CONF-8308106--17

MASTER

# SHALLOW LAND BURIAL TECHNOLOGY -- HUMID[1]

E.C. Davis, B.P. Spalding, and S.Y.Lee
ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

CONF-8308106--17

DE84 000343

# SHALLOW LAND BURIAL TECHNOLOGY - HUMID[1]

E.C. Davis, B.P. Spalding, and S.Y.Lee
ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

## ABSTRACT

The Shallow Land Burial Technology - Humid Project is being conducted for the Department of Energy Low-Level Waste Management Program with the objective of identifying and demonstrating improved technology for disposing of low-level solid waste in humid environments. Two improved disposal techniques are currently being evaluated using nine demonstration trenches at the Engineered Test Facility (ETF). The first is use of a cement-bentonite grout applied as a waste backfill material prior to trench closure and covering. The second is complete hydrologic isolation of waste by emplacement in a trench that is lined on all four sides, top and bottom using a synthetic impermeable lining material. An economic analysis of the trench grouting and lining demonstration favored the trench lining operation ($1055/demonstration trench) over trench grouting ($1585/demonstration trench), with the cost differential becoming even greater (as much as a factor of 6 in favor of lining for typical ORNL trenches) as trench dimensions increase and trench volumes exceed those of the demonstration trenches. In addition to the evaluation of trench grouting and lining, major effort has centered on characterization of the ETF site. Though only a part of the overall study, characterization is an extremely important component of the site selection process; it is during these activities that potential problems, which may obviate the site from further consideration, are found. Characterization of the ETF has included studies of regional and site-specific geology, the physical and chemical properties of the soils in which the demonstration trenches are located, and hydrology of the small watershed of which the ETF is a part. Using an approach that includes extensive site characterization, monitoring, and model development, should lead to construction of a representative

[1]Supported by the Office of Defense Waste and By-Product Management, U.S. Department of Energy, under contract W-7405-eng-26 with Union Carbide Corporation. Publication No. 2233, Environmental Sciences Division, ORNL.

site hydrologic model which may be expanded and used at larger disposal sites with similar complex geology and water-related problems.

## INTRODUCTION

Shallow land burial (SLB) of industrial and municipal solid wastes has been the most common disposal practice in the United States (1). The principal reasons for this have been that land for disposal has been easy to obtain, and the methods used are relatively inexpensive. Like other industrial wastes, essentially all low-level radioactive wastes (LLW) produced in the United States have been disposed using SLB practices. Some of these low-level waste sites have provided less than ideal geological/hydrological site conditions, and as a result, have led to localized groundwater contamination outside of the burial trench boundaries. In addition, most sites in humid regions have experienced problems with trench cover subsidence Although these occurrences have not resulted in significant off-site movement of radioactivity or exposure of the general public, their presence raises concern with the long-term performance of SLB facilities (2,3).

As part of the DOE research and development activities, the Oak Ridge National Laboratory (ORNL) has designed and constructed an experimental facility (the Engineered Test Facility or ETF) to investigate and demonstrate the application of improved engineering practices to the design of land disposal facilities in geographic areas in which precipitation equals or exceeds evapotranspiration (4). Although many of the precipitation-related problems encountered in this climate could be avoided by locating SLB facilities in arid areas, the presence of a large portion of the nuclear waste generating facilities in humid areas (Eastern United States), and the high costs and legal constraints associated with shipping wastes across country, indicate that disposal facilities are required in these climates. Thus, the experimental work associated with the ETF focuses on anticipated waste leaching and contaminant transport problems associated with disposal in humid climates. The ORNL site is considered typical of the eastern United States and results are applicable to other humid sites experiencing similar water-related problems.

Four major objectives were considered in designing the ETF. The first was that the facility should provide a field-scale location to experimentally verify improvements in shallow land disposal procedures that minimize, through the application of a grout or a liner, the potential for contact between the buried waste and water. The remaining three objectives include assessment of site characterization techniques as they relate to understanding the ETF site, the construction of a hydrologic model using measured site characteristics, and verification of the model by comparison to site performance data. This review paper will focus on the first two of these objectives, improved burial technology and ETF site characterization. Hydrologic modelling efforts have recently been initiated and, though a major area of concern over the next three years, will only briefly be mentioned. Additional groundwater modelling efforts at ORNL applicable to the ETF are described in another paper at this meeting by Huff, Yeh, and DeAngelis (5).

## EXPERIMENTAL DEMONSTRATION BURIAL

### Background

Applying engineered modifications to present SLB practices is a possible method of stabilizing waste trenches and improving overall disposal site performance. Two such engineered modifications, trench lining and grouting, are currently being demonstrated and evaluated at the ETF. The experimental design for the demonstration consists of nine trenches (approximate trench volume = 28 $m^3$), three grouted, three lined, and three serving as untreated controls. The trenches are arranged in a 3 by 3 matrix with each treatment being present in each row and column of the matrix. In addition to the trenches, an array of 12 preconstruction monitoring wells (Figure 1) and 24 tracer monitoring wells (located approximately 1 m from the side walls of each trench) have been constructed at the ETF for purposes of trench treatment evaluation.

Of the large number of liners and grouts currently in use, reinforced Hypalon fabric and a Portland cement-bentonite grout slurry were selected for demonstration in the experimental trenches which contained compacted low-level waste generated at ORNL (activity $\leq$ 200 mR/h). The selection of these two trench treatments was based on a number of considerations which included availability of materials, cost of materials and their installation, ease of application, and, to a certain extent, the degree of waste isolation afforded. The cement-bentonite grout applied as a waste backfill material was hypothesized as providing an intermediate level of waste isolation, ranking somewhere between the two extremes of the control (untreated) trenches and those lined trenches that completely isolate the waste in a sealed Hypalon liner.

### Results and Conclusions

The trench lining and grouting operations have been previously reported (6) and are illustrated in Figures 2 and 3 which show a trench being grouted and a lined trench, respectively. During the demonstration, a total of 29 $m^3$ of grout was delivered to three of the demonstration trenches at a cost of $\$164/m^3$ (cost includes mixing and delivery fee). With each trench having roughly the same void volume (estimated to be 50% of the total volume) and thus requiring the same volume of grout, the cost, on a per demonstration trench basis, equals \$1585 for the grout treatment. For comparison, the cost of grouting a typical size ORNL trench (3.0 by 3.7 by 15.2 m) using the same methods and materials is estimated at \$13,850.

Unlike grouting, where the entire void volume of buried waste needs to be filled with the impermeable grout material, lining requires that only the surfaces of a trench be covered so that the large void volume within the waste surrounded by the liner need not be considered. As a result, grouting costs can be calculated, almost exclusively, on the trench void volume whereas lining costs depend on the surface area of the total aggregate of waste or, more directly, on trench dimensions. Thus, the economic comparison of lining and grouting is quite dependent on scale.

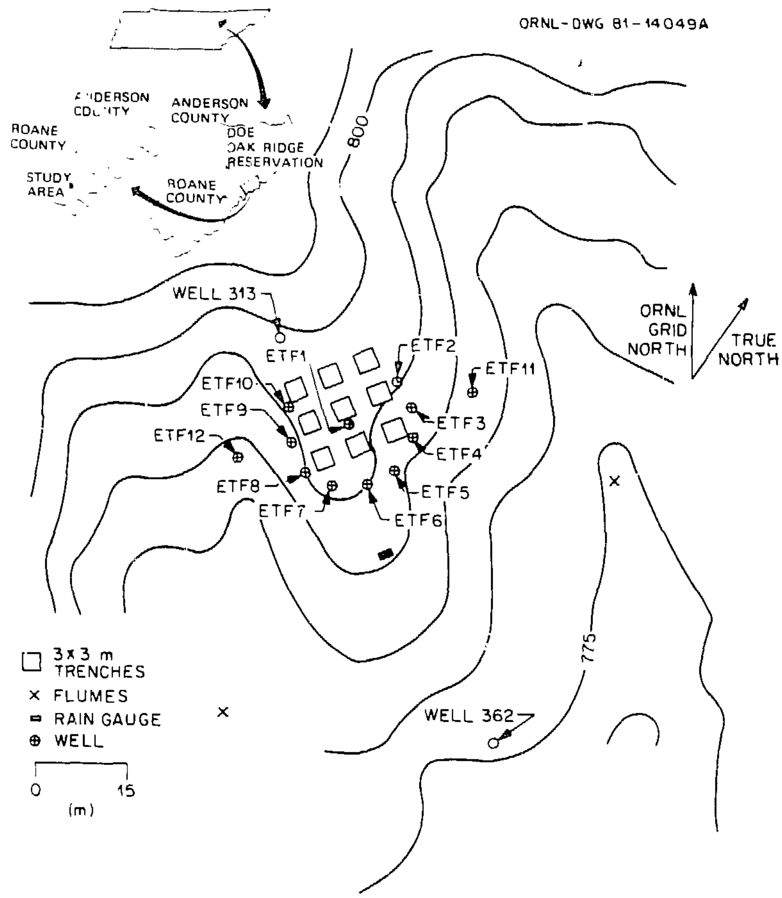


Fig. 1. Location of the ETF in ORNL Solid Waste Storage Area 6 showing the arrangement of the nine experimental trenches, the preconstruction monitoring wells, the surface drainage flumes, and the rain gauge.

Fig. 2. Grout application to one of the ETF experimental trenches filled with compacted low-level waste.

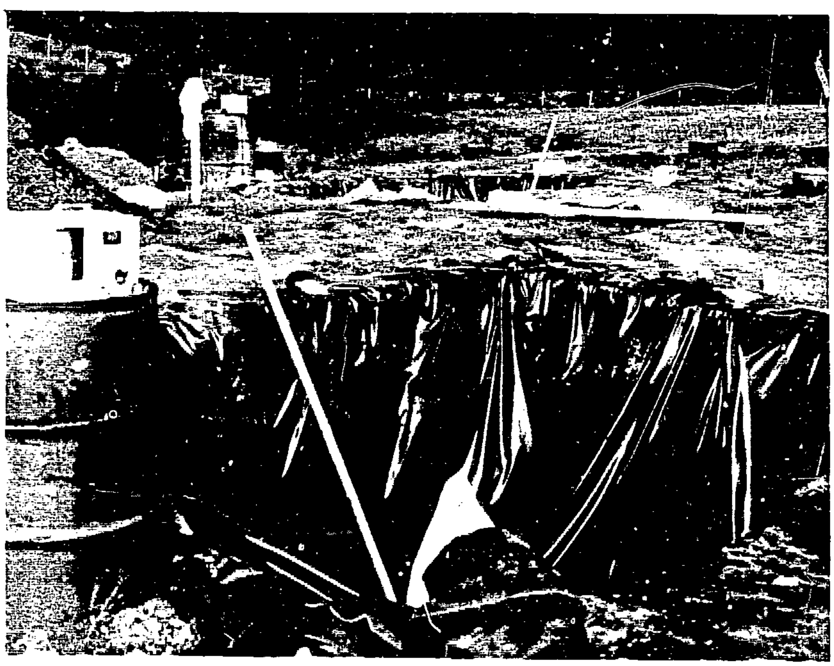

Fig. 3. ETF demonstration trench lined with Hypalon fabric to effect a water-tight seal. After trench filling, a Hypalon cover was sealed in place followed by application of a soil cover.

To illustrate this point the cost (materials plus installation) of lining one of the ETF demonstration trenches was calculated to be $1055, only $500 less than trench grouting. However, when considering a larger-scale ORNL trench, the cost of lining becomes only $2330, a factor of 6 lower than grouting such a large trench. Thus, the cost comparison of the small-scale grouting and lining demonstration being carried out at the ETF does not reflect the true cost differential and savings that would result in selecting trench lining over trench grouting on a larger field-scale.

In addition to demonstrating a successful trench lining and grouting operation, an important part of the ETF experimental design involves evaluating trench treatment effectiveness. Two criteria have been selected to make this evaluation, the movement and detection of unique chemical tracers associated with each of the nine experimental trenches, and the reduction in waste/backfill hydraulic conductivity when compared to the untreated trenches. Both of these criteria reflect the ease with which water can come into contact with the buried waste, leach, and potentially transport radionuclides. To date, sampling of the 12 preconstruction and 24 tracer monitoring wells has not indicated leachate movement from any of the nine demonstration trenches. Even tritium, which is highly mobile and often the first sign of leachate movement from low-level waste trenches, has not been detected in any of the monitoring wells. Further evidence that the lined trenches are thus far not leaking can be seen by the fact that their intra-trench water levels, which resulted from direct rainfall infiltration during trench filling, have not fluctuated as the ETF water table has, and remain perched between 1.5 and 3 m above the existing water table. If significant leakage were occurring, these levels would fluctuate and drop below the trench bottom during the drier summer months. This has not been observed nor has water been detected in wells located in the control or grouted trenches. As a result, it is concluded that, for the one year period of monitoring since the trenches have been closed, there has been no detectable leachate generated from the nine demonstration trenches. Field measurements of waste/backfill hydraulic conductivity have, by design, not been initiated because of possible influence on existing hydraulic gradients and tracer movement. These experiments are planned as a part of the trench treatment evaluation activities for FY-1984.

## ETF SITE CHARACTERIZATION

### Background

The second major objective of the ETF is to evaluate various techniques that have been used to characterize the demonstration facility, and will likely be used to characterize large candidate disposal sites in the Eastern United States. Site characterization is an extremely important component of the site selection process; it is during these activities that potential problems, which may obviate a site from further consideration, may be found. Further, information collected during site characterization will be used by site developers to construct a hydrologic model of the site for licensing purposes; the model can be used as a tool for making predictions about future site performance. It has not been the intent of the ETF site characterization to collect all the information required by

NRC or DOE to open a new disposal site, but rather to concentrate on the data requirements for hydrologic modeling. With this goal in mind, the three categories of geology, soils, and hydrology were selected as being the critical areas where information was needed. Three reports have been prepared which deal with the ETF site characterization (7,8, an 9) and can be referred to for more detailed information.

## Results and Conclusions

The ETF is located in Melton Valley, approximately 2 km south of ORNL. Geologically, it is within the Copper Creek thrust block and is underlain by strata of the Middle to Late Cambrian Conasauga Group. The specific formation is the Maryville, which consists of silty limestone interbedded with mudstones and shales. The structure of the formation is highly deformed with small-scale folds, several of which were exposed during trench excavation at the ETF. The formation is also heavily fractured and flow through these fractures is believed to be quite significant during periods of heavy precipitation. Soil thickness, as measured from core samples and surface geophysical techniques, ranges from 2 to 7 m, being thinnest in the vicinity of experimental wells ETF-9, -1, and -2 (above a major limestone fold) and increasing in thickness with movement to the northwest and southeast of the array of experimental trenches (Figure 1).

Geological characterization of the ETF included a detailed examination of cores taken at various locations across the site Cores taken during drilling of wells ETF-1, -3, -4, -5, -6, -11, -12, and -16 indicate that the Maryville is a gray to gray-black, massive- to medium-bedded, silty, interclastic limestone and ribbon-bedded silty limestone, interbedded with a thin-bedded mudstone/shale. The limestone ranges from a silty lime mud (or micrite) to a fine-grained crystalline material (or microspar). The shale and mudstone are calcareous and locally very rich in detrital mucovite which is oriented parallel to bedding planes. Bedding geometry in the shale ranges from a parallel- to wavy-bedded pattern. Locally, discontinuous lenticular-bedded stratification is also observed.

All of the cores exhibit numerous joints and fractures, some of which are filled. Fracture-filling material varies from white to pink, fine to coarse, crystalline calcite. The calcite may be accompanied by dolomite, pyrite, marcasite, bladed gypsum, or other minerals. Small-scale (<0.25 m) solution cavities are also observed in cores. The solution cavities have local coatings of iron oxides, gypsum, and carbonates. Further information on fracture width, distribution, and wall chemistry in the near surface Conasauga near ORNL can be found in Sledz and Huff (10) and Krumhansl (11).

Selected core samples were studied by X-ray diffraction techniques to determine their clay mineralogy. Eight samples were collected at depths of 6.6 m, 7.3 m, 7.6 m, 8.1 m, 8.4 m, 8.8 m, and 9.0 m from wells ETF-1, -3, -11, and -12. The samples were disaggregated by crushing using a mortar and pestle, grinding for a short time in a ball mill, and subsequently dissolving the carbonate constituent with a (pH 5) sodium acetate/acetic acid solution (approximately 1 N). Both whole rock and size fractionated X-ray diffraction analyses were carried out following the standard procedures of Jackson (12). Size fractions studied were 45 to 2 μm (silts), 2 to 0.2 μm (coarse clay), and <0.2 μm (fine clay). Air-dried, glycolated, and potassium- and magnesium-saturated preferred orientation (to the 001 crystallographic direction of the minerals) specimens were prepared and X-ray diffractograms obtained for the 2- to 0.2- and <0.2-μm fractions for each sample. X-ray diffraction data indicated that chlorite, illite, and mixed layer illite/vermiculite were the major clay mineral constituents (Table 1). Locally, smectite and mixed-layer illite/smectite are minor trace constituents; however, kaolinite is absent. Much of the illite is probably detrital and, along with plagioclase feldspar and quartz, make up the major constituents of the 45 to 2 μm size fraction. Whole-rock, random powder orientation X-ray analyses indicate the presence of either calcite or dolomite or both, in addition to the above-mentioned clays, plagioclase and (locally) potassium feldspars, and quartz. Mineralogically, the patterns were similar, suggesting a reasonable level of homogeneity in the sequence for the site.

Two major joint/fracture orientations can be found in the Conasauga near the ETF site (9). The first is a high angle joint set that is generally found to strike perpendicular to geologic strike. The second type of movement is along bedding planes where slickensides, polishing and offset can be found. Locally, fracture distribution and orientation are controlled by structural deformities such as folds and small-scale thrusting. The size of fractures, some of which have been chemically widened to form solution cavities, range up to 15 cm; however, most fractures are from 1 to 15 mm in width and the majority are 1 to 3 mm. The dip of bedding planes, as measured with respect to the side of cores, is highly variable over small lateral or vertical distances. It ranges from 30° to vertical, depending on the nature of the structures that have been intercepted by the bore hole.

The Conasauga Group weathers to a saprolite in which structural features and lithologic variations are still distinct, but the rock is chemically altered. Most carbonate cement is leached out, but purer limestone beds are still intact. Because of chemical alteration and leaching, fractures tend to be widened and the rock is structually less competent. The extent of weathering is usually recognizable by color (saprolite is usually brown or tan as opposed to gray), by poor core recovery, or by auger refusal.

The chemical and radionuclide adsorption properties of the saprolite-bedrock continuum were characterized using samples collected during the augering of a 35-m deep borehole in a nearby area of Melton Valley. This borehole was located approximately 3 km northeast of the ETF site, but at approximately the same stratigraphic position within the Maryville limestone of the Conasauga Group. Samples were collected every 1.5 m, sieved to <2 mm, and air-dried (70°C). Radionuclide distribution coefficients, chemical analyses, and physical property determinations were performed on each sample. Figure 4 depicts the distribution coefficients of five radionuclides as well as the hardness determining cations ($Ca^{+2}$ + $Mg^{+2}$). One of the more salient characteristics is the decline in $^{85}Sr$ Kd with depth which parallels the distribution of hardness cations. Two radionuclides, $^{125}I$ and $^{241}Am$ showed little variation with depth while both $^{134}Cs$ and $^{58}Co$ exhibited a gradual decline with depth as less-weathered rock was encountered. Only the shallowest

TABLE 1. CLAY MINERALOGY FOR ROCK SAMPLES FROM WELLS ETF-1, -3, -11, and -12

(In order of abundance)

| Sample depth (m) | Size Fraction (μm) | Clay mineralogy |
|---|---|---|
| E1-6.6 | <0.2 | Illite, chlorite, illite/smectite |
| | 2-0.2 | Illite, chlorite |
| | 45-2 | Chlorite, illite |
| E1-8.8 | <0.2 | No sample |
| | 2-0.2 | Chlorite, illite |
| | 45-2 | Illite, chlorite, illite/smectite (vermiculite) |
| E3-7.3 | <0.2 | Illite, chlorite |
| | 2-0.2 | Illite, chlorite |
| | 45-2 | Chlorite, Illite, illite/smectite |
| E3-8.1 | <0.2 | Illite, chlorite |
| | 2-0.2 | Illite, chlorite |
| | 45-2 | Chlorite, illite |
| E3-8.4 | <0.2 | Illite, chlorite |
| | 2-0.2 | Illite, chlorite, smectite |
| | 45-2 | Chlorite, illite/vermiculite or smectite |
| E3-8.8 | <0.2 | Illite, chlorite |
| | 2-0.2 | Illite, chlorite, vermiculite |
| | 42-2 | Chlorite, illite, vermiculite (?) |
| E11-8.8 | <0.2 | Illite, chlorite |
| | 2-0.2 | Illite, chlorite, smectite (?) |
| | 45-2 | Chlorite, illite |
| E12-7.6 | <0.2 | Illite, chlorite |
| | 2-0.2 | Illite, chlorite |
| | 45-2 | Illite, chlorite |

(?) = Trace amount, tentative identification
/ = Interstratified association

ORNL-DWG-83-11498

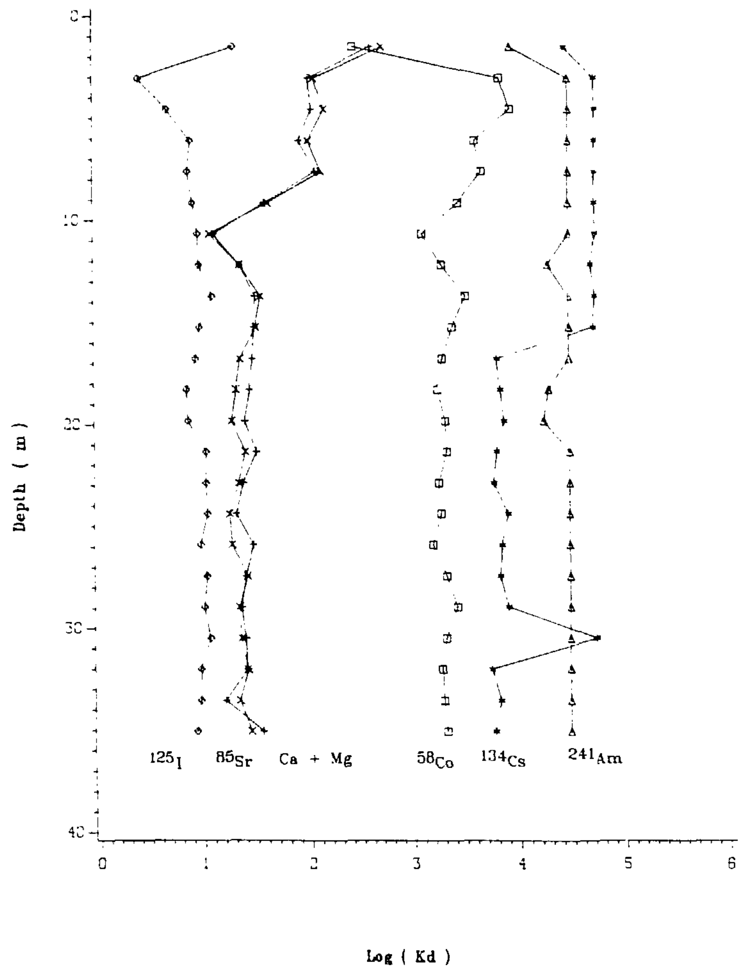


Fig. 4. Distribution coefficients of $^{125}I$, $^{85}Sr$, $^{58}Co$, $^{134}Cs$, and $^{241}Am$ and hardness cations ($Ca^{+2}$ - $Mg^{+2}$) with depth within the Maryville limestone of the Conasauga Formation.

sample within the borehole would be similar to the soils encountered at the ETF; this top sample tended to be much higher in $^{85}Sr$ and $^{125}I$ Kd's and significantly lower in $^{58}Co$, $^{241}Am$, and $^{134}Cs$ Kd's.

The chemical properties of these borehole samples exhibited a more consistent depth relation (Figure 5). The upper profile samples showed greater total exchangeable cations than the deeper samples. Most of these exchangeable cations were $Ca^{+2}$ as would be expected for the weathering of a limestone. The decline with depth of exchangeable $Ca^{+2}$ and total cations is indicative of the degree of weathering of the Maryville limestone. As the limestone and its clay mineral components weather, more cation exchange sites become functional, i.e. measurable by cation exchange analyses, as their surfaces become exposed. Although limestone was present throughout the depth of the borehole, only in the top sample had the $CaCO_3$ weathered to the degree that the saprolite was acidic (pH = 5.4); all other samples were above pH 7 reflecting the presence of residual carbonate. The apparent clay contents within the Maryville limestone declined with depth (from 19% at 1.5 m to 7% at 35 m) and indicated the stronger aggregation of the rock at depth. Thus, the general conclusion that the Maryville limestone becomes more inert to cation and radionuclide adsorption with depth is supported by both the chemical and physical characteristics.

The soil of the ETF site is described as being very shallow (A and B horizons) even taking into account the material removed during site clearing. The underlying C horizons were found to be highly leached (strongly acidic) and highly structured due to stratigraphic characteristics inherited from the bedrock. The soil's stratigraphic orientation was extremely variable in both dip and strike due to folding and faulting present. Root penetration was generally not noted below approximately 40 cm, presumably due to dense horizons and tight structure.

Measurement of distribution coefficients for seven radionuclides in soil samples collected from the ETF trenches indicate a range of 11.7 L/kg ($^{125}I$) to 64,100 L/kg ($^{137}Cs$). Extremely low Kd's ($\leq 10^{-1}$ L/kg) were not encountered for any soil samples as might be the case with tritium. There was no observable pattern with depth for the Kd's of any of the radionuclides tested, nor were there any differences among the three profiles tested. Thus, the best representation of these Kd values for modelling purposes would be the averages and standard deviations which are presented in Table 2. As mentioned earlier, on a depth scale extending into comparatively unweathered bedrock, i.e., depths of 30 m, there appeared to be some general decline in most radionuclide Kd's (Figure 4).

Soils at the ETF site can be summarized as highly leached and strongly acidic. Cation exchange capacities averaged 210 meq/kg and were quite uniform in this characteristic. There appeared to be only a minor influence of vegetational nutrient cycling as evidenced by the modest decline in exchangeable $Ca^{+2}$ with depth in each profile tested.

A number of significant correlations were observed among the soil chemical properties. Of particular note, are the correlations between exchangeable acidity and percent base saturation and pH (r = 0.80 and -0.72, respectively). This relationship is expected since the lower the soil pH, the more exchange sites would be occupied by acid cations

ORNL-DWG-83-11499

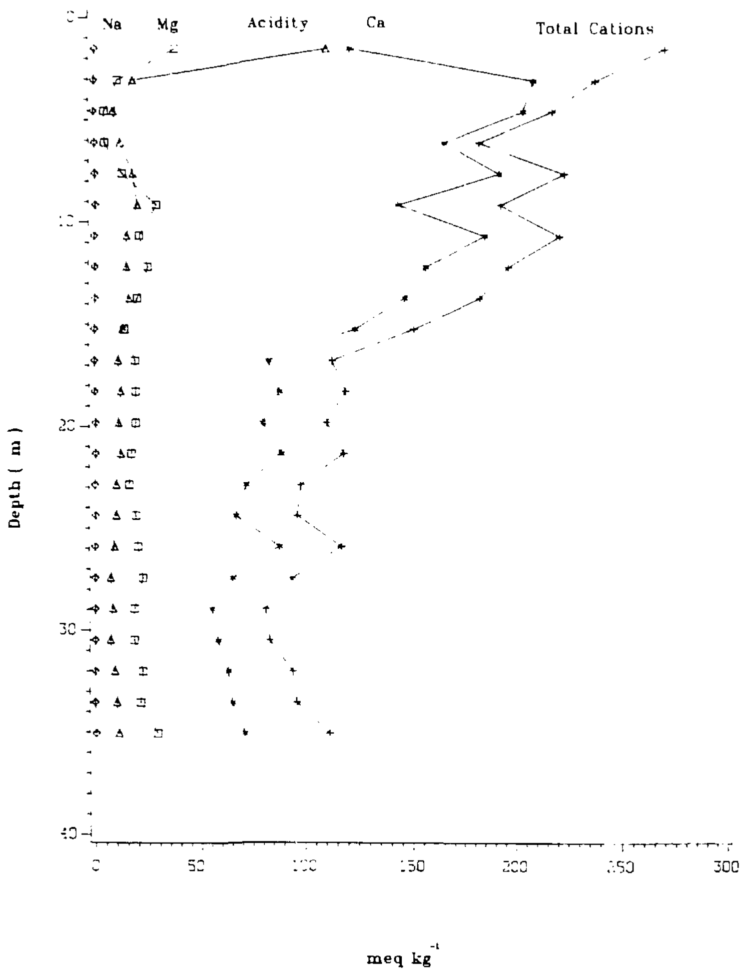


Fig. 5. Exchangeable Na, Mg, Ca, acidity, and total cation with depth within the Maryville limestone of the Conasauga Formation.

($Al^{+3}$ and $H^+$) and, hence, the lower the percentage of these sites would be occupied by basic cations. Calcium dominated these exchangeable bases when the base saturation increased, which accounts for its high correlation ($r = 0.90$) with percent base saturation and its negative correlation with exchangeable acidity ($r = -0.73$).

Hydrologic studies at the ETF site have focused on measurement of precipitation, surface runoff, and groundwater fluctuations. Precipitation for 1981 and 1982 was 1022 and 1295 mm, respectively, 19% lower (1981) and 2% higher (1982) than the annual average for the area. Runoff in two drainage channels (Flumes I and II) resulting from precipitation events has been summarized (7) and shows that the maximum flow was observed on May 30, 1981 (57.8 L/s for Flume I and 50.8 L/s for Flume II). Mean peak discharge for the 30 month period of record was calculated as 10.[illegible] L/s for Flume I (n = 60 storm events) and 10.0 L/s for Flume II (n = 121 storm events). These peak runoff values are being correlated with precipitation data so that expected maximum flows can be assigned for various amounts or classifications of precipitation. Runoff during periods of no precipitation is insignificant when compared to that occurring during storm activity, hence major effort has been on characterizing and measuring flow during storm events.

Groundwater fluctuations have been measured for a period of 2 years and indicate that the yearly change in water levels is approximately 1 m, exhibiting a maximum in the winter and a minimum in the late summer. Response of water levels to rainfall events is rapid, usually on the order of 5-10 h, and requires several days to return to prestorm conditions (Figure 6). Deeper wells (30-70 m) located on-site respond much less dramatically than the shallower wells (10 m deep) and appear to exhibit a <1 m annual fluctuation. Aquifer characteristics have been determined through a combination of tracer tests, pump tests, and in situ measurements of hydraulic conductivity. Tracer tests have been interpreted as showing rapid (60-65 d to peak concentration) movement of tracer along strike, between injection well ETF-1 and monitoring well ETF-3. The calculated value of a linear velocity is 0.17 m/d, based on the arrival time of the peak concentration of tracer. Values of hydraulic conductivity have been measured in each of the wells located at the ETF and appear to be spatially related to a fault structure found during trench construction. Mean hydraulic conductivity, based on these individual well slug tests, is $6.31 \times 10^{-5}$ cm/s, generally being higher between anticlines found in the center of the site and lower to the north and south of the site. Pump test data have been evaluated using a curve matching technique based on the Theis equation. From this analysis an aquifer transmissivity of $2.54 \times 10^{-3}$ $m^2$/min and a storage coefficient of 0.01 were calculated for the formation. These and additional data required as input for hydrologic modeling have resulted from the characterization study of the ETF site and are summarized in Table 2.

In summary, the ETF site characterization activities have been underway for two years with the goal of obtaining enough data to allow for hydrologic modeling and trench treatment evaluation. Constructing a reliable site model is essential for prediction and control of radionuclide migration which is required for approval to construct and operate a shallow land burial facility. However, no specific information is available to

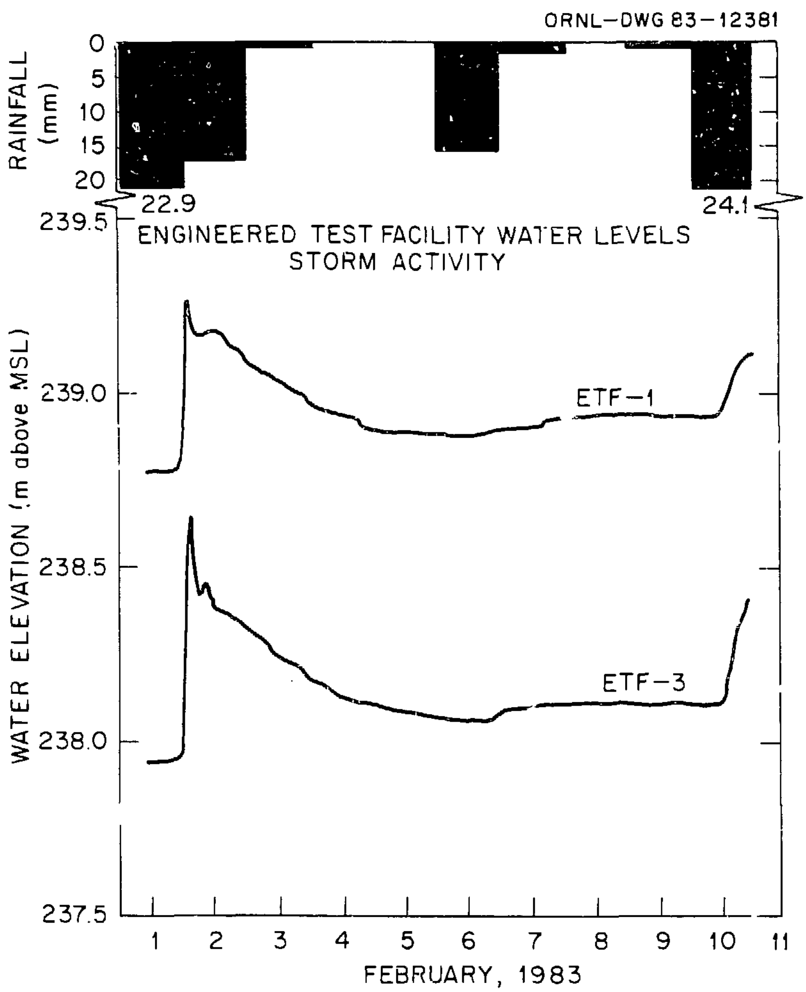


Fig. 6. Groundwater response to rainfall events for one week in February 1983.

TABLE 2. SUMMARY OF ENGINEERED TEST FACILITY SITE CHARACTERISTICS

GENERAL INFORMATION (see Sects. 2 and 3)

| | |
|---|---|
| Location | Oak Ridge, Tennessee<br>ORNL SWSA-6 |
| Experimental trench area | 0.3 ha |
| Flume I drainage area | 0.65 ha |
| Flume II drainage area | 0.88 ha |
| Monitoring wells | 44 (see Table 26) |

GEOLOGY (see Sect. 4.1)

| | |
|---|---|
| Formation | Maryville |
| Lithology | Silty limestone with interbedded mudstones and shales |
| Strike | N50°W |
| Dip | 30°SE |
| Structure | Highly deformed by small scale folding; heavily fractured |

Radionuclide, Chemical, and Physical Properties
(mean, 23 samples, 5-35 m depth, Maryville limestone)

| Property | Units | Value |
|---|---|---|
| Kd-$^{85}$Sr | L/kg | 63.1 |
| Kd-$^{134}$Cs | L/kg | 27,400 |
| Kd-$^{58}$Co | L/kg | 2720 |
| Kd-$^{125}$I | L/kg | 9.4 |
| Kd-$^{241}$Am | L/kg | 27,600 |
| Kd-(Ca+Mg) | L/kg | 56.0 |
| Exchangeable Ca | meq/kg | 113 |
| Exchangeable Mg | meq/kg | 19.1 |
| Exchangeable Na | meq/kg | 0.3 |
| Exchangeable acidity | meq/kg | 16.3 |
| Cation exchange capacity | meq/kg | 149 |
| pH | -log[H+] | 7.6 |
| $CaCo_3$ | % | 17.1 |
| Sand | % | 76 |
| Silt | % | 13 |
| Clay | % | 11 |
| Particle density | $Mg/m^3$ | 2.63 |

Table 2. (Continued)

SOILS (see Sect. 4.2)

Radionuclide Adsorption: Mean Kd-(0-2 m soil depth)

| Radionuclide | Units | Value |
|---|---|---|
| $^{241}Am$ | L/kg | 5670 |
| $^{85}Sr$ | L/kg | 494 |
| $^{137}Cs$ | L/kg | 64,100 |
| $^{60}Co$ | L/kg | 782 |
| $^{125}I$ | L/kg | 11.7 |
| $^{59}Fe$ | L/kg | 46,800 |
| $^{51}Cr$ | L/kg | 2780 |

Chemical Properties: Mean (0-2 m soil depth)

| Property | Units | Value |
|---|---|---|
| Exchangeable Ca | meq/kg | 20 |
| Exchangeable Mg | meq/kg | 31 |
| Exchangeable Na | meq/kg | 1 |
| Exchangeable K | meq/kg | 3 |
| Exchangeable acidity | meq/kg | 154 |
| Cation exchange capacity | meq/kg | 210 |
| Base saturation | % | 26 |
| Organic matter | % | 0.37 |
| $CaCo_3$ | % | 0 |
| pH | -log[H+] | 4.4 |
| Water hardness | mM | 0.12 |

Physical Properties: (0-2 m depth)

| | | |
|---|---|---|
| Bulk density | kg/L | 1.34 |
| Total porosity | L/L | 0.50 |
| Sand | % | 36 |
| Silt | % | 22 |
| Clay | % | 42 |
| Clay mineralogy | species | Illite chlorite vermiculite |
| Soil series | | Montevallo |
| Soil classification | Family | Loamy-skeletal, mixed, thermic shallow typic dystrochrept |

Table 2. (Continued)

HYDROLOGY (see Sect. 4.3)

| | |
|---|---|
| Climatic factors | |
| Precipitation, mean annual | 1388 mm |
| Precipitation, observed 1981 | 1022 mm |
| Precipitation, observed 1982 | 1295 mm |
| Surface water | |
| Peak discharge Flume I | 57.8 L/s |
| Peak discharge Flume II | 50.8 L/s |
| Low flow | 0 L/s |
| Infiltration (saturated) | |
| Trench cover material | $13.3 \times 10^{-5}$ cm/s |
| Undisturbed area | $1.56 \times 10^{-5}$ cm/s |
| Groundwater | |
| Aquifer characteristics | |
| Transmissivity (T) | $2.54 \times 10^{-3}$ $m^2$/min |
| Storage coefficient (S) | 0.01 |
| Hydraulic conductivity | $6.31 \times 10^{-5}$ cm/s |
| Effective aquifer thickness | 67 m |
| Effective porosity | 0.03 |
| Water chemistry | Calcium/ bicarbonate |
| Unsaturated zone | |
| Mean saturated | |
| Hydralic conductivity | $2.0 \times 10^{-7}$ m/s |

guide one in the modeling process. Work conducted at the ETF has focused on site characterization techniques relevent to hydrologic modeling, anticipating that many of these same methods will be used for characterizing future disposal sites with similar water-related problems.

## REFERENCES


1. Wilson, D.G. 1977. Handbook of Solid Waste Management. Van Nostrand Reinhold, Inc. New York, New York. 752 pp.

2. U.S. Department of Energy (USDOE). 1983. Radioactive Waste Management - Draft DOE Order 5820. U.S. Department of Energy, Washington, D.C. 22 pp.

3. U.S. Nuclear Regulatory Commission (USNRC). 1982. Final Environmental Impact Statement on 10CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." Summary and Main Report. U.S. Nuclear Regulatory Commission, Washington, D.C. NUREG-0945 Vol. 1.

4. Boegly, W.J., Jr., and E.C. Davis. 1983. Design and Construction of a Low-Level Waste Shallow Land Burial Experimental Facility. Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL/TM-8847. 22 pp.

5. Huff, D.D., G.T. Yeh, and D.L. DeAngelis. 1983. Effects of Macropores on Groundwater Flow and Transport of Radionuclides. In Proceedings, 5th Annual DOE LLWMP Participants' Information Meeting. August 30 to September 1. Denver CO. In Press.

6. Davis, E.C., B.P. Spalding, and N.D. Vaughan. 1982. Development of Trench Lining and Grouting Techniques for the Field Demonstration of Improved Shallow Land Burial Practices for Low-Level Radioactive Solid Waste. Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL/NFW-82/31. 41 pp.

7. Davis, E.C., W.J. Boegly, Jr., E.R. Rothschild, B.P. Spalding, N.D. Vaughan, C.S. Haase, D.D. Huff, S.Y. Lee, E.C. Walls, and E.D. Smith. 1983. Site Characterization Techniques Used at a Low-Level Waste Shallow Land Burial Field Demonstration Facility. Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL/NFW-83/13. 230 pp.

8. Vaughan, N.D., C.S. Haase, D.D. Huff, S.Y. Lee, and E.C. Walls. 1982. Field Demonstration of Improved Shallow Land Burial Practices for Low-Level Radioactive Solid Wastes: Preliminary Site Characterization and Progress Report. Oak Ridge National Laboratory, Oak Rid , Tenn., ORNL/TM-8477. 112 pp.

9. Geo-Centers, Inc. 1982. Ground Penetrating Radar Proof of Principle Test, Oak Ridge National Laboratory. Geo-Centers Inc., Newton Upper Falls Mass., GC-TR-82-229. 46 pp.

10. Sledz, J.J., and D.D. Huff. 1981. Computer Model for Determining Fracture Porosity and Permeability in the Conasauga Group. Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL/TM-7695. 138 pp.

11. Krumhansl, J.L. 1979. Final Report: Conasauga Near-Surface Heater Experiment. Sandia Laboratory, Sandia, New Mexico, SAND 79-1855.

12. Jackson, M.L. 1974. Soil Chemical Analysis - Advanced Course. 2 nd. Ed., Univ. of Wis., Madison, Wis. 990 pp.