretize a given regional model. It has the disadvantage of being an approximation that introduces negligible errors only if the angle of the stratigraphic layer interface tilt is less than about 5 degrees. This restriction is probably satisfied in all the modeled regions based on personal examination of the published model cross sections available. However, in applying this approach to a local model near the salt intrusion domes, it will probably be impossible to adhere to this restriction on angle of layer slope. While errors in the flow calculations are negligible, it is reasonable to question the suitability of this approximation on subsequent solute (nuclide) transport calculations. Tests should be made to demonstrate that the somewhat restricted interconnection of cells (blocks) does not introduce artificial constraints on solute transport simulations. The method of treating stratigraphic layers that pinch out within the model region was not made clear in the reports. Direct communication at the Columbus meeting revealed that layers which pinch out still exist in the finite difference grid represented as "invisible" layers of small thickness and high hydraulic conductivity. Thus, they should not affect the flow patterns in subregions where they do not exist.

Several alternatives to this method of treatment of tilted, warped, and pinched out stratigraphic layers exist. One is to employ a denser finite difference grid with constant cell thickness in each plane and unshifted cell location, and property variation patterns to represent the stratigraphic layers. This would greatly increase the number of computational cells required. Another option would be to use a finite element based model. This is the more attractive choice but would mean abandoning the SWENT code. This may be necessary for local modeling of nuclide transport at the salt domes. A third option would be to use curvalinear coordinates that coincide with the upper and lower surfaces of the simulation region. This would require extensive recoding of the model.

The last general comment about the SWENT model is that it does not handle the free-surface boundary condition of unconfined flow. At steady-state, the free-surface is a surface of flow streamlines that can be considered a rigid, impermeable surface. However, the location of this surface is not known a priori. This makes unconfined flow a particularly difficult problem for three-dimensional simulation. An approximation is used in the SWIP code whereby a volumetric balance is made on the cells in the upper layer when unconfined conditions are to be simulated. The resultant calculated pressure is compared to the atmospheric pressure and this locates the position of the free surface in each cell of the top layer. This method should be employed in the SWENT code also.

Adjoint sensitivity theory was used to compute distributions of the "importance function" and the "marginal sensitivities" of function of heads and Darcy velocities in the vicinities of the proposed repositories. While this is a useful technique to obtain indications of where aquifer parameters and boundary conditions need to be most accurately known, it would be of limited utility in a parameter searching technique to locate the parameter set which minimizes some goodness-of-fit criterion between observed and model calculated potentials. There seems to be no computational advantage to the adjoint method to compute state sensitivities needed to solve such an optimization problem. However, that type of calculation was not considered by the authors.

The document on model selection by ERTEC is basically a justification for selection of their own inhouse model. It is too brief and incomplete to be regarded as a rigorous comparison that others could use to guide their selection of a simulation model. There is a prejudice toward finite elements, the wellbore model capability of the INTERA code is underrated, and there are inconsistencies between the table and the discussion on the text. They gloss over the density dependence on salinity since their model is constant density. They should have just said that they preferred to use their ground-water flow model because they were most familiar with it and let it go at that.

Modeling the Richton Dome Region of Mississippi

The modeling work by INTERA at this site will be reviewed first. For some of their simulations, INTERA used a density that was salinity and temperature dependent. But it is not clear from the report just how this was done. Apparently no transport of salt was simulated, but densities in the wells were set to fixed values based on the cell temperature and salinity. It appears that the density field was set as a known distribution unaffected by the computed flow field. As such it takes on the role of a property distribution like the permeability. The computed pressure and flow fields will depend on the assumed salinity and temperature distribution. However, one must be careful not to specify any boundary conditions which are inconsistent with the specified density field since the computed flow field cannot affect the density field even though, for example, a significant flow of freshwater may be occurring into a cell filled with saline water. The implications of assumptions made in the course of application of the SWENT code to the simulation of the various salt regions considered should be discussed in the reports.

With little additional work, the viscosity variation with temperature and the effects of density and viscosity variations on the hydraulic conductivity could have been incorporated. Perhaps the authors felt that the uncertainty in the permeability distribution greatly exceeded any effect the density and viscosity distributions would have on the hydraulic conductivity.

ERTEC modeling of the Richton Dome region was done with a finite element based code used for steady-state simulation with no density variation from salinity or temperature. The advantages of the finite element method in designing a mesh to represent the tilted, folded, and pinched out stratigraphic layers are apparent. Unconfined or free-surface conditions were treated by the volumetric balance approximation mentioned above. The river aquifer interaction through leakage is handled in a more sophisticated manner by the ERTEC model which includes river routing. It is not determinable if wells could be completed in more than one element in this model.

Some of the boundaries were treated by using a leakage function that is similar to one of the aquifer influence functions available in the SWENT code but not used by INTERA. In view of the parameter uncertainty and possible hydrological influences between the recharge area and the model boundary that are not accounted for in the leakage function, it might be better to just estimate the boundary flux directly. A simple parameter determination routine was used. In fact, it appears to be a bit too simple in that the algorithm for adjustment of the model parameters to obtain an improved match between observed and model calculated heads ensures neither that the optimum solution will ever be reached nor that it even will be approached more closely with each successive parameter adjustment. The report indicates some confusion between sensitivity analysis and optimum parameter determination. It was not clear how many parameters were used in the search for the optimum set of values, how many observed heads were employed, or just what the objective function to be minimized was. A statement was made that the river leakance factors were adjusted, but wells near the river were excluded from those calculations. This seems strange since the wells near the river should be most sensitive to adjustments in river leakance. Without a more complete explanation, the value of this parameter determination work seems marginal.

Modeling the Vacherie Dome Region of Louisiana

INTERA applied the SWENT code to model the Vacherie Dome region using a specified density distribution. The only particular comment on this model region concerns the assumption of no flux boundary for the lower aquifers beneath the Red River. This assumption needs to be validated by potentiometric data since there is no reason that the lower aquifer units should reflect the same flow symmetry about the Red River that the surficial aquifer does.

Modeling the Palo Duro Basin Region in Texas

The reports reviewed included a regional model using SWENT by INTERA; repository system assessments by INTERA: a brief report chapter of a a two-dimensional, cross-sectional model by Simpkins & Fogg, perhaps from TBEG, and a kriging study done by Pacific Northwest Laboratory (PNL).

Documentation of the FLUMP code used by Simpkins & Fogg was not accessible and as their model study was of rather limited scope, their work was not reviewed in depth, and no particular comments were made.

The kriging study by PNL was to evaluate the potentiometric surface in the Wolfcamp Formation and to assess the recommendations of TBEG for additional drilling. Although we have limited experience and familiarity with this this kriging geostatistical method, we have a few questions to raise concerning the kriging report on the Wolfcamp potentiometric data. PNL does not state quantitatively their criterion for deleting 17 potentiometric data points. Why were eight values selected for the kriging equation factor calculation? Were other numbers tried? There should be some discussion of the implications of selecting a linear covariance functional form. When the block averaged kriging calculation was performed, no constant or "nugget" term appeared. Was this a calculated result or was the coefficient set to zero a priori? Were other than locally constant potentiometric distributions tried? If so, what were the results? The fact that the second coefficient in the covariance function was nearly the same under point and block calculations was used to claim that the block averaging did not cause excessive smoothing of the potentiometric surface. Is the constancy of the second coefficient a sensitive test for possible oversmoothing? At one place, flyers in the data were defined as being more than 2.5 standard deviations from the expected value, and at another place, the factor 1.46 was used. There is some inconsistency here. Finally, how was the head value of 300 feet determined to create hypothetical extreme potential values for the planned new wells?

The regional simulations by INTERA with the SWENT code followed the same approach as discussed above for the salt domes. Only constant density ground-water flow was considered. The report quality for the Palo Duro Basin was inferior to that of the salt dome reports. Figures are missing, legends and units on figures are missing, and too much of the description of what was done is qualitative so that an in-depth review was not possible. We have no particular comment about this work. Of course, the general comments about the SWENT model presented above apply.

INTERA also did some repository system assessments. Chapters on the thermal prediction studies and local flow analysis were reviewed. In the thermal energy transport equation of the SWENT code, there appears to be an error that was inherited from the SWIP code involving a thermal capacity term and its variation with changes in pressure.

In the description of the local flow analysis to model the presence of a borehole into the bedded salt formation, density is taken to be a function of salinity and temperature. However, it is unclear if they used the wellbore model or a stack of cells with high hydraulic conductivity to simulate the wellbore. The impression from the text is that perhaps the local identity of the wellbore was lost by averaging its properties with the cells that it passed through. It seems that on a refined modeling scale, the wellbore itself should at least be delineated by its own set of cells with appropriate properties or a wellbore model that couples the wellbore to the appropriate aquifer cells should be used.

Modeling the Paradox Basin Region in Utah

Woodward-Clyde and INTERA developed ground-water flow models for the Paradox Basin region. The Woodward-Clyde report was a brief letter report, but its clarity and conciseness made it easier to read than the INTERA report on the same site.

Woodward-Clyde used the Trescott-Larson USGS finite difference, three-dimensional flow code. This code can only treat constant density fluids. A simple two-layer model was formulated. They used constant head boundary conditions for rainfall recharge. It would be more appropriate to specify an areal flux. Some of the constant head boundary conditions at lateral faces were modeled by INTERA as no flow boundary conditions. This illustrates differences in interpretation. The surrounding of the model region by cells of no flow does not improve the numerical efficiency as stated. That is an old historical artifact of this code which is now obsolete. There appears to be a discrepancy in the figures regarding the leakage cells. It seems reasonable that a leakage cell in the upper layer must overlie a leakage cell in the lower layer. If this is not the case, further explanation is necessary.

The INTERA regional simulations in the Paradox Basin were steady-state, constant-density, ground-water flow as for the previous sites. Treatment of stratigraphic layers eroded through by the Colorado River was similar to the treatment of pinched out layers. The layers were reduced to 10-foot thickness and given a high-hydraulic conductivity. The cells of the uppermost layer extended to the land surface. The fact that the water table was below the upper cell surface was taken into account by reducing the horizontal hydraulic conductivity. If the water table elevation in each cell is known for the steady-state simulation, then adjustment of the conductivity is equivalent to reducing the cross-sectional area to account for the cells being only partly full. It would seem to be just as easy in this case to make the tops of the cells coincide with the water table. If the water table elevation is taken to be unknown over much of the region, then the approach mentioned above requiring some code modification to handle the free surface seems more appropriate.

On p. 78, the prescription of atmospheric pressure at the tops of the cells which were set at the top of the Cedar/Cutler Formation is analogous to making the tops of the cells coincide with the water table, a surface of zero pressure. Thus, the water table is made to coincide with the top of the Cedar/Cutler Formation, which is not true over the entire simulation area. Their description makes methods one and three sound about the same with method one allowing for non-zero pressures along the upper boundary. Perhaps an aquifer influence function boundary condition should be used to account for Moenkopi leakage across the upper boundary.

On p. 92, the above description is more clearly made for the refined model than for the regional one. The boundary condition on the northwestern edge of the refined model is not mentioned.

In some of the tables of mass fluxes, it appears that there are some sign problems. For example, the way numbers are presented it looks like there is only leakage from Elephant Canyon to Cedar Mesa.

The following comments address the eight points of the proposal for this review of the DOE salt-site hydrologic modeling:

1. We believe that the appropriate flow equations were solved. No transport solutions were presented for review.

2. We question the two-line successive over-relaxation solution scheme termination criterion.

3. & 4. Input parameter data and boundary condition data seem reasonable in light of the sparsity of data available and my lack of familiarity with these sites. We made comments above on the treatment of the water table boundary condition.

5. We were unable to verify that assumptions would always cause the output to err on the conservative side.

6. We had access to only the INTERA SWENT code documentation and the adjoint variable sensitivity documentation. The flow simulator was tested by INTERA for a single-well injection problem. This simple test did not include variable density or free surface effects. No test documentation of the ERTEC or other models was available.

7. Only steady-state simulations were performed. The comparison of modeled to observed conditions was sketchy and hard to deduce. Lack of data probably contributed to this, but clearer presentation of the results would help the reader determine the quality of the simulation. Uncertainty in parameter values was not applied to an uncertainty estimate of travel times.

8. Only the ERTEC modeling results had mass balances presented in a form that would seem to satisfy a one-percent maximum error criterion.

This concludes the technical review comments on various aspects of the listed reports. Although there is much room for improvement in the completeness and readability of the reports, this type of editorial critique was assumed to be outside the scope of our task. The organization and clarity of the writing was better in the ERTEC and Woodward-Clyde reports than in the INTERA reports.

After completing general review of the modeling efforts, reviews of revised editions of three of the site reports for publication were also requested. They were the INTERA reports on the Richton Dome, Palo Duro Basin, and Paradox Basin areas. There are a few general comments on these reports. They are too long and detailed for the preliminary nature of the modeling work reported. The organization is awkward and hard to read because there are too many cross references to other sections. Except for the INTERA report on Richton Dome, there was no effort to relate the modeling results from one study to another on the same site. Several of the figures are unreadable and thus of little value to the reader making a close study of the work. Some scales and legends were also missing. A section of pages in the Palo Duro Basin report was out of order. There are deficiencies apparent in all three of the reports. However, only examples from the Richton Dome report are cited for illustration.

1. General statements are made which are not supported by facts or data. An example is on p. 99; "Thus somewhat different boundary conditions are being used but this does not detract from the generated results." There is no quantitative demonstration of this.

2. Another example is on p. 105; "Although these changes are important, they are not significant enough to warrant a change . . . . " What is the measure of significance?

3. There are statements with poor logical structure. An example of this is on p. 105; "Although the vertical flow ratios are affected by density . . . the impact . . . is diminished as the result of the low K_v . . . " The low conductivity causes the low flow rates, rather than the implication here that given flow rates are attenuated by the low conductivity.

4. Statements are made that give an erroneous impression of the reasoning used in adjustment of model parameters. An example is on p. 113: "The lower Wilcox was given a somewhat higher salinity . . . to minimize vertical flows . . . ." This implies that the desired flow field was known and that the salinity parameter distribution was adjusted to achieve the desired results. We believe that the salinity was probably better known and that the flow velocity field should be considered the dependent variable. If there was any known flow information it was not mentioned.

5. No quantitative statements are made as to the uncertainty with which the various parameters are known. Thus, a statement like that on p. 133 that the boundary conditions are better known than the conductivity is purely qualitative and does not support the conclusion about the uncertainty of the local head values.

6. There are cases where results are not presented, without explaining why they are not. An example is on p. 139; why were the heads not converted to EFWH? Was the salinity information missing?

Reference Cited

Jennings, A., 1977, Matrix computation for Engineers and Scientists: John Wiley, Interscience, p. 184.