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Geochemistry of Formation Waters in the Lower Conasauga Group at the New Hydrofracture Facility: Preliminary Data from the Deep Monitoring (DM) Wells

C. Stephen Haase
John Switek
Stephen H. Stow

Environmental Sciences Division
Publication No. 2887

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ENVIRONMENTAL SCIENCES DIVISION

GEOCHEMISTRY OF FORMATION WATERS IN THE LOWER CONASAUGA GROUP AT THE NEW HYDROFRACTURE FACILITY: PRELIMINARY DATA FROM THE DEEP MONITORING (DM) WELLS

C. Stephen Haase, John Switek, and Stephen H. Stow

Environmental Sciences Division
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ABSTRACT

Haase, C. S., J. Switek, and S. H. Stow. 1987. Geochemistry of Formation Waters in the Lower Conasauga Group at the New Hydrofracture Facility: Preliminary Data from the Deep Monitoring (DM) Wells. ORNL/RAP-6. 50 pp.

Deep monitoring (DM) wells surrounding the New Hydrofracture Facility were sampled in September 1984, January 1985, and January 1986. The seven DM wells are open to various intervals within the Rutledge Limestone, the Pumpkin Valley Shale, and the Rome Formation. These wells provide a means to sample groundwaters within these formations and an opportunity to detect the presence of radionuclides within those groundwaters. Samples were analyzed for major, minor, and trace elements. Gross alpha, beta, and gamma spectral scans were obtained along with specific analyses for ^{3}H, ^{60}Co, ^{90}Sr, and ^{137}Cs.

Groundwaters sampled by the DM wells are low-alkalinity, low-pH, Na-Ca-Mg-Cl brines. Total dissolved solid values for most wells range between 150,000 and 200,000 μg/mL. Compositional variability between individual wells and between various samplings of each well suggests that the subsurface hydrological system at the hydrofracture facility is not static.

Chemical and radionuclide data for the samples suggest that significant amounts of waste-derived fluids have mixed with groundwaters in the Pumpkin Valley Shale 1000 ft east and west, respectively, of the New Hydrofracture site. Pumpkin Valley Shale groundwaters 1000 ft northwest of the hydrofracture site, however, do not contain appreciable amounts of radionuclides. The data further indicate that significant amounts of waste-derived fluids also occur in groundwaters of the Rome Formation 1000 ft east and west of the hydrofracture site. Rutledge Formation groundwaters 1000 ft to the east and northwest of the site contain very low levels of radionuclides. Levels of radionuclides observed in DM wells open to the Rutledge Formation are similar to those noted in Rock Cover wells open to the Rutledge and Rogersville Formations in the immediate vicinity of the New Hydrofracture Facility. Such data indicate that only small amounts of waste-derived fluids have mixed with groundwaters in the formation immediately overlying the Pumpkin Valley Shale.

1. INTRODUCTION

1.1 BACKGROUND

Liquid, low-level radioactive wastes at Oak Ridge National Laboratory (ORNL) were disposed of by hydrofracturing at a depth of 1000 ft into a low-permeability shale (IAEA 1983; Weeren et al. 1985; Stow and Haase 1986). In August, 1984 radioactively contaminated water was detected in two (wells DM1 and DM2 in Fig. 1) of three deep monitoring (DM) wells 1000 ft from the hydrofracture injection well. Waters in the three wells were subsequently sampled in September 1984 and January 1985. The data obtained suggested that the hydrofracture operation was the source of contamination. Since that time, work has progressed toward characterization of the groundwater movement and chemistry at the hydrofracture site to determine if the rock strata into which the wastes are injected are hydrologically isolated from overlying and underlying strata and to determine the rate and direction of movement of the groundwater. Four new DM wells have been constructed and the original DM wells have been modified (Fig. 2) to allow hydrologic sampling and testing of the injection interval (Pumpkin Valley Shale), the underlying formation (Rome Formation), and the overlying formation (Rutledge Limestone). Sampling of these seven wells was conducted in January 1986.

1.2 OBJECTIVE

This report presents the initial analytical data for groundwater samples taken from the seven DM wells, as well as data for water samples taken from the original three DM wells. Analytical data are presented for radionuclides, as well as major, minor, and trace non-radioactive constituents in the groundwater. This report also contains some preliminary interpretation of the data and provides details of the sampling procedures and background information on DM well construction. A report with more complete interpretation of the data will be issued in the future.

Analytical data are discussed in two parts. The first discussion deals with samples taken from the original three DM wells; the second part deals with samples from the four new and three reconfigured DM wells.

2. SAMPLING PROCEDURE

2.1 SAMPLE COLLECTION

Samples were obtained with a Mineral Logging Systems downhole fluid sampler. This device is operated with a single-conductor wireline logging draw works. The sampler seals 1400 mL of water at depth in a stainless steel tube and eliminates the possibility of sample mixing or contamination with other waters during sampler retrieval.

Immediately after the sampler reached the ground surface, the sample was removed, and pH, temperature, and conductivity were measured with a Hydro Lab meter (Model 4041). The samples from the initial DM wells, collected in September 1984 and January 1985, were filtered in the field with a 0.45-μm acetate membrane filter. During the field filtering, substantial amounts of iron oxide precipitated from the sample and repeatedly clogged the

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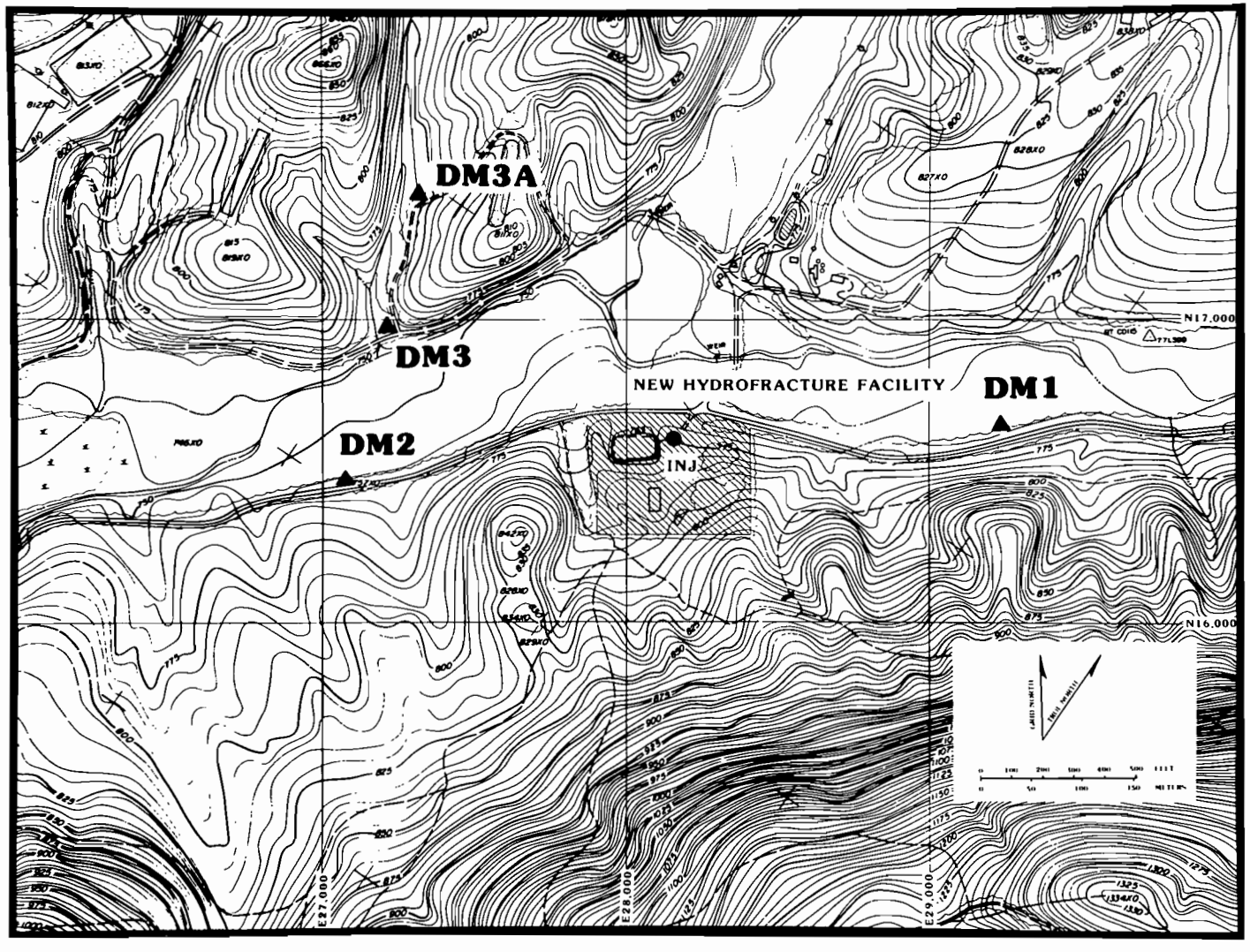

Fig. 1. Location map illustrating the New Hydrofracture vicinity and the initial DM wells.

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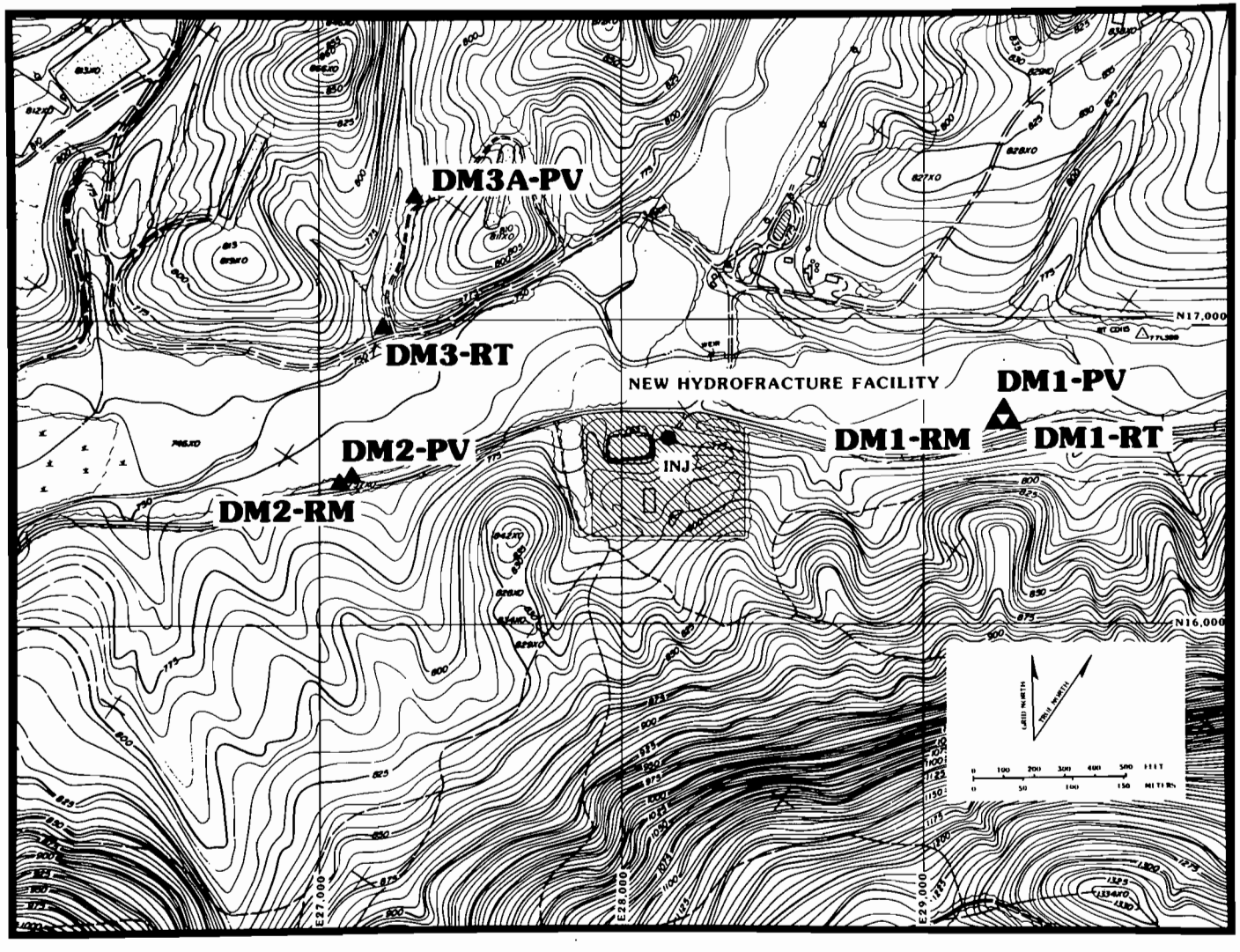

Fig. 2. Location map illustrating the New Hydrofracture Facility and the seven current DM wells. The three initial DM wells were reconfigured and are now called DM1-RM, DM2-RM, and DM3a-PV.

filters, increasing the time necessary to filter the 1400-mL sample to 30 to 45 min and possibly altering the chemistry of the samples by stripping some of the dissolved metals from solution. Because of this possibility, samples collected from the seven reconfigured and new DM wells in January 1986 were not field filtered. Instead, they were immediately divided into aliquots (as described below) after pH, temperature, and conductivity were measured.

In the field, the 1400-mL samples were divided into three aliquots for the various chemical and radiochemical analyses. Two of the aliquots consisted of 250-mL splits for cation and anion analysis. The cation aliquot was acidified to a pH of ≤2.0 with 5 vol % nitric acid immediately after filtration (or immediately after removal from the sampler for the unfiltered samples). The anion aliquot was delivered to the laboratory unacidified and, for the January 1986 samples, unfiltered. The third aliquot, approximately 900 mL, was acidified and delivered to the laboratory for radionuclide analyses. As with the cation aliquot, the radionuclide split was acidified with 5 vol % nitric acid immediately after filtration for those samples that were filtered and immediately after removal from the sampler for the unfiltered samples.

2.2 LABORATORY ANALYSES

All analyses were performed by the Analytical Chemistry Division (ACD) at ORNL. Anions were determined using a Dionex Model 16 Anion Analyzer. Cations were determined by inductively coupled plasma (ICP) spectrophotometry. Because of the high concentrations of sodium in the samples, a pretreatment to strip most of the sodium from the samples was developed by ACD to allow better analysis for low-concentration species. To check total analytical accuracy, a charge balance for cations and anions was calculated (see rows 59 through 85 in Appendices A through C). Radionuclide analyses consisted of gross alpha and beta counts and gamma spectral scans. Specific analyses also were conducted for ^{137}Cs, ^{60}Co, ^{106}Ru, and ^{90}Sr for all samples. Specific analyses for ^{99}Tc and ^{3}H were conducted on the samples collected in September 1984 and January 1986.

3. RESULTS

3.1 INITIAL DM WELLS

3.1.1 Background

Construction procedures for the initial DM wells are summarized in Haase (1987). Salient construction details are presented in Table 1 and illustrated in Fig. 3. These wells were finished with large open-hole intervals, typically spanning several formation contacts, to facilitate anticipated packer tests, hydrologic investigations, and rock mechanics studies within the wells. Therefore, water samples from these wells are not representative of any single rock formation.

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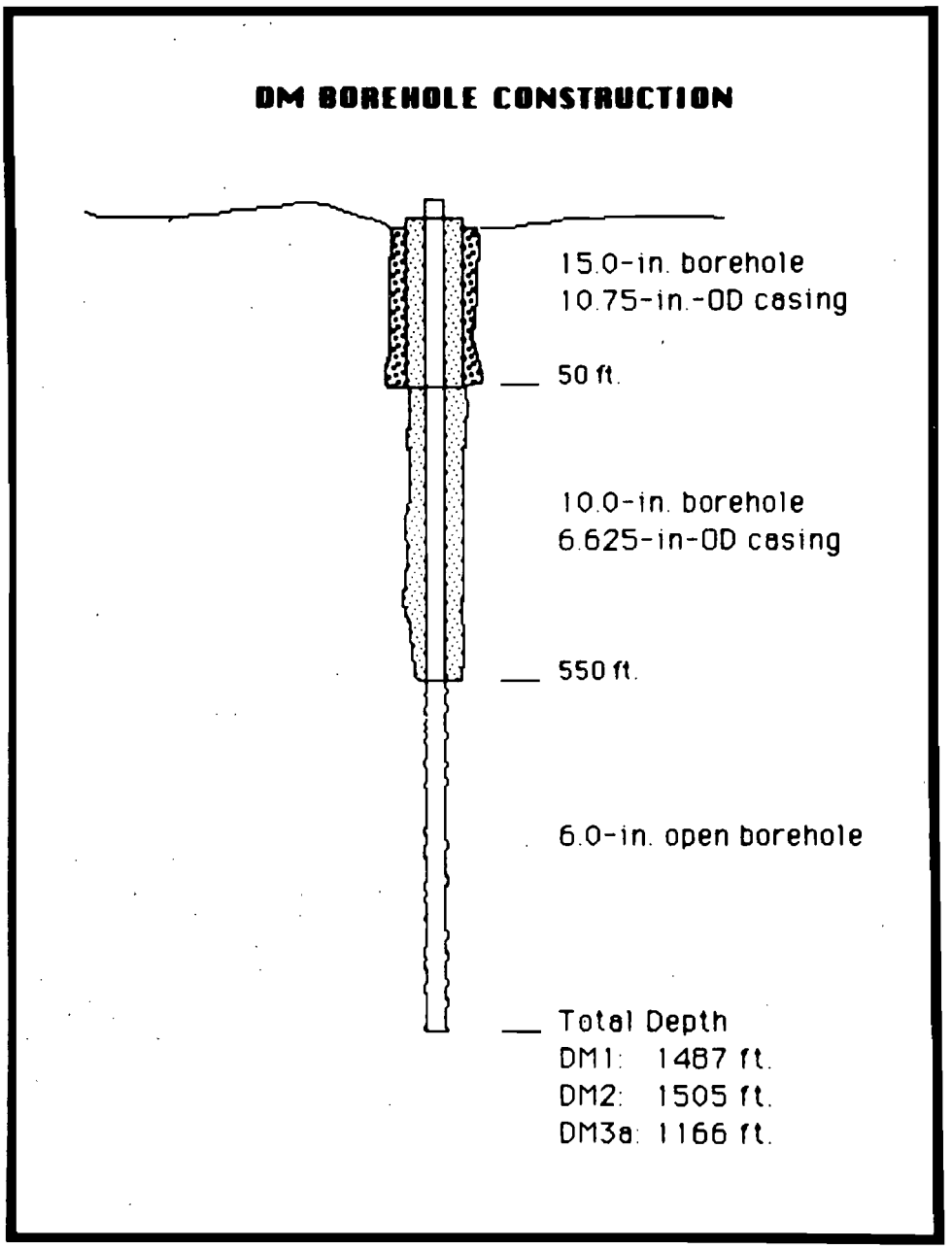

Fig. 3. Construction details of the initial three DM wells.

Grab samples from various depths within each of the DM wells were collected in September 1984 and January 1985. Sample depths were selected based on apparently anomalous regions within the well bore as identified from geophysical logs of the boreholes. Depths where electrical resistivity and resistance anomalies and abrupt deflections in the temperature log occurred were selected for sampling because such anomalies typically indicate regions of fluid movement into and out of the well bore. In the case of the DM wells, regions associated with geophysical log anomalies may be intervals where contaminated water was entering the well bore (Haase 1987).

Table 1. Well construction details for the three initial DM wells.

(All values are in feet and are downhole depths referenced to ground surface)

Well	Depth of 10-3/4-in. casing	Depth of 6-5/8-in. casing	Depth of 6-in. hole	Open interval
DM1	50	550	1,487	550 to 1,487
DM2	50	550	1,505	550 to 1,505
DM3a	50	550	1,166	550 to 1,166

3.1.2 Results

Fourteen grab samples were taken from the three DM wells during each sampling period. Analytical data from the samples are presented in Appendices A and B. For at least two reasons, the water samples taken from these three wells are termed "grab" samples, and they are only grossly representative of groundwater compositions at the site. First, the water within the well bore at the time of sampling represents a mixture of naturally occurring groundwater and fluorescein-tagged fire hydrant water that was added shortly after well construction to facilitate geophysical logging. All samples showed some fluorescein dye, although the deepest samples from wells DM1 and DM2 exhibited the least coloration, suggesting that these samples may represent relatively pure groundwater.

Second, because the three initial DM wells were open to several rock formations, it is difficult to relate the composition of a water sample to the groundwater actually occurring within the rock strata adjacent to that depth. Vertical movement of water within the well and diffusion of material within the standing column of water make accurate geological interpretation of grab samples difficult.

The analytical data (Appendices A and B) indicate that the compositions of waters from wells DM1 and DM2 are similar, and that waters within these wells are significantly different from well DM3a waters. For example, total dissolved solids (TDS) values for wells DM1 and DM2 are generally similar and typically >20,000 µg/mL (Fig. 4 and 5). Samples from well DM3a, however, are generally characterized by TDS values <10,000 µg/mL (Fig. 6).

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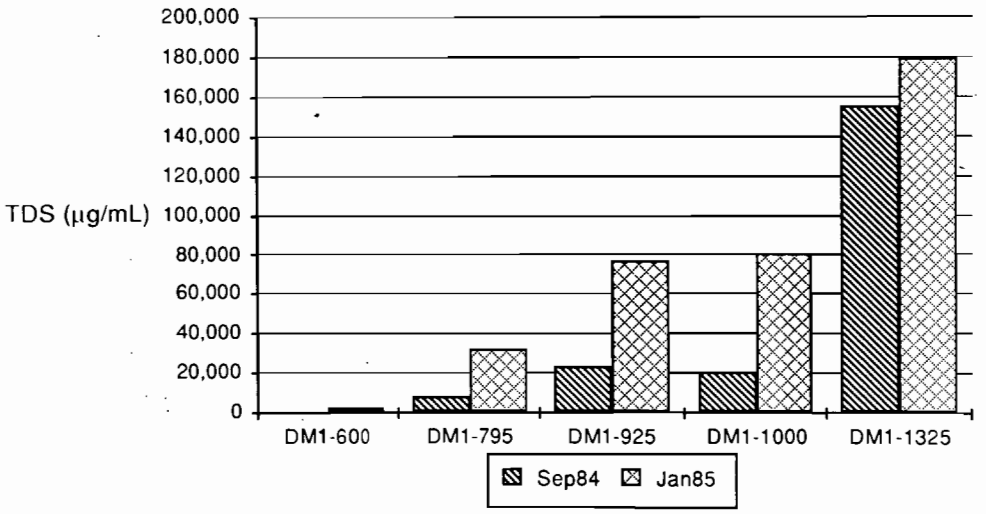

Fig. 4. Histograph illustrating TDS values with depth in well DM1 for the September 1984 and January 1985 samplings.

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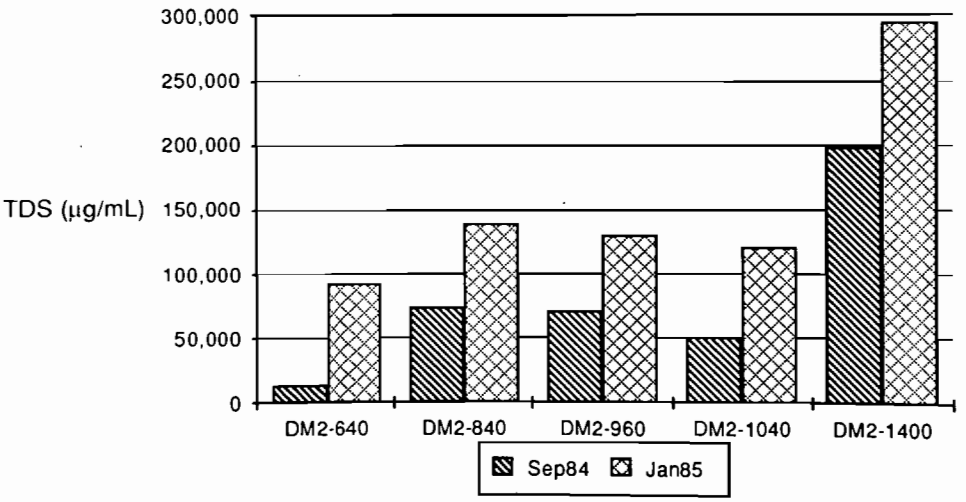

Fig. 5. Histograph illustrating TDS values with depth in well DM2 for the September 1984 and January 1985 samplings.

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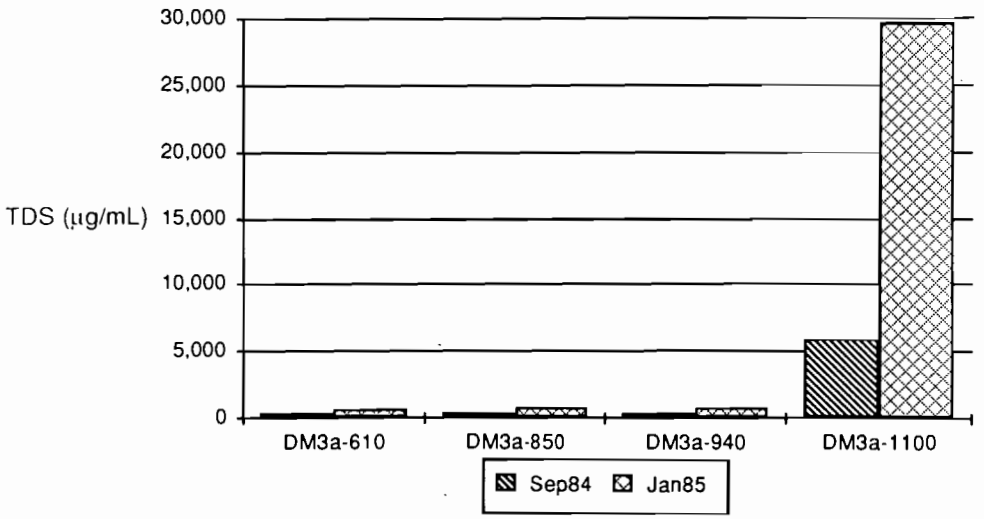

Fig. 6. Histograph illustrating TDS values with depth in well DM3a for the September 1984 and January 1985 samplings.

Waters within wells DM1 and DM2 are stratified and waters below depths of 800 ft have TDS values in excess of 100,000 µg/mL (Figs. 4 and 5). The most abundant cation is Na^+, followed by Ca^{++}, Mg^{++}, and Sr^{++}. The most abundant anion is Cl^-, followed by Br^-. In terms of major and minor components, many of the samples from the deeper levels of wells DM1 and DM2 resemble saline fluids, such as oil field brines, that occur within many sedimentary rock units throughout the world (Hanor, 1979).
Samples from well DM3a contain no measurable nitrate concentrations. Samples from wells DM1 and DM2, however, exhibit nitrate concentrations ranging to 1500 µg/mL. This constituent does not occur naturally in the groundwaters at the site and represents contamination by waste-derived fluids.

Significant concentrations of radionuclides (rows 87 through 99, Appendices A and B) characteristic of wastes injected at both the Old and New Hydrofracture Facilities are essentially absent from samples taken from well DM3a. Samples from DM3a lack measurable ^3H and contain only trace amounts of ^{90}Sr, ^{99}Tc, and ^{137}Cs. Significant concentrations of ^{90}Sr and ^3H occur in most samples from the DM1 and DM2 wells. Concentrations of these radionuclides in the two wells are greatest at the same depths (approximately 1000 ft) where maximum nitrate concentrations are observed (Figs. 7 and 8). All three components are abundant in the wastes injected at the New Hydrofracture Facility.

3.1.3 Discussion of Results from the Initial DM Wells

The deepest samples from the DM1 and DM2 wells are extremely saline brines with TDS values exceeding 200,000 µg/mL. These samples contain the smallest amount of fluorescein dye, suggesting that they may represent relatively pure samples of some of the natural groundwater. Because of the factors discussed previously, however, it is not possible to relate these fluids to particular rocks penetrated by the well bore.

Comparison of data for each well between the two sampling times indicates significant changes in TDS values (Figs. 4 through 6) and in major and minor element concentrations (rows 13 through 51, Appendices A and B). Within all DM wells, TDS values and element concentrations are generally greater in samples obtained in January 1985. Such trends may be related to circulation within the well bore, to groundwater movement in response to hydrologic conditions within strata surrounding the well, or to both factors.

The concentration maxima for ^{90}Sr (Figs. 7 and 8) and nitrate (row 47, Appendices A and B) observed at a depth of approximately 1000 ft in wells DM1 and DM2 is significant; nine of the last thirteen injections at the New Hydrofracture Facility were at this depth. This correspondence suggests that the activity observed within the wells is related to waste injections at the New Hydrofracture Facility. Further support for this conclusion is provided by the trace amounts of ^{106}Ru in wells DM1 and DM2 (row 98, Appendices A and B). The presence of this short half-life (1 year) radionuclide in water samples demonstrates that at least some of the activity within the samples must be derived from the injection of newly generated liquid low-level waste during the period 1982 through 1984.

Levels of radionuclides in well DM3a are barely above detection limits. Radionuclide concentrations in this well are within the same ranges observed for the same radionuclides in the reconfigured DM3a-PV well and in the new DM3-RT and DM1-RT wells (see Sect. 3.2 and rows 87 through 99 in Appendix C). The origin of these small concentrations of

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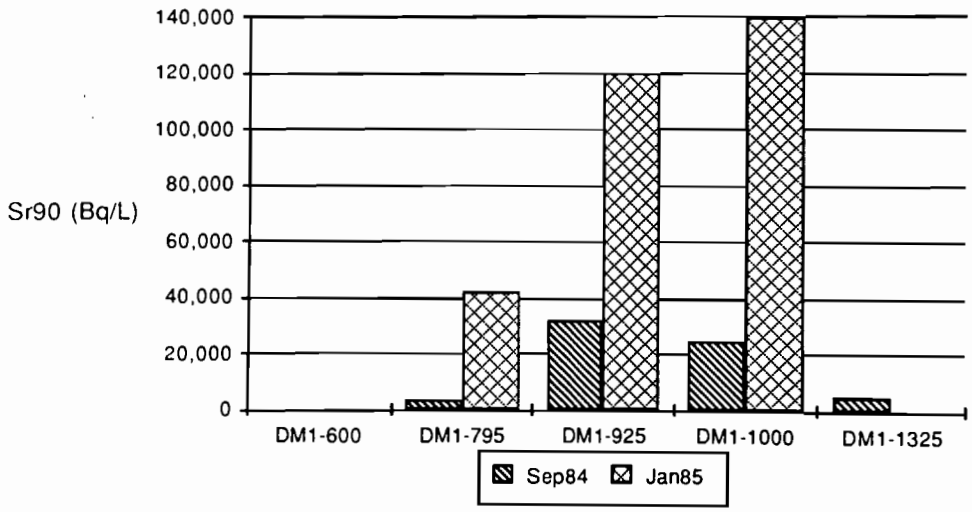

Fig. 7. Histograph illustrating ^{90}Sr concentrations with depth in well DM1 for the September 1984 and January 1985 samplings. Samples at 600 ft contain small concentrations of ^{90}Sr that are not visible at the scale of the diagram.

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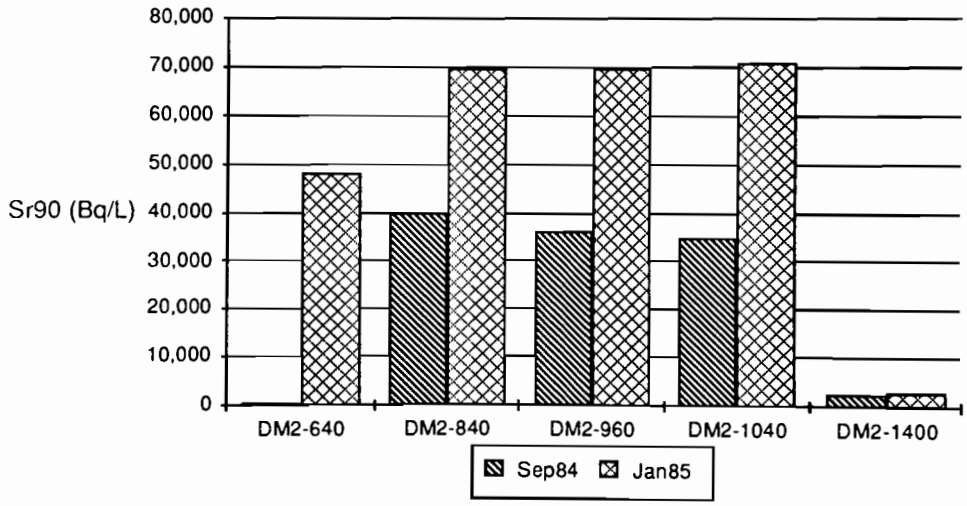

Fig. 8. Histograph illustrating ^{90}Sr concentrations with depth in well DM2 for the September 1984 and January 1985 samplings.

radionuclides in well DM3a is problematic and cannot be resolved with available data. This problem is under study and will be addressed in a subsequent report.

3.2 NEW AND RECONFIGURED DM WELLS

3.2.1 Background

Construction details and procedures for the four new and three reconfigured DM wells, completed in January 1986, are summarized by Geraghty and Miller (1986). Salient construction data are presented in Table 2 and illustrated in Figs. 9 through 12. The objective of the reconfiguration of the old DM wells and the construction of additional DM wells was to allow specific stratigraphic intervals to be investigated and to allow acquisition of groundwater samples representative of specific rock formations. The initial DM wells were reconfigured by installation of cement bottom plugs and 4.5-in.-OD casing (Figs. 9 and 10). New DM wells were installed adjacent to the reconfigured wells to allow for piezometer clusters at each original DM site (Figs. 11 and 12). Of the seven wells, two are open to the Rutledge (RT) Limestone; three are open to the Pumpkin Valley Shale (PV); and two are open to the Rome Formation (RM).

Table 2. Well construction of the seven DM wells

(All values are in feet and are downhole depths referenced to ground surface)

Well	Depth of 10-3/4-in. casing	Depth of 6-5/8-in. casing	Depth of 4-1/2-in. casing	Depth of 6-in. hole	Depth of 4-in. hole	Open interval
DM1-RT	50	550		721		550 to 721
DM1-PV	50	750		1,063		550 to 1,063
DM1-RM	50	550	1,092	1,149		1,092 to 1,149
DM2-PV	50	750		1,063		750 to 1,063
DM2-RM	50	550	1,084	1,275		1,084 to 1,275
DM3-RT	50		552		615	552 to 615
DM3a-PV	50	550		910		550 to 910

The wells were developed by bailing or air lifting immediately after construction. The samples discussed were taken within three weeks after development of the wells. In most cases, it is unlikely that the wells had fully recovered to static water levels at the time of sampling.

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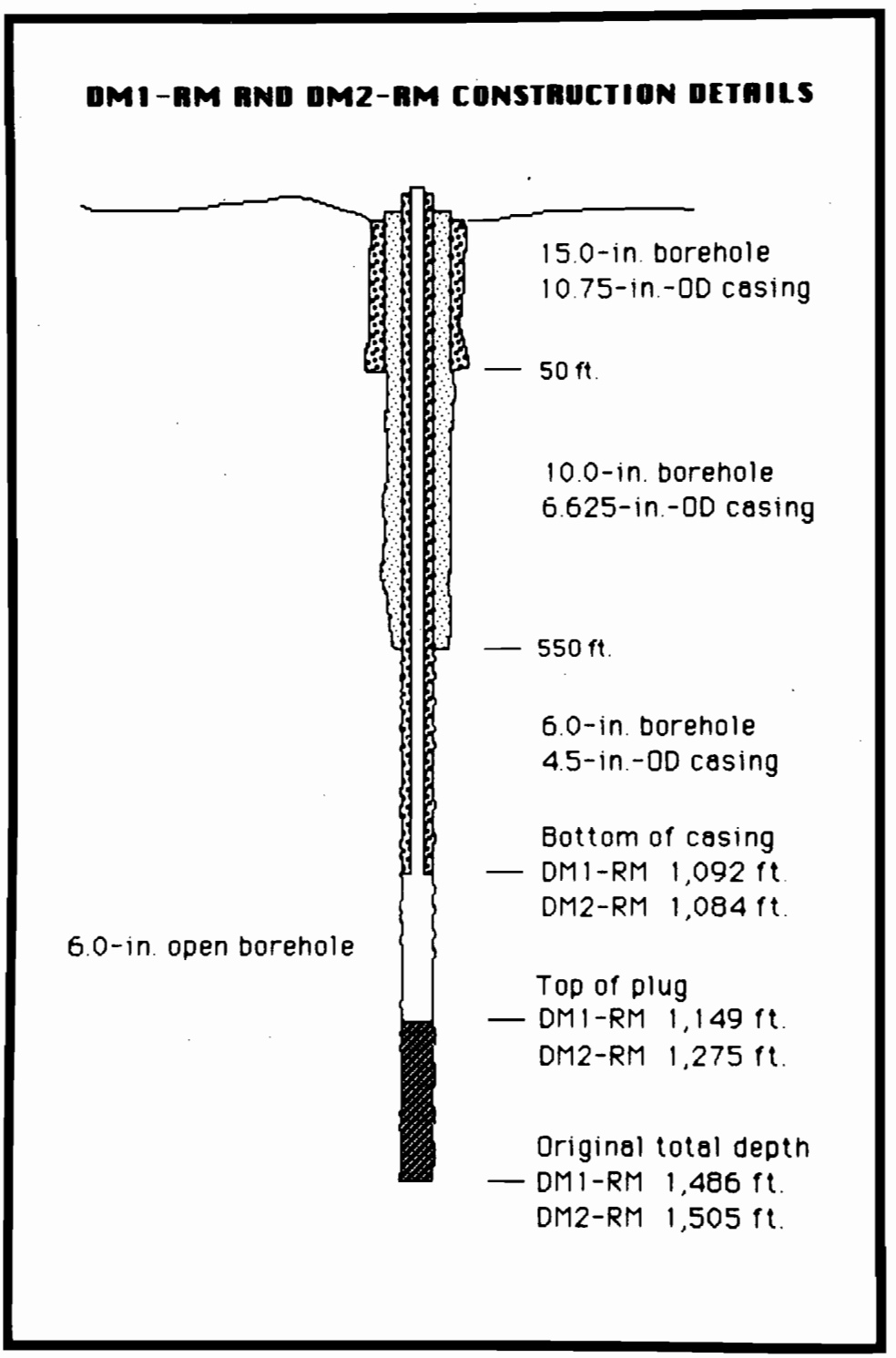

Fig. 9. Construction details for wells DM1-RM and DM2-RM.

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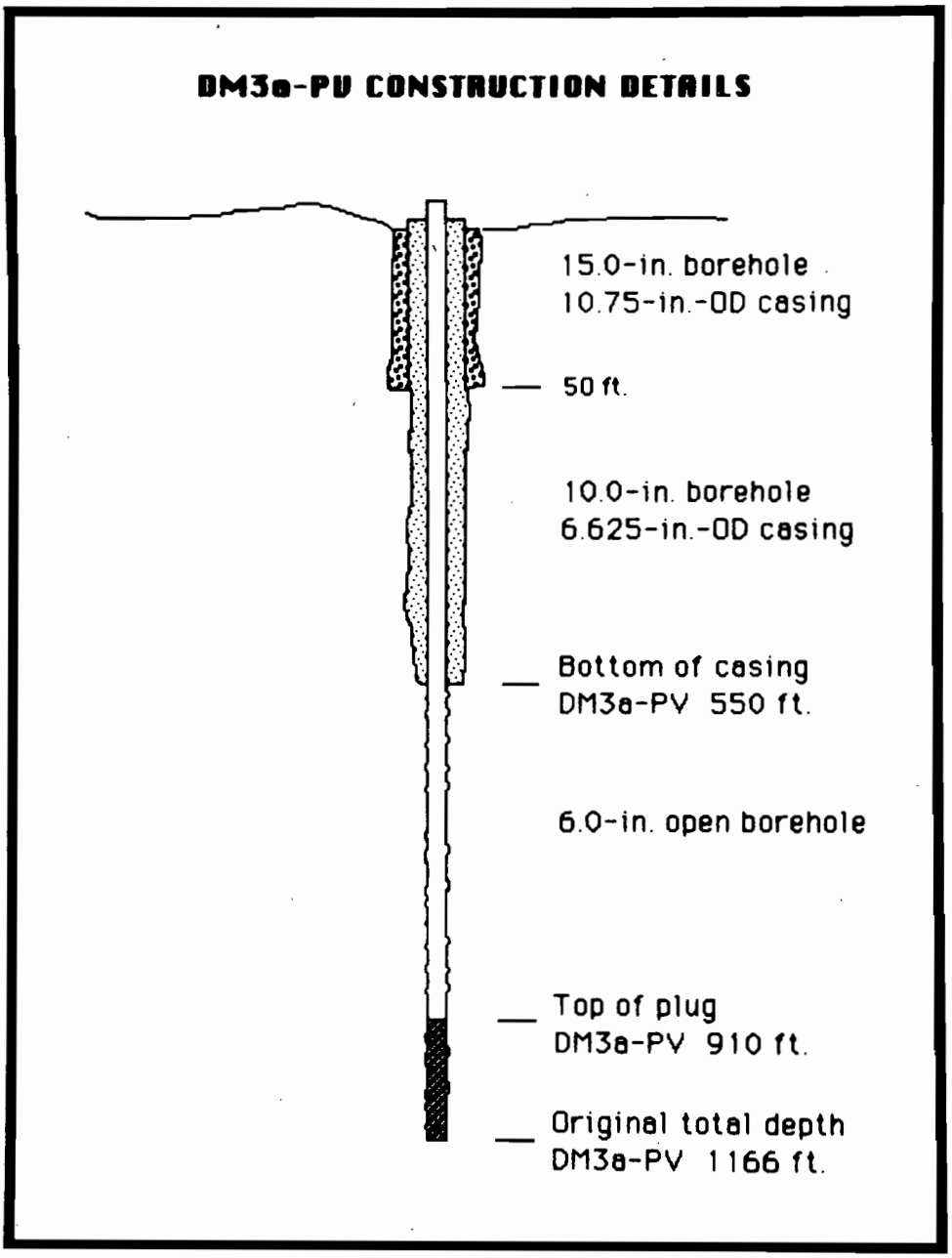

Fig. 10. Construction details for well DM3a-PV.

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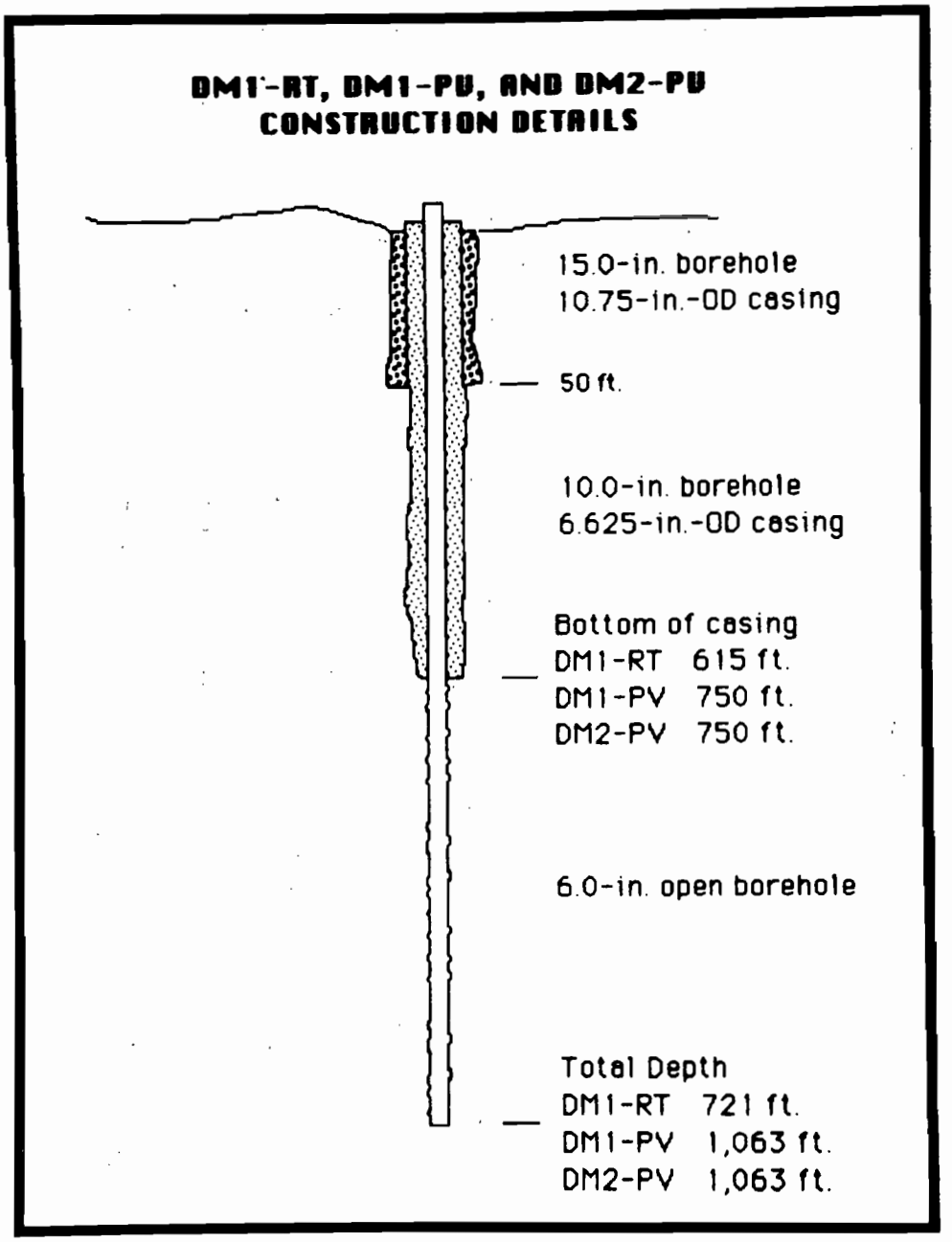

Fig. 11. Construction details for wells DM1-RT, DM1-PV, and DM2-PV.

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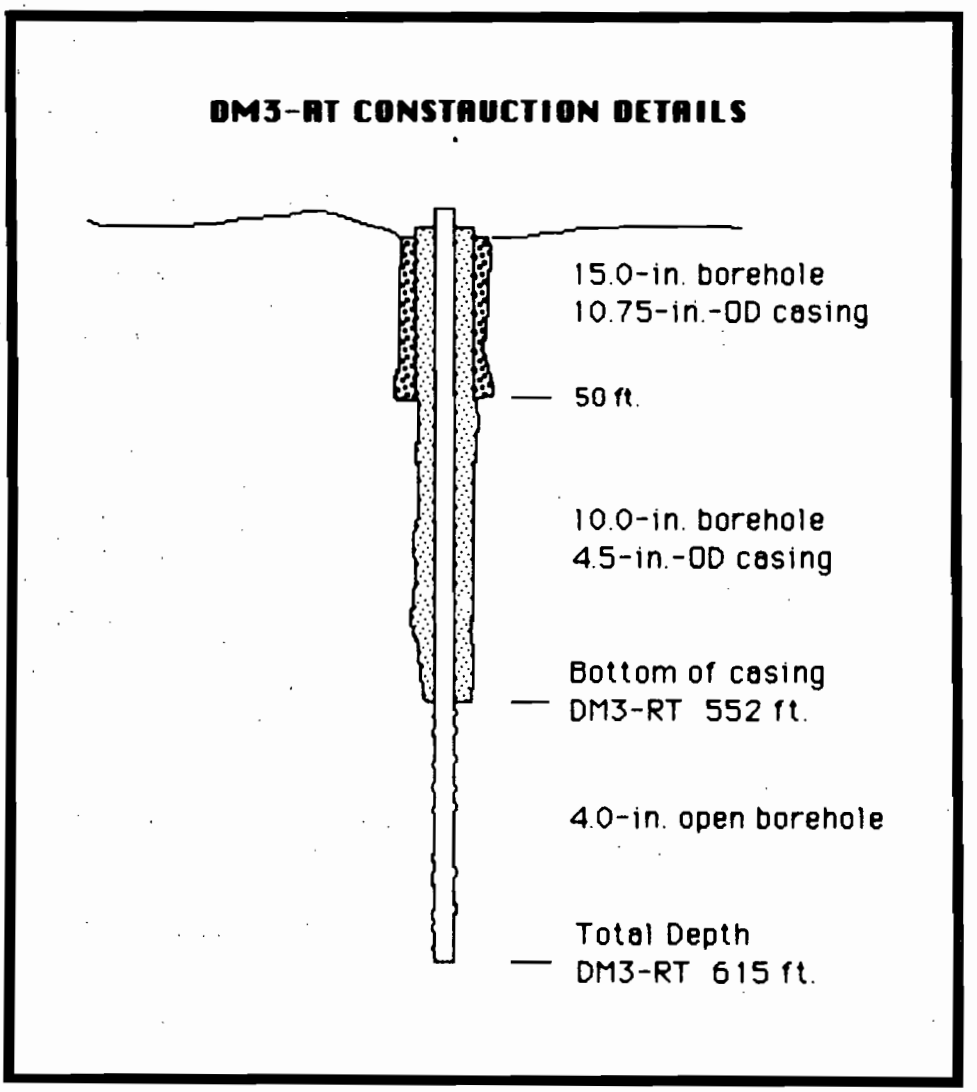

Fig. 12. Construction details for well DM3-RT.

3.2.2 Results

Analytical results are presented in Appendix C. The data indicate that waters within the DM wells are generally similar to those from the deeper portions of the initial wells DM1 and DM2 (Appendices A and B). Data for the Pumpkin Valley Shale groundwaters in wells DM1-PV andDM2-PV have generally similar composition TDS values >200,000 μg/mL (Fig. 13). As before, groundwater from well DM3a-PV differs from the groundwater from other wells. Water from the Pumpkin Valley Shale at this locality has a significantly lower TDS value than samples from other wells open either to the Pumpkin Valley Shale or the overlying and underlying formations (Fig. 13). Waters from the wells open to the Rutledge Limestone (DM3-RT and DM1-RT) are quite similar in terms of major and minor components. Values for TDS are approximately 150,000 μg/mL. The two water samples from the Rome Formation, (DM1-RM and DM2-RM) differ substantially in major and minor element compositions. The TDS values for these samples range from approximately 140,000 to >200,000 μg/mL.

Variation diagrams illustrating the details of major element chemical trends for the January 1986 sampling are presented in Figs. 14 through 17. Chemical data from these samples should be representative of the groundwaters in the strata open to the wells. The data fall on a generally linear trend and exhibit ranges of cation and anion values generally similar to those observed for the Rock Cover (RC) wells at the New Hydrofracture Facility (Switek et al. 1987). Specific differences in major component trends on chloride variation diagrams do exist between some RC samples and the trends defined by the DM samples. Such differences, however, are relatively small and because the RC wells are finished predominantly in the Rogersville Shale may simply reflect natural groundwater chemistry differences between the various formations of the Conasauga Group (Switek et al. 1987).

Samples of groundwater from the Pumpkin Valley Shale (DM1-PV and DM2-PV) contain ^{90}Sr concentrations of 35,000 and 94,000 Bq/L, respectively (Fig. 18). Such values are generally similar to or slightly lower than those measured in samples obtained from the initial DM wells (Appendices A and B). Groundwater from the Pumpkin Valley Shale (DM3a-PV) also contains a trace amount of ^{90}Sr (100 Bq/L). Such a value is similar to, but slightly elevated from, that obtained during sampling of the initial DM3a well. Samples from the wells in the Rome Formation (DM1-RM and DM2-RM) also contain significant concentrations of ^{90}Sr (15,000 to 20,000 Bq/L, respectively). Low concentrations of ^{90}Sr occur in groundwaters from the Rutledge Limestone sampled in wells DM1-RT and DM3-RT (250 and 46 Bq/L, respectively) and the DM1-RT sample also contains 18 μg/mL nitrate. Samples from the four wells containing significant concentrations of ^{90}Sr also contain elevated concentrations of nitrate. Such an association is identical to that observed in samples obtained from the initial DM wells.

3.3.3 Discussion of Results from the New and Reconfigured DM Wells

Data for the samples from the seven new and reconfigured DM wells must be interpreted with caution. Further development of the wells is necessary to ensure that the groundwater samples are representative of the formation waters within the open intervals of each of the wells. Because of the generally low permeability of the formations investigated, well development is difficult and must be conducted over several months. These initial samples from the seven wells provide a preliminary examination of the formation waters within the open intervals. They should not be interpreted as representative of these groundwaters until they can be compared to subsequent samples taken after additional well development.

ORNL-DWG 87-6666

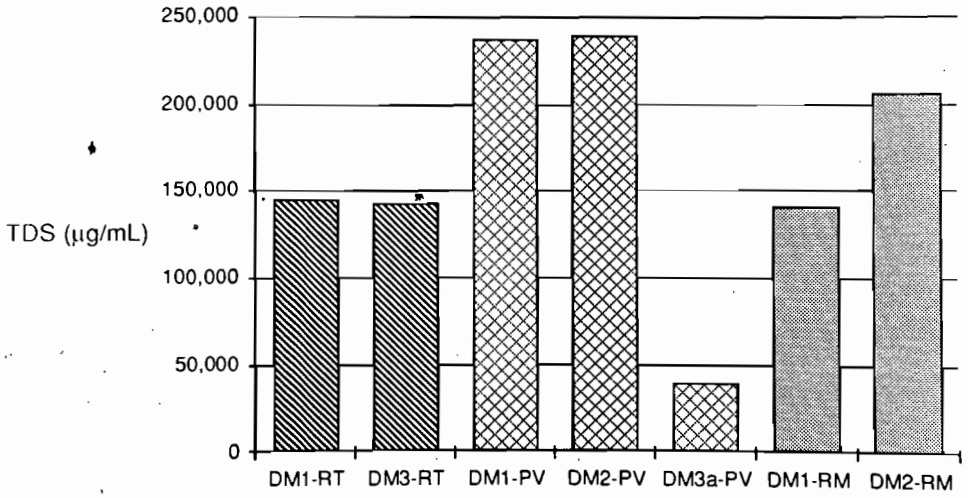

Fig. 13. Histograph illustrating TDS values for January 1986 sampling of the seven DM wells.

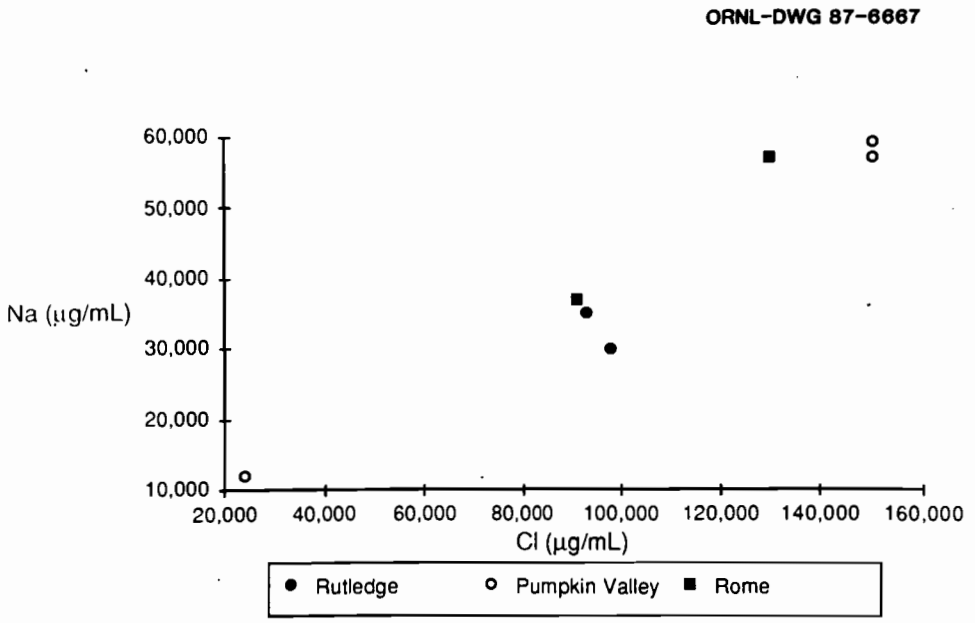

Fig. 14. Sodium vs chloride variation diagram for data from the January 1986 sampling of the seven DM wells.

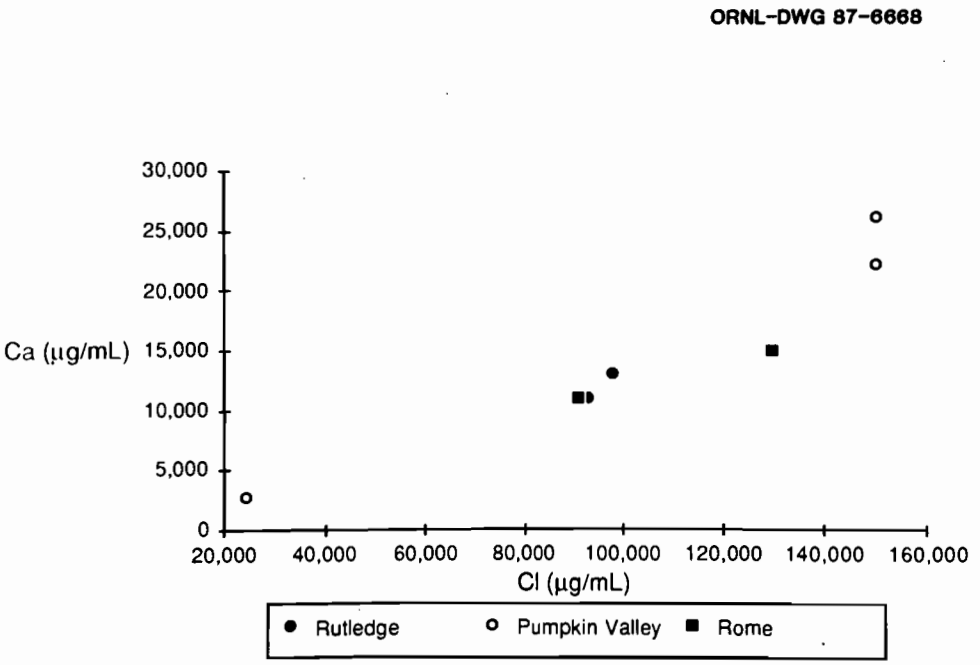

Fig. 15. Calcium vs chloride variation diagram for data from the January 1986 sampling of the seven DM wells.

ORNL-DWG 87-6669

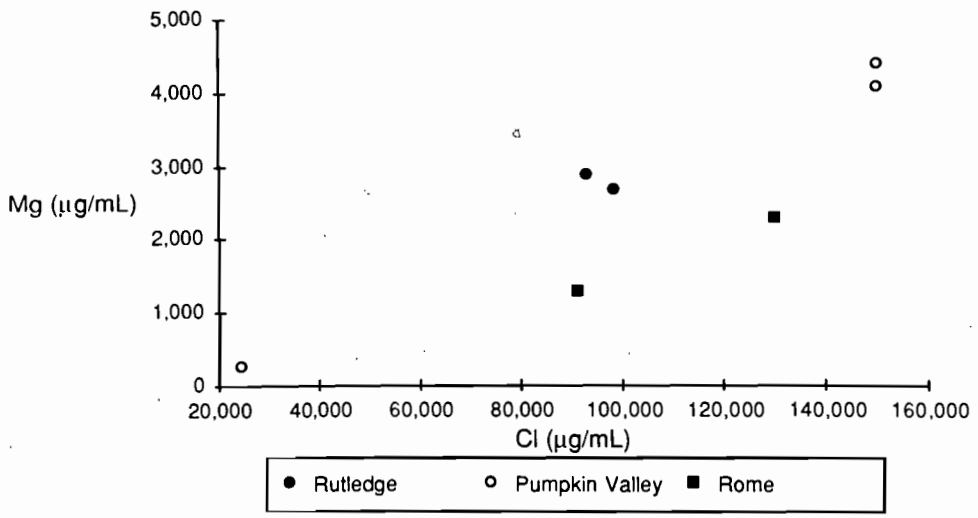

Fig. 16. Magnesium vs chloride variation diagram for data from the January 1986 sampling of the seven DM wells.

ORNL-DWG 87-6670

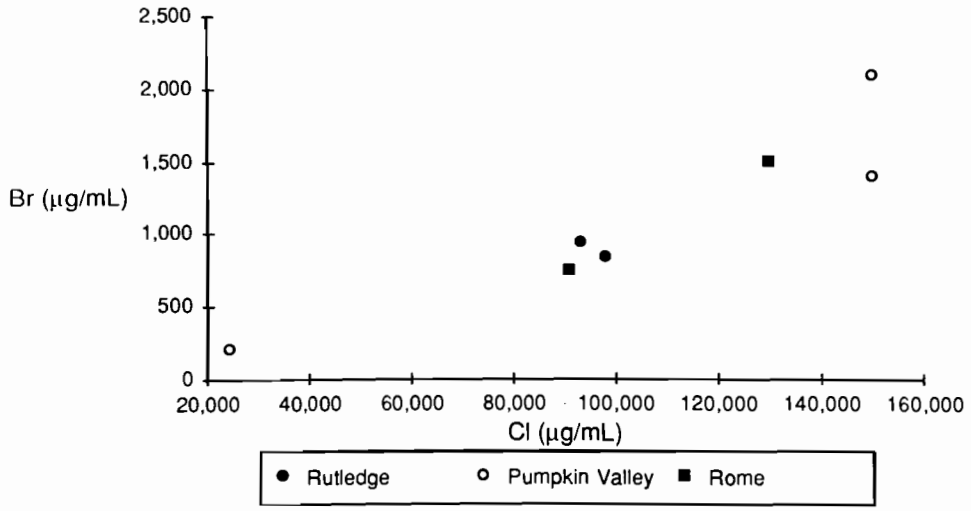

Fig. 17. Bromide vs chloride variation diagram for data from the January 1986 sampling of the seven DM wells.

ORNL-DWG 87-6671

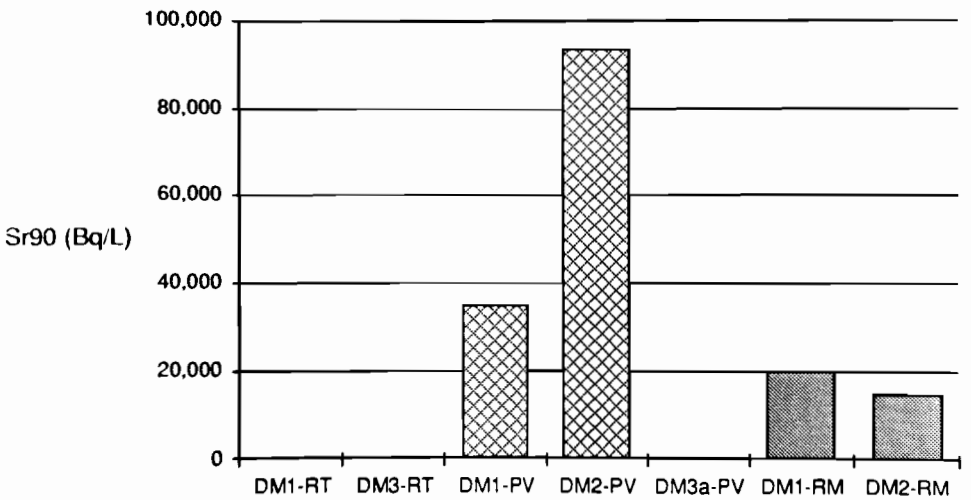

Fig. 18. Histograph illustrating ^{90}Sr concentrations for data from the January 1986 sampling of the seven DM wells. Samples from the Rutledge Limestone contain small concentrations of ^{90}Sr that are not visable at the scale of the diagram.

With the above cautions in mind, perhaps the most significant data are the concentrations of ^{90}Sr in the DM1-RM and DM2-RM samples. Taken at face value, these data suggest contamination of the groundwaters of the Rome Formation, immediately underlying the Pumpkin Valley Shale. These two wells were the original DM1 and DM2 wells and the interval from which these two samples were taken was open to a standing column of contaminated water for approximately 15 months before the wells were reconfigured. This situation may have caused infiltration ofcontaminated water into the Rome Formation. Thus, some, or perhaps all, of the ^{90}Sr in the samples obtained from wells DM1-RM and DM2-RM may not be representative of actual formation groundwater. Subsequent sampling of the wells after additional development will permit this issue to be resolved and conclusions regarding hydrologic isolation to be drawn.

The significance of the low concentrations of ^{90}Sr found in groundwater from the Rutledge Limestone is not yet clear. The data may indicate small upward movement of ^{90}Sr-bearing groundwater from the Pumpkin Valley Shale. This possibility is supported by the small amounts (18 μg/mL) of nitrate in the sample from well DM1-RT. Alternatively, there is also a possibility that the sample from DM1-RT was cross-contaminated during sampling. Precautionary measures were taken to avoid this, but it remains as a possible explanation of the data. This issue can only be resolved by sampling the Rutledge wells after further well development has been completed.

4. RECOMMENDATIONS

Evaluation of the data obtained from the DM wells, as well as the rock cover wells at the New Hydrofracture Facility (Switek et al. 1987), indicates the importance of well development to obtaining representative samples of groundwaters. In the case of the DM wells, results from each subsequent sampling should be compared. If significant differences are noted, the wells must be developed again and the sampling repeated. This cycle of well development and sampling must continue until the analytical results stabilize. Only when this condition is reached will there be a reasonable assurance that the samples obtained from the well are representative of indigenous groundwaters.

Sampling equipment used in the wells is acid-cleaned and triple-rinsed in distilled water between sampling in each well. It is recommended that in addition to this procedure the sampling device be steam-cleaned between wells and that an aliquot of the last distilled water rinse material be archived for chemical and radionuclide analysis if necessary.

5. SUMMARY

Groundwaters in the Rutledge Limestone, Pumpkin Valley Shale, and Rome Formation in the vicinity of the New Hydrofracture Facility are highly saline, typically with TDS values >150,000 μg/mL. The major cations are Na^+, Ca^{++}, and Mg^{++} and the major anion is Cl^-. In the groundwater, the principal radioactive contaminant is ^{90}Sr and the principal nonradioactive contaminant is nitrate.

There is a significant hydrogeologic dissimilarity between the DM3 and DM3a sites and the DM1 and DM 2 sites. Wells finished in the Pumpkin Valley Shale and the Rome

Formation at sites DM1 and DM2 contain significant amounts of ^{90}Sr and nitrate. A well finished in the Pumpkin Valley Shale at the DM3a site, however, does not contain either contaminant and appear to be largely isolated from injection-related fluids.

Preliminary examination of the data suggest that the Pumpkin Valley Shale may not be completely hydrologically isolated because there are significant concentrations of ^{90}Sr found in the underlying Rome Formation and trace concentrations are found in the overlying Rutledge Limestone. However, there are multiple explanations for these data, some of which may be consistent with the hydrologic isolation the Pumpkin Valley Shale.

6. REFERENCES

Geraghty and Miller, Inc. 1986. Deep monitor well installation at the Hydrofracture Facility, Oak Ridge National Laboratory. Consultant's Report.

Haase, C. S. 1987. Geophysical data from boreholes DM1, DM2, DM3, and DM3a, New Hydraulic Fracturing Facility, Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL/TM-9681.

Hanor, J. S. 1979. Sedimentary genesis of hydrothermal fluids. IN H. L. Barnes, (ed.), Geochemistry of Hydrothermal Ore Deposits, John Wiley, New York, NY.

International Atomic Energy Association (IAEA) 1983. Disposal of Radioactive Grouts into Hydraulically Fractured Shale. IAEA Technical Reports Series No. 232.

Stow, S. H. and C. S. Haase 1986. Subsurface disposal of liquid low-level radioactive wastes at Oak Ridge Tennessee. IN Proceedings of the International Symposium on the Underground Injection of Hazardous Waste, March 3-5, 1986, New Orleans, LA, National Water Well Association, Dublin, OH.

Switek, J., C. S. Haase, and S. H. Stow 1987. Geochemistry of formation waters in the Lower Conasauga Group at the New Hydrofracture Facility: Preliminary data from the Rock Cover (RC) Wells. ORNL/RAP-5.

Weeren, H. O., E. W. McDaniel, and L. C. Lasher 1985. Status of hydrofracture operations at Oak Ridge National Laboratory. IN R. G. Post and M. E. Wacks, (eds.), Proceedings of Waste Management '85, March 25-28, 1985, Tucson, AZ, University of Arizona Press, Tucson, AZ.

Appendix A

Analytical data from the three initial DM wells for the September 1984 sampling. Blank entries or the entry *nm* in the table indicate that no measurement was attempted. Asterisks indicate pH values obtained by laboratory measurement several days after sampling. The entry *nd* indicates a compentent was looked for but not detected. Analytical uncertainties are within ±10% of the value cited unless otherwise indicated.

	1	2	3	4	5
1	Sample ID	DM1-600	DM1-795	DM1-925	DM1-1000
2	Date Collected	06Sep84	07Sep84	07Sep84	07Sep84
3	Collected By	CSH/OMS	CSH/OMS	CSH/OMS	CSH/OMS
4	Sample Depth	600.0	795.0	925.0	1000.0
5	pH	7.90	6.00	5.80	6.00
6	Temp, °C	20.00	17.40	19.00	20.40
7	Cond, µS/cm	693	14,640	40,400	34,600
8					
9	CHEMICAL DATA				
10	ACD Sample ID	9718	9719	9720	9721
11					
12	Cations, µg/mL				
13	Li				
14	Na	394.00	2,190.00	6,240.00	5,450.00
15	K	3.00	21.40	39.80	36.40
16	Be				
17	Mg	1.26	142.00	443.00	381.00
18	Ca	4.65	628.00	628.00	1,940.00
19	Sr				
20	Ba				
21	Ti				
22	V				
23	Cr				
24	Mn				
25	Fe				
26	Co				
27	Ni				
28	Cu				
29	Zn				
30	Mo				
31	Ag				
32	Cd				
33	B				
34	Al				
35	Si				
36	Pb				
37	P				
38	As				
39	Sb				
40	Se				
41					
42	Anions, µg/mL				
43	F				
44	Cl	520.00	4,900.00	16,000.00	13,000.00
45	Br	0.00	43.00	130.00	110.00
46	I				
47	NO3	19.00	59.00	240.00	240.00
48	SO4	29.00	<40.0	<40.0	<40.0
49	S2-				
50	PO4	<4.0	<40.0	<40.0	<40.0
51	Alkalinity as HCO3	105.00	90.00	72.00	79.00
52	TOC, µg/mL				
53	TKN, mg/mL				

	1	2	3	4	5
54					
55	SAMPLE ID	DM1-600	DM1-795	DM1-925	DM1-1000
56					
57	TDS	923	7,881	23,351	20,807
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.00	0.00	0.00	0.00
62	Na	17.14	95.27	271.44	237.08
63	K	0.08	0.55	1.02	0.93
64	Mg	0.10	11.68	36.44	31.34
65	Ca	0.23	31.34	31.34	96.81
66	Sr	0.00	0.00	0.00	0.00
67	Ba	0.00	0.00	0.00	0.00
68	Mn (2+)	0.00	0.00	0.00	0.00
69	Fe (2+)	0.00	0.00	0.00	0.00
70	Total Cations	17.55	138.83	340.24	366.15
71					
72	Anions, meq/L				
73	F	0.00	0.00	0.00	0.00
74	Cl	14.67	138.23	451.36	366.73
75	Br	0.00	0.54	1.63	1.38
76	I	0.00	0.00	0.00	0.00
77	Alkalinity as HCO3	1.72	1.48	1.18	1.29
78	NO3	0.31	0.95	3.87	3.87
79	SO4	0.60	0.00	0.00	0.00
80	PO4	0.00	0.00	0.00	0.00
81	Total Anions	17.30	141.19	458.04	373.27
82					
83	Net Difference	0.25	-2.36	-117.80	-7.12
84					
85	Percent Difference	-0.72	0.84	14.76	0.96
86					
87	RADIONUCLIDES				
88	ACD Sample ID	21445	21446	21447	21448
89					
90	Gross Alpha, Bq/L	1.3±1.3	4±13	15±25	<20
91	Gross Beta, Bq/L	2.7±2.2	7,300±200	63,000±1,000	53,000±1,000
92					
93	H3, Bq/L	<30.0	170±40	650±50	540±50
94	Co60, Bq/L	<1.0	3.1±1.2	20±3	17±1
95	Sr90, Bq/L	2.3±0.7	3,700±200	32,000±1,000	25,000±1,000
96	Tc99, Bq/L	<0.1	<0.1	0.17±0.16	<0.1
97	Ru106, Bq/L	nd	nd	40±10	27±4
98	Cs137, Bq/L	<0.9	<0.8	<1.0	<0.4
99	Th232, Bq/L				

	6	7	8	9	10
1	Sample ID	DM1-1325	DM2-640	DM2-840	DM2-960
2	Date Collected	07Sep84	10Sep84	10Sep84	10Sep84
3	Collected By	CSH/OMS	CSH/OMS	CSH/OMS	CSH/OMS
4	Sample Depth	1325.0	640.0	840.0	960.0
5	pH	5.10	6.10	5.60	5.70
6	Temp, °C	20.60	18.40	19.40	19.40
7	Cond, µS/cm	175,400	22,900	5,400	83,200
8					
9	CHEMICAL DATA				
10	ACD Sample ID	9722	9723	9724	9725
11					
12	Cations, µg/mL				
13	Li				
14	Na	41,800.00	3,760.00	17,500.00	14,300.00
15	K	324.00	32.30	70.50	79.50
16	Be				
17	Mg	2,760.00	278.00	1,400.00	1,120.00
18	Ca	11,100.00	1,120.00	7,390.00	5,920.00
19	Sr		125.00	821.00	568.00
20	Ba			154.00	122.00
21	Ti				
22	V				
23	Cr				
24	Mn				
25	Fe				
26	Co				
27	Ni				
28	Cu				
29	Zn				
30	Mo				
31	Ag				
32	Cd				
33	B				
34	Al				
35	Si				
36	Pb				
37	P				
38	As				
39	Sb				
40	Se				
41					
42	Anions, µg/mL				
43	F				
44	Cl	100,000.00	8,100.00	47,000.00	50,000.00
45	Br	630.00	66.00	410.00	360.00
46	I				
47	NO3	<40.0	<40.0	650.00	750.00
48	SO4	<40.0	<40.0	<40.0	<40.0
49	S2-				
50	PO4	<40.0	<40.0	<40.0	<40.0
51	Alkalinity as HCO3	0.00	72.00	15.00	27.00
52	TOC, µg/mL				
53	TKN, mg/mL				

	6	7	8	9	10
54					
55	SAMPLE ID	DM1-1325	DM2-640	DM2-840	DM2-960
56					
57	TDS	155,984	13,415	74,182	71,988
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.00	0.00	0.00	0.00
62	Na	1,818.30	163.56	761.25	622.05
63	K	8.28	0.83	1.80	2.03
64	Mg	227.04	22.87	115.16	92.13
65	Ca	553.89	55.89	368.76	295.41
66	Sr	0.00	2.85	18.74	12.97
67	Ba	0.00	0.00	2.24	1.78
68	Mn (2+)	0.00	0.00	0.00	0.00
69	Fe (2+)	0.00	0.00	0.00	0.00
70	Total Cations	2,607.51	246.00	1,267.96	1,026.37
71					
72	Anions, meq/L				
73	F	0.00	0.00	0.00	0.00
74	Cl	2,821.00	228.50	1,325.87	1,410.50
75	Br	7.88	0.83	5.13	4.50
76	I	0.00	0.00	0.00	0.00
77	Alkalinity as HCO3	0.00	1.18	0.25	0.44
78	NO3	0.00	0.00	10.48	12.10
79	SO4	0.00	0.00	0.00	0.00
80	PO4	0.00	0.00	0.00	0.00
81	Total Anions	2,828.88	230.51	1,341.73	1,427.54
82					
83	Net Difference	-221.37	15.49	-73.77	-401.18
84					
85	Percent Difference	4.07	-3.25	2.83	16.35
86					
87	RADIONUCLIDES				
88	ACD Sample ID	21449	21450	21451	21452
89					
90	Gross Alpha, Bq/L	6±36	1±15	11±36	17±34
91	Gross Beta, Bq/L	7,900±200	930±80	66,000±1,000	68,000±1,000
92					
93	H3, Bq/L	270±40	<30.0	1300±100	1500±100
94	Co60, Bq/L	3.2±0.5	1.4±0.3	120±10	140±10
95	Sr90, Bq/L	5,100±200	500±30	40,000±1,000	36,000±1,000
96	Tc99, Bq/L	<0.1	<0.1	0.16±0.12	<0.1
97	Ru106, Bq/L	3.9±2.3	nd	nd	nd
98	Cs137, Bq/L	<0.2	<0.2	<3.0	<0.1
99	Th232, Bq/L				

	11	12	13	14	15
1	Sample ID	DM2-1040	DM2-1400	DM3a-610	DM3a-850
2	Date Collected	11Sep84	11Sep84	05Sep84	05Sep84
3	Collected By	CSH/OMS	CSH/OMS	CSH/OMS	CSH/OMS
4	Sample Depth	1040.0	1400.0	610.0	850.0
5	pH	5.80	5.20	8.90	8.10
6	Temp, °C	17.70	20.20	16.90	18.60
7	Cond, µS/cm	77,500	189,700	866	979
8					
9	CHEMICAL DATA				
10	ACD Sample ID	9726	9727	9728	9729
11					
12	Cations, µg/mL				
13	Li				
14	Na	12,900.00	50,700.00	179.00	211.00
15	K	78.50	352.00	1.08	1.41
16	Be				
17	Mg	982.00	2,850.00	0.24	0.24
18	Ca	5,140.00	12,900.00	0.85	1.09
19	Sr	568.00	12,400.00	0.02	0.03
20	Ba	98.80	23.50	<0.2	<0.02
21	Ti				
22	V				
23	Cr				
24	Mn				
25	Fe				
26	Co				
27	Ni				
28	Cu				
29	Zn				
30	Mo				
31	Ag				
32	Cd				
33	B				
34	Al				
35	Si				
36	Pb				
37	P				
38	As				
39	Sb				
40	Se				
41					
42	Anions, µg/mL				
43	F				
44	Cl	32,000.00	120,000.00	160.00	200.00
45	Br	290.00	980.00	<4.0	<4.0
46	I				
47	NO3	660.00	<40.0	<4.0	<4.0
48	SO4	<40.0	<40.0	34.00	34.00
49	S2-				
50	PO4	<40.0	<40.0	<4.0	<4.0
51	Alkalinity as HCO3	27.00	0.00	113.00	123.00
52	TOC, µg/mL				
53	TKN, mg/mL				

	11	12	13	14	15
54					
55	SAMPLE ID	DM2-1040	DM2-1400	DM3a-610	DM3a-850
56					
57	TDS	51,669	199,202	341	414
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.00	0.00	0.00	0.00
62	Na	561.15	2,205.45	7.79	9.18
63	K	2.01	9.00	0.03	0.04
64	Mg	80.78	234.44	0.02	0.02
65	Ca	256.49	643.71	0.04	0.05
66	Sr	12.97	283.09	0.00	0.00
67	Ba	1.44	0.34	0.00	0.00
68	Mn (2+)	0.00	0.00	0.00	0.00
69	Fe (2+)	0.00	0.00	0.00	0.00
70	Total Cations	914.83	3,376.04	7.88	9.29
71					
72	Anions, meq/L				
73	F	0.00	0.00	0.00	0.00
74	Cl	902.72	3,385.20	4.51	5.64
75	Br	3.63	12.26	0.00	0.00
76	I	0.00	0.00	0.00	0.00
77	Alkalinity as HCO3	0.44	0.00	1.85	2.02
78	NO3	10.65	0.00	0.00	0.00
79	SO4	0.00	0.00	0.71	0.71
80	PO4	0.00	0.00	0.00	0.00
81	Total Anions	917.44	3,397.46	7.07	8.37
82					
83	Net Difference	-2.61	-21.42	0.80	0.92
84					
85	Percent Difference	0.14	0.32	-5.37	-5.23
86					
87	RADIONUCLIDES				
88	ACD Sample ID	21453	21454	21455	21456
89					
90	Gross Alpha, Bq/L	3±21	36±66	0.9±1.8	0.3±1.2
91	Gross Beta, Bq/L	58,000±1,000	4,700±200	<0.2	0.9±1.9
92					
93	H3, Bq/L	1,300±100	96±38	<30	<30
94	Co60, Bq/L	120±10	7.9±1.5	<0.6	<0.6
95	Sr90, Bq/L	35,000±1,000	2,500±100	0.16±0.11	0.15±0.10
96	Tc99, Bq/L	0.07±0.12	0.16±0.12	0.18±0.29	0.58±0.34
97	Ru106, Bq/L	nd	nd	nd	nd
98	Cs137, Bq/L	<2.0	≤0.5	<0.5	<0.5
99	Th232, Bq/L				

	16	17	18
1	Sample ID	DM3a-940	DM3a-1100
2	Date Collected	06Sep84	06Sep84
3	Collected By	CSH/OMS	CSH/OMS
4	Sample Depth	940.0	1100.0
5	pH	8.30	6.80
6	Temp, °C	16.50	18.30
7	Cond, µS/cm	982	3,810
8			
9	CHEMICAL DATA		
10	ACD Sample ID	9730	9731
11			
12	Cations, µg/mL		
13	Li		
14	Na	198.00	2,100.00
15	K	1.67	27.10
16	Be		
17	Mg	0.40	73.90
18	Ca	2.20	
19	Sr	0.04	18.10
20	Ba	<0.2	0.26
21	Ti		
22	V		
23	Cr		
24	Mn		
25	Fe		
26	Co		
27	Ni		
28	Cu		
29	Zn		
30	Mo		
31	Ag		
32	Cd		
33	B		
34	Al		
35	Si		
36	Pb		
37	P		
38	As		
39	Sb		
40	Se		
41			
42	Anions, µg/mL		
43	F		
44	Cl	190.00	3,700.00
45	Br	<4.0	28.00
46	I		
47	NO3	<4.0	<4.0
48	SO4	43.00	85.00
49	S2-		
50	PO4	<4.0	<4.0
51	Alkalinity as HCO3	115.00	90.00
52	TOC, µg/mL		
53	TKN, mg/mL		

	16	17	18
54			
55	SAMPLE ID	DM3a-940	DM3a-1100
56			
57	TDS	392	5,919
58			
59	CHARGE BALANCE		
60	Cations, meq/L		
61	Li	0.00	0.00
62	Na	8.61	91.35
63	K	0.04	0.69
64	Mg	0.03	6.08
65	Ca	0.11	0.00
66	Sr	0.00	0.41
67	Ba	0.00	0.00
68	Mn (2+)	0.00	0.00
69	Fe (2+)	0.00	0.00
70	Total Cations	8.80	98.54
71			
72	Anions, meq/L		
73	F	0.00	0.00
74	Cl	5.36	104.38
75	Br	0.00	0.35
76	I	0.00	0.00
77	Alkalinity as HCO3	1.88	1.48
78	NO3	0.00	0.00
79	SO4	0.90	1.77
80	PO4	0.00	0.00
81	Total Anions	8.14	107.97
82			
83	Net Difference	0.66	-9.43
84			
85	Percent Difference	-3.89	4.57
86			
87	RADIONUCLIDES		
88	ACD Sample ID	21457	21458
89			
90	Gross Alpha, Bq/L	0.4±1.3	0.4±3.2
91	Gross Beta, Bq/L	0.8±2.0	0.5±3.7
92			
93	H3, Bq/L	<30	<30
94	Co60, Bq/L	<0.4	<0.4
95	Sr90, Bq/L	0.25±0.13	0.41±44
96	Tc99, Bq/L	<0.2	<0.2
97	Ru106, Bq/L	nd	nd
98	Cs137, Bq/L	<0.3	<0.3
99	Th232, Bq/L		

Appendix B

Analytical data from the three initial DM wells for the January 1985 sampling. Blank entries or the entry *nm* in the table indicate that no measurement was attempted. Asterisks indicate pH values obtained by laboratory measurement several days after sampling. The entry *nd* indicates a compentent was looked for but not detected. Analytical uncertainties are within ±10% of the value cited unless otherwise indicated.

	1	2	3	4	5
1	Sample ID	DM1-600	DM1-795	DM1-925	DM1-1000
2	Date Collected	28Jan85	28Jan85	28Jan85	28Jan85
3	Collected By	JS/KH	JS/KH	JS/KH	JS/KH
4	Sample Depth	600.0	795.0	925.0	1,000.0
5	pH	7.60	5.80	5.30	5.30
6	Temp, °C	12.10	10.20	11.10	10.80
7	Cond, µS/cm	3,880	47,000	91,500	105,000
8					
9	CHEMICAL DATA				
10	ACD Sample ID	2278	2279	2280	2281
11					
12	Cations, µg/mL				
13	Li	0.28	<10	<20.	<20.0
14	Na	1,000.00	7,900.00	19,000.00	19,000.00
15	K	5.70	46.00	97.00	92.00
16	Be	0.11	<0.051	<0.1	<0.1
17	Mg	6.60	550.00	1,300.00	1,300.00
18	Ca	25.00	3,000.00	7,400.00	7,400.00
19	Sr	2.10	300.00	740.00	740.00
20	Ba	0.32	34.00	140.00	140.00
21	Ti	<0.02	<1.0	<2.	<2.0
22	V	<0.03	<1.5	<3.0	<3.0
23	Cr	<0.008	<0.41	1.90	<0.81
24	Mn	0.10	14.00	35.00	35.00
25	Fe	<0.03	2.30	29.00	28.00
26	Co	<0.02	<1.0	<2.0	<2.0
27	Ni	<0.06	<3.1	<6.1	<6.1
28	Cu	<0.02	<1.0	<2.0	<2.0
29	Zn	0.08	<1.0	<2.0	<2.0
30	Mo	<0.02	<1.0	<2.0	<2.0
31	Ag	<0.07	<3.6	<20.	<7.1
32	Cd	0.01	<0.46	0.95	<0.91
33	B	0.11	<5.1	<10.	<10.0
34	Al	<0.2	<10.	<20.	<20.0
35	Si	0.88	<4.1	<8.1	<8.1
36	Pb	<0.2	<10.0	<20.	<20.0
37	P	<0.3	<15.0	<30.0	<30.0
38	As	<0.2	<10.	<20.	<20.0
39	Sb	<0.3	<15.0	<30.	<30.0
40	Se	<0.4	<20.0	<40.	<40.0
41					
42	Anions, µg/mL				
43	F	0.53	0.46	0.48	0.46
44	Cl	1,500.00	20,000.00	49,000.00	52,000.00
45	Br	11.00	170.00	440.00	380.00
46	I	<5.0	<5.0	7.00	6.00
47	NO3	<1.0	290.00	700.00	640.00
48	SO4	10.00	<1.0	<1.0	<1.0
49	S2-	<1.0	<1.0	<1.0	<1.0
50	PO4	<0.4	<4.0	<4.0	<4.0
51	Alkalinity as HCO3	110.00	70.00	8.00	10.00
52	TOC, µg/mL				
53	TKN, mg/mL	0.01	0.05	0.11	0.13

	1	2	3	4	5
54					
55	SAMPLE ID	DM1-600	DM1-795	DM1-925	DM1-1000
56					
57	TDS	2539	31796	77537	80532
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.04	0.00	0.00	0.00
62	Na	43.50	343.65	826.50	826.50
63	K	0.15	1.18	2.48	2.35
64	Mg	0.54	45.24	106.94	106.94
65	Ca	1.25	149.70	369.26	369.26
66	Sr	0.05	6.85	16.89	16.89
67	Ba	0.00	0.50	2.04	2.04
68	Mn (2+)	0.00	0.51	1.27	1.27
69	Fe (2+)	0.00	0.08	1.04	1.00
70	Total Cations	45.53	547.71	1,326.42	1,326.26
71					
72	Anions, meq/L				
73	F	0.03	0.02	0.03	0.02
74	Cl	42.32	564.20	1,382.29	1,466.92
75	Br	0.14	2.13	5.50	4.75
76	I	0.00	0.00	0.06	0.05
77	Alkalinity as HCO3	1.80	1.15	0.13	0.16
78	NO3	0.00	4.68	11.29	10.32
79	SO4	0.21	0.00	0.00	0.00
80	PO4	0.00	0.00	0.00	0.00
81	Total Anions	44.49	572.18	1,399.30	1,482.23
82					
83	Net Difference	1.04	-24.47	-72.87	-155.97
84					
85	Percent Difference	-1.16	2.19	2.67	5.55
86					
87	RADIONUCLIDES				
88	ACD Sample ID	24550	24551	24552	24553
89					
90	Gross Alpha, Bq/L	9±18	7±22	16±35	9±31
91	Gross Beta, Bq/L	70±26	61,000±1,000	170,000±10,000	160,000±10,000
92					
93	H3, Bq/L	<30.0	670±50	1800±100	1700±100
94	Co60, Bq/L	<0.5	15±2	51±5	50±5
95	Sr90, Bq/L	15±7	42,000±1,000	120,000±10,000	140,000±10,000
96	Tc99, Bq/L	1.2±0.9	0.39±0.93	1.2±1.1	1.1±1.0
97	Ru106, Bq/L	nd	15±10	46±14	51±16
98	Cs137, Bq/L	34±3	37±4	26±3	29±4
99	Th232, Bq/L				

	6	7	8	9	10
1	Sample ID	DM1-1325	DM2-640	DM2-840	DM2-960
2	Date Collected	28Jan85	04Feb85	04Feb85	04Feb85
3	Collected By	JS/KH	JS/KH	JS/KH	JS/KH
4	Sample Depth	1,325.0	640.0	840.0	960.0
5	pH	4.90	5.40	5.20	5.20
6	Temp, °C	10.20	10.50	11.50	10.30
7	Cond, µS/cm	172,500	42,200	68,400	49,700
8					
9	CHEMICAL DATA				
10	ACD Sample ID	2282	2283	2284	2285
11					
12	Cations, µg/mL				
13	Li	28.00	<20.0	<40.0	<40.0
14	Na	44,000.00	20,000.00	34,000.00	35,000.00
15	K	340.00	110.00	170.00	140.00
16	Be	<10.0	<0.1	<0.2	<0.2
17	Mg	2,800.00	1,600.00	2,500.00	2,600.00
18	Ca	12,000.00	8,800.00	14,000.00	15,000.00
19	Sr	1,000.00	940.00	1,500.00	1,600.00
20	Ba	4.10	180.00	310.00	320.00
21	Ti	2.40	2.00	<4.0	4.30
22	V	<3.0	<3.0	<6.0	<6.0
23	Cr	<0.81	<0.81	<1.6	<1.6
24	Mn	13.00	30.00	53.00	58.00
25	Fe	43.00	36.00	58.00	65.00
26	Co	<2.0	<2.0	<4.0	<4.0
27	Ni	<6.1	<6.1	<12.0	<12.0
28	Cu	<2.0	<2.0	<4.0	<4.0
29	Zn	<2.0	6.90	<4.0	<4.0
30	Mo	<2.0	<2.0	<4.0	<4.0
31	Ag	<7.1	<7.1	<14.0	<14.0
32	Cd	1.00	<0.91	<1.8	1.90
33	B	<10.0	<10.0	<20.	<20.0
34	Al	27.00	21.00	48.00	46.00
35	Si	<8.1	<8.1	<16.0	<16.0
36	Pb	<20.0	<20.0	<40.0	<40.0
37	P	<30.0	<30.0	<60.0	<60.0
38	As	<20.0	<20.0	<40.0	<40.0
39	Sb	<30.0	<30.0	<60.0	<60.0
40	Se	<40.0	<40.0	<80.0	<80.0
41					
42	Anions, µg/mL				
43	F	0.26	0.48	0.44	0.51
44	Cl	120,000.00	61,000.00	87,000.00	76,000.00
45	Br	710.00	620.00	760.00	680.00
46	I	5.00	5.00	7.00	7.00
47	NO3	6.00	683.00	1,200.00	1,500.00
48	SO4	79.00	380.00	<1.0	<1.0
49	S2-	<1.0	<1.0	<1.0	<1.0
50	PO4	<4.0	<4.0	<4.0	<4.0
51	Alkalinity as HCO3	0.00	7.00	0.00	0.00
52	TOC, µg/mL				
53	TKN, mg/mL	0.03	0.12	0.20	0.20

	6	7	8	9	10
54					
55	SAMPLE ID	DM1-1325	DM2-640	DM2-840	DM2-960
56					
57	TDS	180140	92450	139170	130340
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	4.04	0.00	0.00	0.00
62	Na	1,914.00	870.00	1,479.00	1,522.50
63	K	8.69	2.81	4.35	3.58
64	Mg	230.33	131.62	205.65	213.88
65	Ca	598.80	439.12	698.60	748.50
66	Sr	22.83	21.46	34.25	36.53
67	Ba	0.06	2.62	4.51	4.66
68	Mn (2+)	0.47	1.09	1.93	2.11
69	Fe (2+)	1.54	1.29	2.08	2.33
70	Total Cations	2,780.76	1,470.01	2,430.36	2,534.08
71					
72	Anions, meq/L				
73	F	0.01	0.03	0.02	0.03
74	Cl	3,385.20	1,720.81	2,454.27	2,143.96
75	Br	8.88	7.76	9.51	8.51
76	I	0.04	0.04	0.06	0.06
77	Alkalinity as HCO3	0.00	0.11	0.00	0.00
78	NO3	0.10	11.02	19.36	24.20
79	SO4	1.64	7.91	0.00	0.00
80	PO4	0.00	0.00	0.00	0.00
81	Total Anions	3,395.88	1,747.67	2,483.21	2,176.74
82					
83	Net Difference	-615.12	-277.66	-52.85	357.34
84					
85	Percent Difference	9.96	8.63	1.08	-7.59
86					
87	RADIONUCLIDES				
88	ACD Sample ID	24554	24555	24556	24557
89					
90	Gross Alpha, Bq/L	14±48	32±42	22±45	20±42
91	Gross Beta, Bq/L	5,200±200	6,2000±1,000	93,000±1,000	98,000±1,000
92					
93	H3, Bq/L	61±36	1,300±100	2,000±100	2,300±100
94	Co60, Bq/L	1.3±1.0	120±10	170±10	170±10
95	Sr90, Bq/L	5,100±200	48,000±1,000	70,000±1,000	70,000±1,000
96	Tc99, Bq/L	1.3±1.3	0.64±0.91	0.44±0.89	1.1±1.0
97	Ru106, Bq/L	nd	nd	22±19	nd
98	Cs137, Bq/L	26±3	1,100±100	320±20	140±10
99	Th232, Bq/L				

	11	12	13	14	15
1	Sample ID	DM2-1040	DM2-1400	DM3a-610	DM3a-850
2	Date Collected	04Feb85	04Feb85	11Feb85	11Feb85
3	Collected By	JS/KH	JS/KH	JS/KH	JS/KH
4	Sample Depth	1,040.0	1,400.0	610.0	850.0
5	pH	5.20	4.60	8.70	8.50
6	Temp, °C	11.30	11.70	11.20	12.60
7	Cond, µS/cm	47,800	77,400	471	619
8					
9	CHEMICAL DATA				
10	ACD Sample ID	2286	2287	2288	2289
11					
12	Cations, µg/mL				
13	Li	<100.0	69.00	<0.2	<0.2
14	Na	33,000.00	99,000.00	280.00	350.00
15	K	140.00	430.00	1.40	1.70
16	Be	<0.5	<0.2	<0.001	<0.001
17	Mg	2,200.00	5,200.00	1.40	0.44
18	Ca	12,000.00	26,000.00	6.30	1.90
19	Sr	1,300.00	2,200.00	0.44	0.08
20	Ba	260.00	32.00	0.02	<0.02
21	Ti	<10.0	4.70	<0.02	<0.02
22	V	<15.0	<6.0	<0.03	<0.03
23	Cr	<4.0	<1.6	<0.008	<0.008
24	Mn	47.00	32.00	0.04	0.01
25	Fe	38.00	100.00	<0.03	<0.03
26	Co	<10.0	<4.0	<0.02	<0.02
27	Ni	<30.0	<12.0	<0.06	<0.06
28	Cu	<10.0	<4.0	<0.02	<0.02
29	Zn	<10.0	5.40	<0.02	<0.02
30	Mo	<10.0	<4.0	<0.02	<0.02
31	Ag	<35.0	<14.0	<0.07	<0.07
32	Cd	<4.5	<1.8	<0.009	<0.009
33	B	<50.0	<20.0	0.14	0.22
34	Al	120.00	<40.0	<0.2	<0.2
35	Si	<40.0	<16.0	0.78	1.50
36	Pb	<100.0	<40.0	<0.2	<0.2
37	P	<150.0	<60.0	<0.3	<0.3
38	As	<100.0	<40.0	<0.2	<0.2
39	Sb	<150.	<60.0	<0.3	<0.3
40	Se	<200.0	<80.0	<0.4	<0.4
41					
42	Anions, µg/mL				
43	F	0.40	0.46	1.40	1.90
44	Cl	72,000.00	163,000.00	330.00	450.00
45	Br	680.00	1,400.00	2.00	2.00
46	I	6.00	19.00	<5.0	<5.0
47	NO3	1,300.00	<1.0	<1.0	<1.0
48	SO4	<1.0	108.00	40.00	100.00
49	S2-	<1.0	<1.0	<1.0	<1.0
50	PO4	<4.0	<4.0	<4.0	<4.0
51	Alkalinity as HCO3	0.00	0.00	114.00	135.00
52	TOC, µg/mL				
53	TKN, mg/mL	0.24	0.02	0.01	0.01

	11	12	13	14	15
54					
55	SAMPLE ID	DM2-1040	DM2-1400	DM3a-610	DM3a-850
56					
57	TDS	120640	295830	620	804
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.00	9.94	0.00	0.00
62	Na	1,435.50	4,306.50	12.18	15.23
63	K	3.58	11.00	0.04	0.04
64	Mg	180.97	427.75	0.12	0.04
65	Ca	598.80	1,297.40	0.31	0.09
66	Sr	29.68	50.23	0.01	0.00
67	Ba	3.79	0.47	0.00	0.00
68	Mn (2+)	1.71	1.16	0.00	0.00
69	Fe (2+)	1.36	3.58	0.00	0.00
70	Total Cations	2,255.39	6,108.03	12.66	15.40
71					
72	Anions, meq/L				
73	F	0.02	0.02	0.07	0.10
74	Cl	2,031.12	4,598.23	9.31	12.69
75	Br	8.51	17.51	0.03	0.03
76	I	0.05	0.15	0.00	0.00
77	Alkalinity as HCO3	0.00	0.00	1.87	2.21
78	NO3	20.97	0.00	0.00	0.00
79	SO4	0.00	2.25	0.83	2.08
80	PO4	0.00	0.00	#VALUE!	0.00
81	Total Anions	2,060.66	4,618.17	12.11	17.11
82					
83	Net Difference	194.72	1,489.86	0.55	-1.71
84					
85	Percent Difference	-4.51	-13.89	-2.21	5.27
86					
87	RADIONUCLIDES				
88	ACD Sample ID	24558	24559	24560	24561
89					
90	Gross Alpha, Bq/L	11±37	60±77	1±14	5±16
91	Gross Beta, Bq/L	95,000±1,000	25,000±1,000	35±22	38±23
92					
93	H3, Bq/L	2100±100	61±36	<30.0	<30
94	Co60, Bq/L	180±10	5.5±1.0	<0.4	<0.2
95	Sr90, Bq/L	71,000±2,000	2,800±200	15±5	5.0±3
96	Tc99, Bq/L	0.3±1.1	1.1±0.9	0.44±80	0.9±1.1
97	Ru106, Bq/L	21±16	bd	nd	nd
98	Cs137, Bq/L	88±8	78±5	6.8±0.8	5.6±0.5
99	Th232, Bq/L				

	16	17	18
1	Sample ID	DM3a-940	DM3a-1100
2	Date Collected	11Feb85	11Feb85
3	Collected By	JS/KH	JS/KH
4	Sample Depth	940.0	1,100.0
5	pH	8.30	7.80
6	Temp, °C	12.80	11.30
7	Cond, µS/cm	1,860	18,210
8			
9	CHEMICAL DATA		
10	ACD Sample ID	2290	2291
11			
12	Cations, µg/mL		
13	Li	<0.2	<10.0
14	Na	370.00	9,000.00
15	K	2.40	77.00
16	Be	<0.001	<0.051
17	Mg	0.65	340.00
18	Ca	2.50	1,200.00
19	Sr	0.09	78.00
20	Ba	<.02	<1.0
21	Ti	<0.2	<1.0
22	V	<0.3	<1.05
23	Cr	<0.008	3.80
24	Mn	0.01	3.90
25	Fe	<0.03	98.00
26	Co	<0.02	<1.0
27	Ni	<0.06	14.00
28	Cu	<0.02	<1.0
29	Zn	<0.02	<1.0
30	Mo	<0.02	<1.0
31	Ag	<0.07	<3.6
32	Cd	<0.009	<0.46
33	B	0.27	<5.1
34	Al	<0.2	<10.0
35	Si	1.60	<4.1
36	Pb	<0.2	<10.0
37	P	0.32	<15.0
38	As	<0.2	<10.0
39	Sb	<0.3	<15.0
40	Se	<0.4	<20.0
41			
42	Anions, µg/mL		
43	F	2.00	0.81
44	Cl	440.00	19,000.00
45	Br	2.00	140.00
46	I	<5.0	<5.0
47	NO3	<1.0	<1.0
48	SO4	153.00	230.00
49	S2-	<1.0	<1.0
50	PO4	<4.0	<4.0
51	Alkalinity as HCO3	136.00	128.00
52	TOC, µg/mL		
53	TKN, mg/mL	0.01	0.02

	16	17	18
54			
55	SAMPLE ID	DM3a-940	DM3a-1100
56			
57	TDS	816	29695
58			
59	CHARGE BALANCE		
60	Cations, meq/L		
61	Li	0.00	0.00
62	Na	16.10	391.50
63	K	0.06	1.97
64	Mg	0.05	27.97
65	Ca	0.12	59.88
66	Sr	0.00	1.78
67	Ba	0.00	0.00
68	Mn (2+)	0.00	0.14
69	Fe (2+)	0.00	3.51
70	Total Cations	16.34	486.75
71			
72	Anions, meq/L		
73	F	0.11	0.04
74	Cl	12.41	535.99
75	Br	0.03	1.75
76	I	0.00	0.00
77	Alkalinity as HCO3	2.23	2.10
78	NO3	0.00	0.00
79	SO4	3.19	4.79
80	PO4	0.00	0.00
81	Total Anions	17.96	544.67
82			
83	Net Difference	-1.62	-57.92
84			
85	Percent Difference	4.72	5.62
86			
87	RADIONUCLIDES		
88	ACD Sample ID	24562	24563
89			
90	Gross Alpha, Bq/L	35±26	21±27
91	Gross Beta, Bq/L	39±23	33±22
92			
93	H3, Bq/L	<30	<30
94	Co60, Bq/L	0.19±0.16	<0.1
95	Sr90, Bq/L	1.7±2.4	3.2±2.8
96	Tc99, Bq/L	0.37±0.89	0.14±0.78
97	Ru106, Bq/L	nd	nd
98	Cs137, Bq/L	2.3±0.3	8.4±0.7
99	Th232, Bq/L		

Appendix C

Analytical data for samples from the four new and three reconfigured DM wells for the January 1986 sampling. Blank entries or the entry *nm* in the table indicate that no measurement was attempted. Asterisks indicate pH values obtained by laboratory measurement several days after sampling. The entry *nd* indicates a compentent was looked for but not detected. Analytical uncertainties are within ±10% of the value cited unless otherwise indicated.

	1	2	3	4	5
1	SAMPLE ID	DM1-RT	DM3-RT	DM1-PV	DM2-PV
2	Date Collected	30Jan86	29Jan86	31Jan86	31Jan86
3	Collected By	CSH/JS	CSH/JS	JS/AM	JS/AM
4	Sample Depth	700.0	550.0	1,050.0	1,050.0
5	pH	6.80	4.60	4.40	4.30
6	Temp, °C	12.40	9.00	10.00	13.90
7	Cond, µS/cm	160,200	61,000	>190,000	>200,000
8					
9	CHEMICAL DATA				
10	ACD Sample ID	9893	9898	9894	9896
11					
12	Cations, µg/mL				
13	Li	28.00	33.00	55.00	51.00
14	Na	30,000.00	35,000.00	59,000.00	57,000.00
15	K	740.00	140.00	240.00	230.00
16	Be	<0.052	<0.042	<0.1	<0.1
17	Mg	2,700.00	2,900.00	4,100.00	4,400.00
18	Ca	13,000.00	11,000.00	22,000.00	26,000.00
19	Sr	1,300.00	1,300.00	2,300.00	2,600.00
20	Ba	89.00	290.00	680.00	610.00
21	Ti	<0.52	<0.42	<1.0	<1.0
22	V	nm	nm	nm	nm
23	Cr	<1.0	<0.84	<2.0	<2.0
24	Mn	3.40	7.00	140.00	100.00
25	Fe	5.30	100.00	170.00	130.00
26	Co	<0.26	<0.21	<0.51	<0.51
27	Ni	<1.6	<1.3	<3.1	<3.1
28	Cu	<0.52	<0.42	<1.0	<1.0
29	Zn	<0.52	1.00	<1.0	<1.0
30	Mo	<1.0	<0.84	<2.0	<2.0
31	Ag	<1.3	<1.1	<2.5	<2.5
32	Cd	nm	nm	nm	nm
33	B	<2.1	<1.7	<4.1	<4.1
34	Al	<5.2	<4.2	<10.0	<10.0
35	Si	<5.2	<4.2	<10.0	<10.0
36	Pb	<5.2	<4.2	<10.0	<10.0
37	P	9.20	9.50	18.00	20.00
38	As	<2.6	<2.1	<5.1	<5.1
39	Sb	<5.2	<4.2	<10.0	<10.0
40	Se	<5.2	<4.2	<10.0	<10.0
41					
42	Anions, µg/mL				
43	F	0.60	0.59	0.46	0.28
44	Cl	98,000.00	93,000.00	150,000.00	150,000.00
45	Br	840.00	950.00	1,400.00	2,100.00
46	I	0.00	12.00	19.00	18.00
47	NO3	18.00	<10.0	442.00	1,991.00
48	SO4	<50.0	<50.0	<50.0	<50.0
49	S2-	nm	nm	nm	nm
50	PO4	28.00	20.00	17.00	17.00
51	Alkalinity as HCO3	3.00	0.00	0.00	0.00
52	TOC, µg/mL	nm	nm	nm	nm
53	TKN, µg/mL	nm	nm	nm	nm

	1	2	3	4	5
54					
55	SAMPLE ID	DM1-RT	DM3-RT	DM1-PV	DM2-PV
56					
57	TDS	145,740	143,340	237,640	240,230
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	4.04	4.76	7.93	7.35
62	Na	1,305.00	1,522.50	2,566.50	2,479.50
63	K	18.92	3.58	6.14	5.88
64	Mg	222.10	238.55	337.27	361.94
65	Ca	648.70	548.90	1,097.80	1,297.40
66	Sr	29.68	29.68	52.51	59.36
67	Ba	1.30	4.22	9.90	8.88
68	Mn (2+)	0.12	0.25	5.10	3.64
69	Fe (2+)	0.19	3.58	6.09	4.66
70	Total Cations	2,230.05	2,356.03	4,089.22	4,228.61
71					
72	Anions, meq/L				
73	F	0.03	0.03	0.02	0.01
74	Cl	2,764.58	2,623.53	4,231.50	4,231.50
75	Br	10.51	11.88	17.51	26.27
76	I	0.00	0.09	0.15	0.14
77	Alkalinity as HCO3	0.05	0.00	0.00	0.00
78	NO3	0.29	0.00	7.13	32.11
79	SO4	0.00	0.00	0.00	0.00
80	PO4	0.88	0.63	0.54	0.54
81	Total Anions	2,776.34	2,636.17	4,256.85	4,290.58
82					
83	Net Difference	-546.30	-280.15	-167.63	-61.97
84					
85	Percent Difference	10.91	5.61	2.01	0.73
86					
87	RADIONUCLIDES				
88	ACD Sample ID	31990	31995	31991	31993
89					
90	Gross Alpha, Bq/L	nm	nm	nm	nm
91	Gross Beta, Bq/L	56±35	40±33	270,000±20,000	400,000±20,000
92					
93	H3, Bq/L	nm	nm	nm	nm
94	Co60, Bq/L	<0.6	6.6±2	nd	nd
95	Sr90, Bq/L	250±70	46±36	35,000±2,000	94,000±2,000
96	Tc99, Bq/L	nm	nm	nm	nm
97	Ru106, Bq/L	nm	nm	nm	nm
98	Cs137, Bq/L	1.0±0.6	<1.0	nd	nd
99	Th232				

	6	7	8	9
1	SAMPLE ID	DM3a-PV	DM1-RM	DM2-RM
2	Date Collected	29Jan86	30Jan86	30Jan86
3	Collected By	CSH/JS	CSH/JS	CSH/JS
4	Sample Depth	875.0	1,085.0	1,250.0
5	pH	6.90	8.40	10.30
6	Temp, °C	12.80	13.50	10.40
7	Cond, µS/cm	63,000	167,700	75,700
8				
9	CHEMICAL DATA			
10	ACD Sample ID	9899	9895	9897
11				
12	Cations, µg/mL			
13	Li	11.00	55.00	88.00
14	Na	12,000.00	37,000.00	57,000.00
15	K	77.00	330.00	890.00
16	Be	<0.022	<0.052	<0.052
17	Mg	260.00	1,300.00	2,300.00
18	Ca	2,800.00	11,000.00	15,000.00
19	Sr	210.00	870.00	1,400.00
20	Ba	1.50	8.60	28.00
21	Ti	<0.22	<0.52	<0.52
22	V	nm	nm	nm
23	Cr	0.54	<1.0	<1.0
24	Mn	3.00	1.10	<0.13
25	Fe	23.00	3.10	6.50
26	Co	<0.11	<0.26	<0.26
27	Ni	<0.66	<1.6	<1.6
28	Cu	<0.22	<0.52	<0.52
29	Zn	<0.22	<0.52	<0.52
30	Mo	<0.44	<1.0	<1.0
31	Ag	<0.55	<1.3	<1.3
32	Cd	nm	nm	nm
33	B	<0.88	<2.1	<2.1
34	Al	2.40	<5.2	<5.2
35	Si	5.60	<5.2	<5.2
36	Pb	<2.2	<5.2	<5.2
37	P	<3.3	<7.8	9.60
38	As	<1.1	<2.6	<2.6
39	Sb	<2.2	<5.2	<5.2
40	Se	<2.2	<5.2	<5.2
41				
42	Anions, µg/mL			
43	F	0.08	0.06	0.11
44	Cl	24,000.00	91,000.00	130,000.00
45	Br	210.00	750.00	1,500.00
46	I	<10.0	11.00	12.00
47	NO3	<10.0	66.00	9.20
48	SO4	522.00	330.00	<50.0
49	S2-	nm	nm	nm
50	PO4	22.00	19.00	19.00
51	Alkalinity as HCO3	60.00	20.00	366.00
52	TOC, µg/mL	nm	nm	nm
53	TKN, µg/mL	nm	nm	nm

	6	7	8	9
54				
55	SAMPLE ID	DM3a-PV	DM1-RM	DM2-RM
56				
57	TDS	39,347	141,500	206,590
58				
59	CHARGE BALANCE			
60	Cations, meq/L			
61	Li	1.59	7.93	12.68
62	Na	522.00	1,609.50	2,479.50
63	K	1.97	8.44	22.76
64	Mg	21.39	106.94	189.20
65	Ca	139.72	548.90	748.50
66	Sr	4.79	19.86	31.96
67	Ba	0.02	0.13	0.41
68	Mn (2+)	0.11	0.04	0.00
69	Fe (2+)	0.82	0.11	0.23
70	Total Cations	692.41	2,301.84	3,485.24
71				
72	Anions, meq/L			
73	F	0.00	0.00	0.01
74	Cl	677.04	2,567.11	3,667.30
75	Br	2.63	9.38	18.77
76	I	0.00	0.09	0.09
77	Alkalinity as HCO3	0.98	0.33	6.00
78	NO3	0.00	1.06	0.15
79	SO4	10.87	6.87	0.00
80	PO4	0.69	0.60	0.60
81	Total Anions	692.22	2,585.45	3,692.91
82				
83	Net Difference	0.19	-283.61	-207.67
84				
85	Percent Difference	-0.01	5.80	2.89
86				
87	RADIONUCLIDES			
88	ACD Sample ID	31996	31992	31994
89				
90	Gross Alpha, Bq/L	nm	nm	nm
91	Gross Beta, Bq/L	21±26	45,000±1,000	37,000±1,000
92				
93	H3, Bq/L	nm	nm	nm
94	Co60, Bq/L	<0.8	5.3±1.9	42±5
95	Sr90, Bq/L	100±50	20,000±2,000	15,000±2,000
96	Tc99, Bq/L	nm	nm	nm
97	Ru106, Bq/L	nm	nm	nm
98	Cs137, Bq/L	0.88±0.81	<1.0	2.8±1.2
99	Th232			

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