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REMEDIAL-ACTION TECHNOLOGY-ARID

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ABSTRACT

A summary is presented of the low-level waste remedial action program at Los Alamos. The experimental design and progress is described for the experiments on second generation intrusion barrriers, subsidence effects on SLB components, moisture cycling effects on chemical transport, and erosion control methodologies.

The soil moisture data from the bio-intrusion and moisture cycling experiments both demonstrate the overwhelming importance of vegetation in minimizing infiltration of water through trench covers and backfill. Evaporation, as a water loss component in trench covers, is only effective in reducing soil moisture within 40 cm of the trench cover surface. Moisture infiltrating past the zone of evaporation in unvegetated or poorly vegetated trench covers is in storage and accumulates until drainage out of the soil profile occurs. Judicious selection of vegetation species for revegetating a low-level waste site may prevent infiltration of moisture into the trench and, when coupled with other design features (i.e. trench cover slope,tilling and seeding practice,) may greatly reduce problems with erosion.

Standard U.S. Department of Agriculture erosion plots, when coupled with a state-of-the-art water balance and erosion model (CREAMS) promises to be highly useful in screening proposed remedial action cover designs for low-level waste sites. The erosion plot configuration allows for complete accounting of the water balance in a soil profile. This feature enables the user to optimize cover designs to minimize erosion and infiltration of water into the trench.

INTRODUCTION

This paper summarizes the status of experiments to develop and evaluate arid site remedial action technology for low-level radioactive waste. The extensive data sets that are available for several of the remedial action subtasks have been reserved for publication elsewhere and will not appear in this summary.

Most of the problems requiring remedial action at low-level waste sites in the U.S. involve water and/or erosion of the trench cover, infiltration of water into the trench contributing to subsurface transport and subsidence, and capillary movement of water upward as a result of wetting-dry cycles (Fig. 1). Potential problems with biota include intru sion of plant roots and burrowing animals into the waste and enhanced water related problems (i.e.increased infiltration and surface erosion) as a result of excessive animal burrowing in the cover soil and backfill.

Because most of the preceding problems either directly or indirectly involve processes interacting with the trench cover (Fig.1), most of our remedial action studies have focused on this component of the shallow land burial system. The approach we have taken in developing remedial action technology for low-level waste sites is to recognize that physical and biological processes affecting site integrity are interdependent and, therefore, cannot be treated as separate problems. For example, vegetation cover on a site plays a vital role in regulating the behavior of water in the trench cover and backfill (i.e. erosion and infiltration). In retrospect, then, it is clear that an understanding of the nature of the interdependence of physical and biological processes is necessary in order to capitalize on relationships which increase waste site stability

Remedial action experiments which will be addressed in this paper are:

(1) second generation bio-intrusion barrier testing,

(2) subsidence effects on burial system components,

(3) moisture cycling effect on chemical transport,and

(4) erosion control technology.

SECOND GENERATION BIO-INTRUSION BARRIER SYSTEMS

There are several experiments underway in the U.S. to develop bio-intrusion barrier systems for large volume solid wastes (1,2). At Los Alamos, we have pursued the feasibility of using geological materials as bio-intrusion barriers because these materials are not readily subject to decom position and they are generally locally available and relatively inexpensive to apply.

Results of short-term, small-scale experiments (1) conducted in 25 cm diameter lysimeters at the Los Alamos Experimental Engineered Test Facility (EETF) demonstrated the effectiveness of layered cobble-gravel-soil cover systems in preventing plant root and burrowing animal intrusion into simulated waste compared with conventional cover systems. The next step in the further evaluation of cobble-gravel intrusion barriers for application to low-level waste sites requires answers to the following questions:

(1) Do cobble-gravel intrusion barriers perform satisfactorily at larger scales,

(2) What effect do layered rock barrier systems have on the water balance, and

(3) How are the layered rock intrusion barrier systems affected by subsidence?

The questions about experiment scale and the effect of the rock barrier on the water balance are being addressed simultaneously in two separate experiments. An intermediate scale experiment is underway in the large caissons at the EETF (Fig.2) while a large scale study plot (Fig.3) has been included in the cover system recently applied to Area B as a part of a necessary remedial action. The Area B low-level waste site was decommissioned in 1947. Both experiments include a cobble-gravel intrusion barrier along with a corresponding control (or conventional) cover treatment. Simulated waste placed in a narrow band immediately below the cover profiles will indicate root penetration through periodic sampling of vegetation for the plant- available tracers.

A cover profile consisting of either crushed tuff or cobble-gravel overlain by 60 cm of topsoil was placed over the simulated waste in the caisson experiments. In the Area B plots, the tracer was applied directly to the old waste cover surface. In the control plot, 90 cm of topsoil was applied over the tracer similar to the treatment that the remainder of Area B received. The other plot consisted of the cobble-gravel intrusion barrier overlain by 60 cm of topsoil.

A topsoil depth of 60 cm was used on most of the plots as a compromise between optimum topsoil depth and cost. Simulations with a water balance model (CREAMS (3)) indicated that 60 cm of topsoil with a medium density (25%) range grass cover would reduce the probability of water infiltrating into and through the barrier system by a factor of four compared with a bare soil surface. Additional topsoil, up to 90 cm, would eliminate the probability of water infiltrating through the rock barrier system and into the waste, but at additional expense and loss of waste storage volume.

Neutron moisture probe measurements have been made routinely in the cover to evaluate soil moisture status in each plot. The intermediate scale experiments in the caissons at the EETF receive both natural and supplemental precipitation while the large scale plots at Area B receive only natural precipitation. The caisson experiments were seeded to Barley while the Area B plots were seeded with a mixture of native grasses.

Measurements that have been made through time include the tracer (simulated waste) content of vegetation and soil moisture versus depth in the cover and backfill.

Data on the moisture status of the topsoil and backfill above and below the crushed tuff and cobble-gravel intrusion barriers in the large caissons are plotted in Figs. 4 and 5 along with the precipitation added to each plot.

The moisture data in the backfill indicate no appreciable differences between plots despite acute inputs of as much as 5 cm (2 in) precipitation. Backfill soil moisture has averaged about 14-15% by volume in both plots from the beginning of the experiment.

The importance of vegetation in controlling the moisture balance in the soil profile is shown by the moisture data for topsoil in (Figs. 4 & 5). Initial soil moisture of about 26% by volume in both plots decreased steadily to about 10% during the first 4-6 weeks of the study. Although precipitation additions to the topsoil are reflected by increases in topsoil moisture, these additions have little lasting effect on moisture in storage. For example, the addition of 2.3 cm of water to the plots on July 29 were apparent in soil moisture for only about a 6 day period. Calculations suggest that evapotranspiration rates under these circumstances (28% ground cover by Barley) are roughly 10 L M^{-2} D^{-1} (or 10^5 L Ha^{-1} D^{-1}). Supplemental precipitation is now being added in increasing amounts to determine the maximum potential of the vegetated topsoil in preventing infiltration through the cover and into the simulated waste. The 5 cm water addition on August 9 represents the first of the additions. Comparisons of the response of soil moisture to the additions of water will be made with predictions based upon the CREAMS water balance model (3) in order to further evaluate the potential use of CREAMS in designing low-level waste cover systems that mimimize water related problems.

Data on the tracer content of vegetation from the beginning of the caisson experiment are not available at this time, nor are any of the data from the recently completed Area B plots.

SUBSIDENCE EFFECTS ON BURIAL TRENCH COMPONENTS

Subsidence cavities measured on actual burial trenches vary widely in both size and shape and range from broad, shallow depressions to narrow pipes that may extend into the waste. Burial site surveys indicate that about 85% of the measured subsidence cavities are less than 2.75 m in diameter and 95% are less than 4.25 m in diameter. Subsidence efects on various components of SLB systems will be evaluated from field experiments at the EETF. The intial focus of these studies has centered on the effects of subsidence on bio-intrusion barrier system integrity. Subsidence cavities of five sizes ranging from none (control) through the maximum size observed at actual sites will be created beneath cobble-gravel cover systems as shown in Table 1. The experiments will be conducted in a trench 38 m long, 15 m wide, and 3 m deep. Beneath each plot a 0.9 m diameter hole will be augered into solid tuff to a depth necessary to equal the desired volume of the subsidence cavity (Table 1). A 1.5 m square steel plate containing a hinged trap door fastened closed by mechanical closures will be placed over each of the drawholes. (Fig. 6). The drawhole configuration will allow the trap door to open fully. The entire trench will be backfilled to a depth of 2.2 m with screened (5 cm mesh) crushed tuff. In order to cause immediate subsidence, the uncompacted backfill will be used, allowing free gravity flow into the drawholes when the trap doors are released. The backfill will be covered with 0.9 m of cobble-gravel barrier material and 0.6 m of topsoil. A layer of cesium-chloride tracer will be placed at the backfill/barrier interface to indicate root penetration through the barrier under various degrees of subsidence (Fig. 7). Alfalfa will be planted on the surface of each plot.

When the drawhole closures are released, backfill will drain into the drawholes, causing subsidence at the surface. The subsided cavities will approximate right circular cones having slope angles of 35° to 40°.

Unavoidable slow subsidence of the entire trench surface will be observable throughout the duration of the experiment, resulting from continued compaction of the backfill. This secondary subsidence will be monitored by routinely surveying the elevation of the trench surface by means of marked rods positioned at the corners of the experimental plots.

Plant root penetration will be monitored by routine sampling of leaves. Cesium concentrations in the leaves will be measured as a function of time and location relative to the subsided cavities. Root penetration (if any) can be expected to occur first at the cavity rims, where maximum tensile stress will occur.

At the end of the experiments (FY84), the plots will be excavated to verify the tracer data. At the same time, both the upper and lower surfaces of the biobarrier will be mapped to determine the physical effects of subsidence on the barrier and to correlate with the tracer data and root measurements.

MOISTURE CYCLING EFFECTS ON CHEMICAL TRANSPORT

A process about which little is known is the effect of capillary forces created by evaporation of water at the soil surface in drawing soil moisture and soluble chemicals to the surface of a low-level waste site. A study was initiated to evaluate the importance of the process as a radionuclide transport mechanism and to determine the relationships of this transport to soil water status, soil temperature, and the presence or absence of vegetation on the soil surface. Information was also gathered on the relative importance of evaporation versus evapotranspiration (Fig. 1) in soil water behavior.

Sixteen soil columns (0.91 m diameter by 1.5 m deep) were contsructed in metal culverts that were filled with screened (0.6 cm mesh) crushed tuff according to the experimental design shown in Fig. 8. Experimental variables were initial soil moisture status, simulated waste burial depth, and the presence or absence of plants (Table 2). Stable isotopes of cesium, strontium and cobalt were used to monitor liquid phase transport while tritiated water was used to evaluate vapor phase transport.

Measurements of soil moisture within each profile were made through time with a neutron probe. Soil temperature measurements were routinely made at various depths in each profile (Fig. 9) with copper-constantan thermocouples. Both natural and supplemental precipitation were used in watering the soil columns. The vegetated plots were seeded to Barley, Alfalfa and Yellow Sweet Clover. At the conclusion of the experiment (late FY82), horizontal soil cores will be taken at various depths in each profile to evaluate vertical transport of the tracers as a function of experimental variables. Average soil moisture in two of the 16 soil columns as a function of time are plotted in (Fig. 10) along with monthly water additions. The upper curve represents average soil moisture in an unvegetated plot; the lower curve is the corresponding data for the vegetated plot. A total of about 90 cm of water was applied to each column during the one year period represented in Fig. 10.

Soil moisture (% by volume) as a function of time increased by about a factor of two in the non-vegetated soil column. The implication of these data are that evaporation at the soil surface (Fig. 1) does not have the capability of preventing soil moisture accumulation within the soil profile at the watering levels used in this experiment. In fact, the soil moisture data as a function of depth in the profile (Fig. 9) suggest that evaporation only affects soil moisture to a maximum depth of 40 cm. Soil temperature data support that contention (Fig. 9) in that the major variation (based on early morning and mid-afternoon measurements in June) in soil temperature occurs within 25 cm of the soil surface. Soil moisture at about 36% (by volume) as measured 130 cm deep in the soil column (Fig. 9) suggest that the lower layers of the unvegetated soil column are approaching or are at saturation.

In contrast, the vegetated surface not only has effectively transpired all of the added water (90 cm) from the soil column, but has also removed most of the initial soil water present at the start of the experiment (Fig. 10). Soil moisture as a function of depth in the vegetated profile was relatively constant and low at 10% by volume water.

The addition of water to the non-vegetated and vegetated soil columns is clearly reflected by increases in soil moisture. In the unvegetated column, addition of precipitation caused corresponding increases in soil moisture with little or no losses between subsequent water additions. In the vegetated soil column, addition of water was reflected by the soil moisture data but only for short periods of time because of the capability of transpiration to remove these additions.

The soil moisture data from this experiment clearly demonstrates the advantages of vegetation in controlling soil moisture and thus preventing accumulation of water in the soil profile. Information is needed on the water use efficiency of native plant species that are seeded or that invade low-level waste sites to select a vegetation cover that maximizes transpiration losses of water to the atmosphere.

SOIL EROSION CONTROL TECHNOLOGY

A particularly important aspect of erosion control methods is that they are often effective because they enhance infiltration rates and reduce surface runoff. Although this may reduce erosion it can cause additional problems with moisture seepage or percolation through the trench cover profile. Research is needed to quantify the interaction between erosion control technologies and water balance in the soil profile.

The results of the modeling and experiments in this subtask will provide experimental data on erosion control technologies suitable for arid SLB sites, as well as information on the effect of erosion control technologies on subsurface components of the water balance. The results obtained in these experiments will permit the comparison of these results with the results obtained in similar experiments by the USDA and will provide the interface to use the data obtained from agricultural systems for application to SLB. It will also extend the hydrologic model, CREAMS (a field scale model for Chemicals, Runoff and Erosion from Agricultural Management Systems), to cover the unusual surface treatments proposed to cover closed out disposal sites.

Both the CREAMS (3) modeling and field research efforts at Los Alamos will center around successfully determining values for the soil erodibility factor and the cover management factor of the Universal Soil Loss Equation(USLE), as well as determining water balance relationships for the trench cap environment. The soil erodibility factor of the USLE is an experimentally determined value for a particular soil, whose value is influenced by properties such as soil texture, organic matter content, soil structure, and permeability. The cover management factor of the USLE is influenced by plant canopy, plant residue mulch and tillage and waste management practices affecting soil porosity, roughness, compaction and microtopography. The water balance relationships are not only important for a successful prediction of soil loss rates from the trench cap, since there is such a strong correlation between soil erosion rates and soil runoff rates, but also also us to predict percolation of water through the trench cap and surface losses of water through evaporation and plant transpiration.

Four pairs of 10X35 foot erosion plots have been constructed at the Experimental Engineered Test Facility (EETF) where soil loss rates have been measured during experimental runs with a USDA rotating boom rain simulator. Soil erodibility factors will be determined on four of these plots for bare soil covers with standard Los Alamos SLB configurations (six inches of topsoil over about thirty inches of backfill) and with disked surfaces (Fig. 11). The other four plots will be used to determine the cover management facor for a 25% and 75% vegetative cover of barley.

Water balance relationships will be determined for all 8 plots using a neutron moisture probe at various soil depths in 3 locations per erosion plot. The amount of precipitation (applied at a rate of 2.5 inches/hour) was measured during each 1-hour simulator run, as well as the total amount of runoff and sediment yield. Evapotranspiration will be calculated by solving the water balance equation using experimental data to estimate all the remaining variables in the equation. Field measurements of leaf area index for the barley cover will also be made to validate CREAMS estimation of water losses due to plant transpiration.

In (FY83) 4 new pairs of 10X35 foot erosion plots will be emplaced at the EETF and 2 of the (FY82) plot pairs will be reused. The four vegetated plots that were used in (FY82) will be reused to determine the cover management factor for gravel and riprap erosion control treatments (Fig. 12). The most promising biobarrier or wick system, as determined by other Los Alamos experiments, will be included in the four new erosion plots to determine a soil erodibility and cover management factor for CREAMS. The remaining 4 new plots will be used to determine the cover management factor for natural range grass cover on a trench cover to compare with similar data collected in FY-82 on barley covers.

The data generated on soil erosion, water balance relationships, and CREAMS parameters at Los Alamos, at Bosie, Idaho and at Tombstone, Arizona will be used by research groups in the USDA and within the LLWMP. This will allow the LLWMP to utilize a very broad data base from the agricultural research community, and result in a more generic solution to problems encountered in the design of shallow land repositories located throughout the arid and semiarid areas of the western U.S.

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   WASTE MANAGEMENT '82'

TABLE 1. DIMENSIONS OF CAVITIES AND DRAWHOLES

Desired Subsidence Cavities[a]			Required Drawhole Dimensions	
Drawdown (m)	Diameter (m)	Volume (m^3)	Diameter (m)	Depth (m)
0.75	2.4 – 2.9	1.5 – 2.22	0.9	3.3
1.0	3.6 – 4.4	5.3 – 76	0.9	11.5
1.25	1.8 – 2.1	0.6 – 0.9	0.9	1.35
1.5	3.0 – 3.6	2.9 – 4.2	0.9	6.4

[a]Slope of cavity sidewalls is 35 to 40°.

TABLE 2. MOISTURE CYCLING EXPERIMENT

The purpose is to determine whether water movement back to the surface of a low-level radioactive waste disposal pit caused by the drying of the surface in an arid environment is a possible pathway for transporting contaminants to the surface of the facility.

Experiment Variables	
Tracer depth	30 and 60 cm
Average moisture content	25 and 50% saturation
	10 and 20 vol% water
Presence or absence of plants	
Measurements	
Water content	Neutron moisture probe
Temperature	Copper Constantan thermocouples
Analysis of soil profile at the end of the experiment	
Tracers Used	
Liquid phase	Stable Cs, Sr, and Co
Vapor phase	Tritium as tritiated water

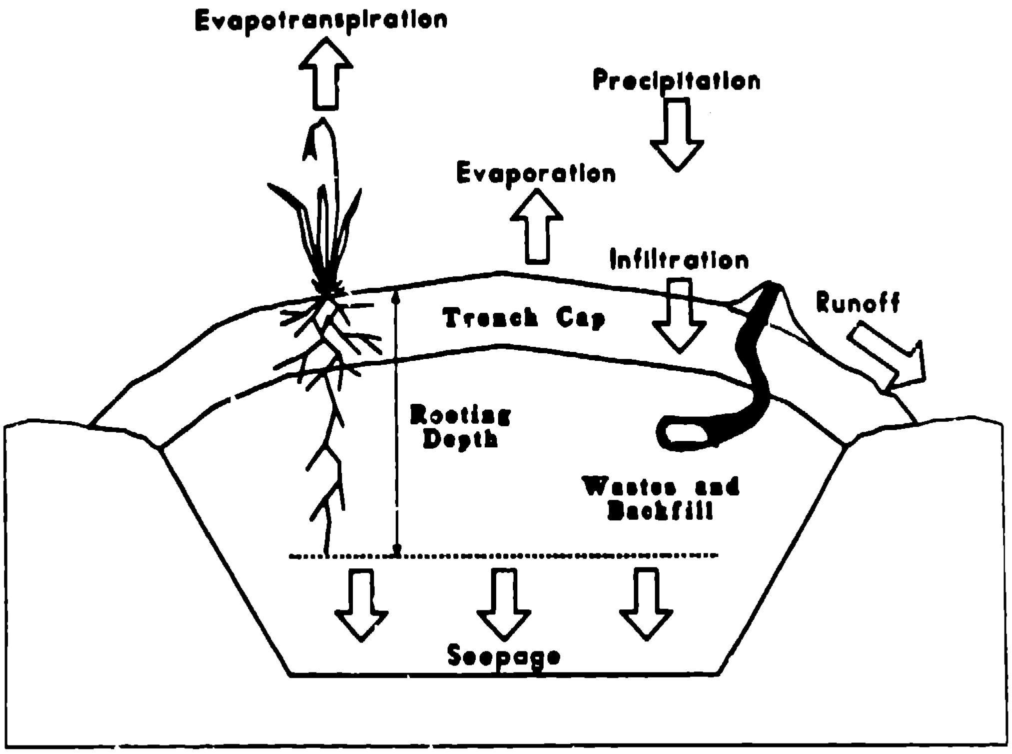


FIGURE 1

TRANSPORT PATHWAYS - SLB

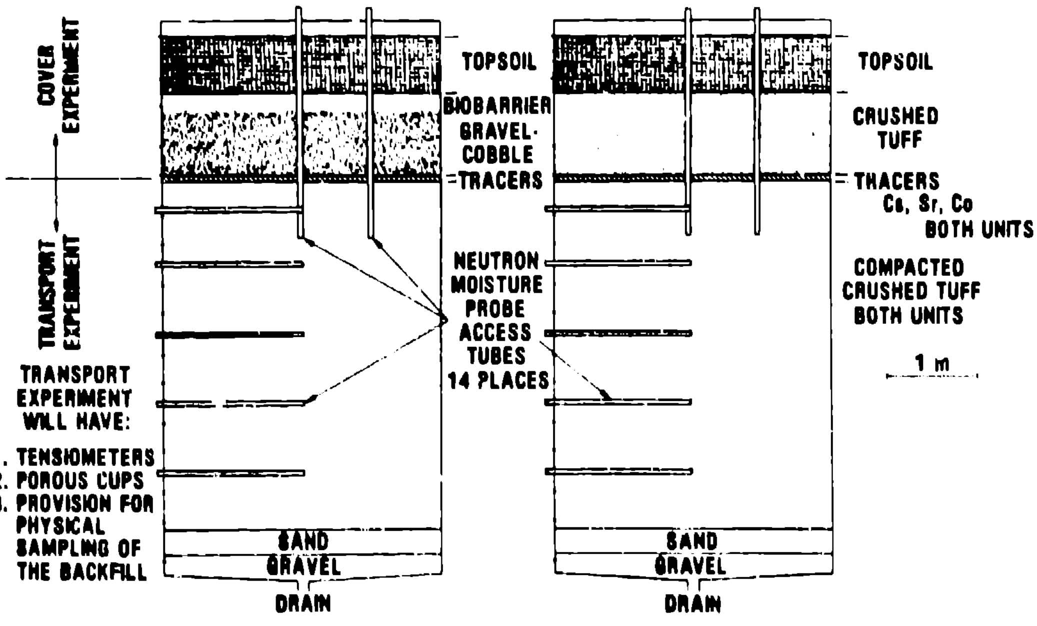


FIGURE 2

BIOINTRUSION BARRIER/TRANSPORT EXPERIMENT

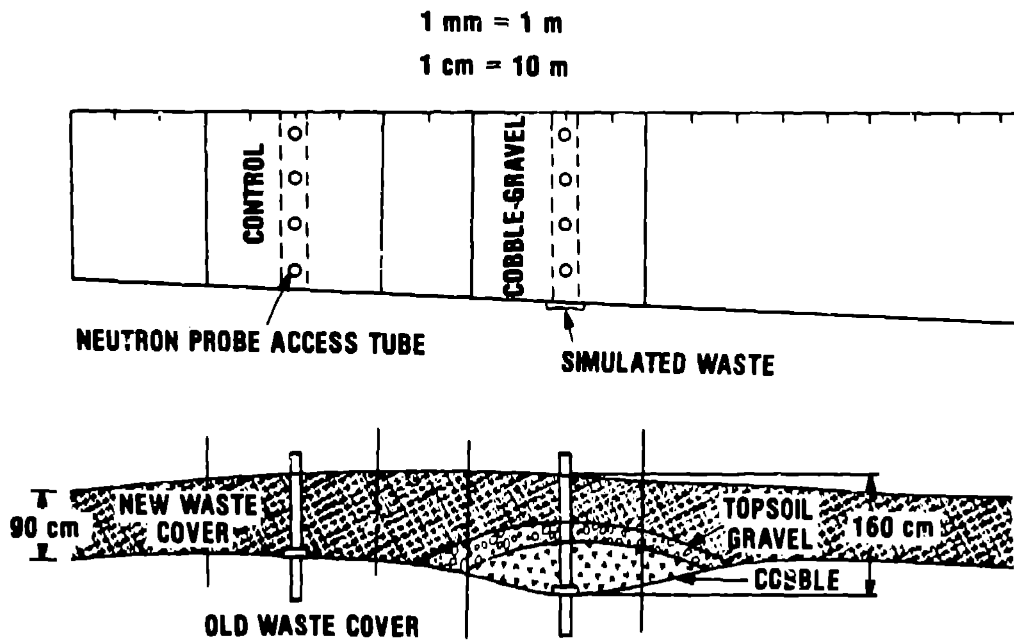


FIGURE 3

AREA B — LOW-LEVEL WASTE SITE BIO-INTRUSION STUDY (SITE DECOMMISSIONED IN 1947)

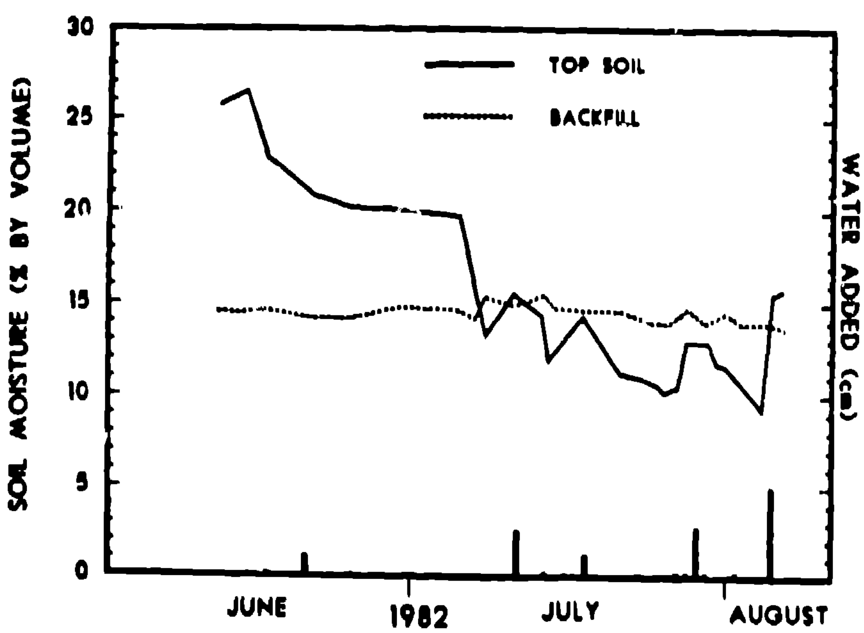


FIGURE 4

MOISTURE IN CRUSHED TUFF BARRIER COVER SYSTEM

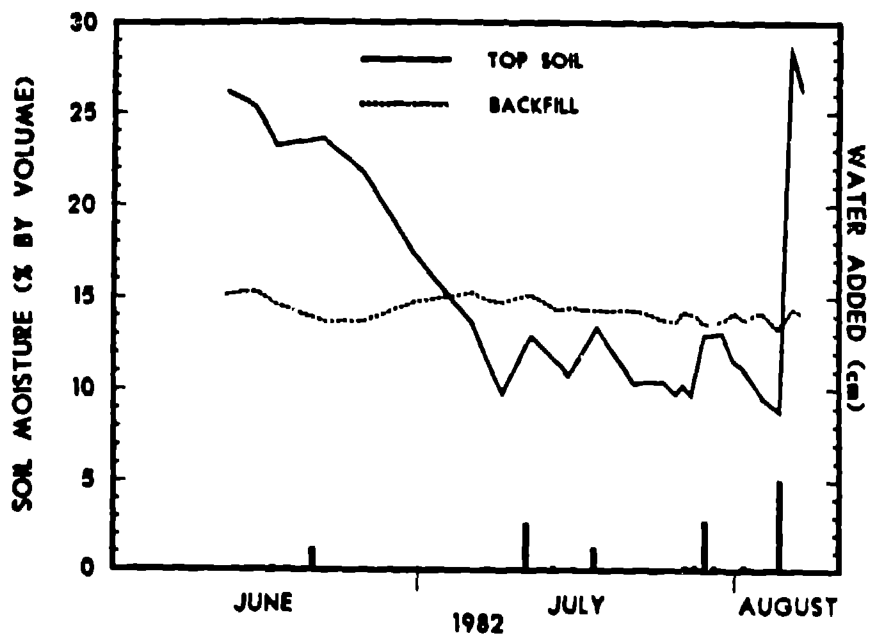


FIGURE 5

MOISTURE IN COBBLE - GRAVEL BARRIER COVER SYSTEM

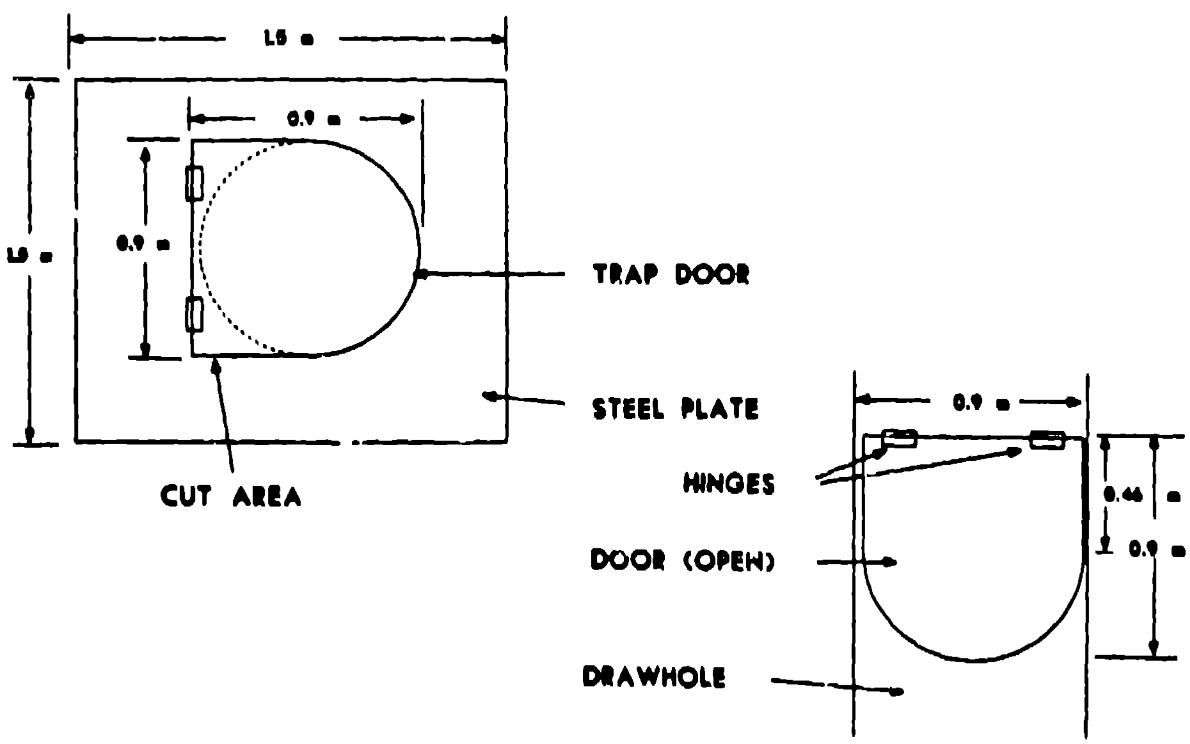


FIGURE 6

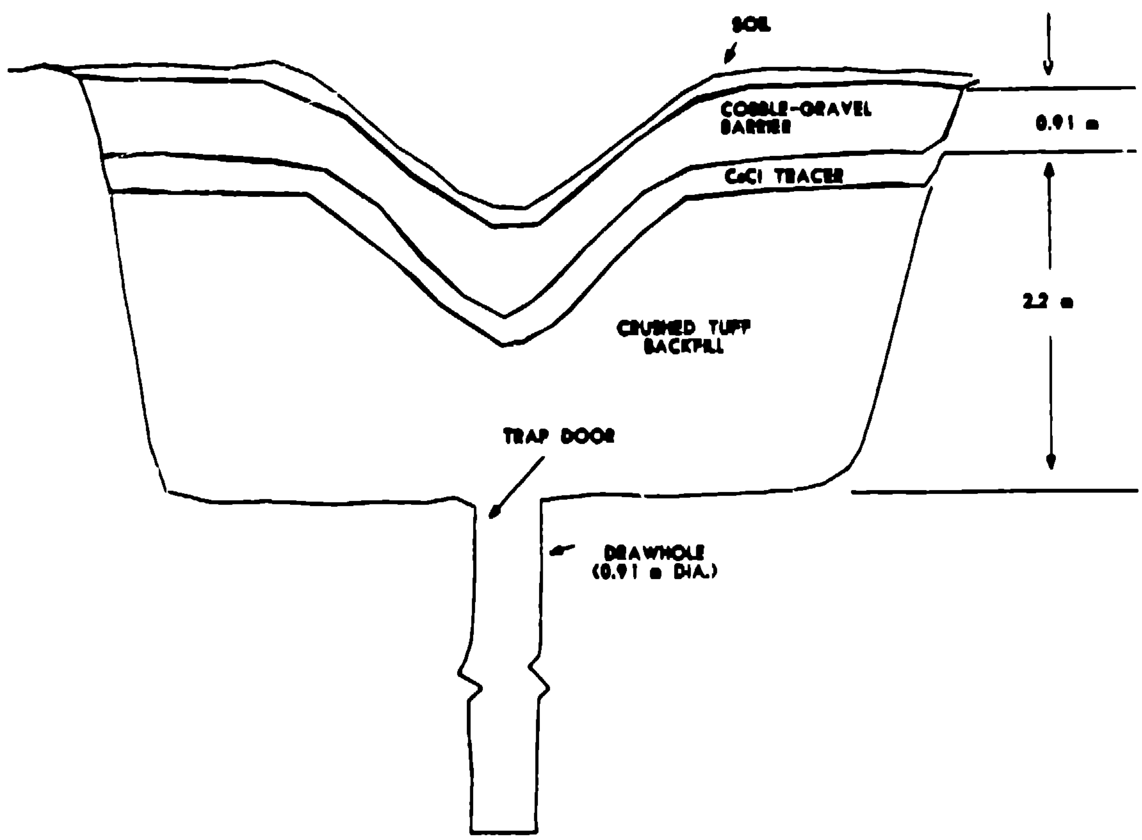


FIGURE 7

SUBSIDENCE TESTING OF BIOLOGICAL INTRUSION BARRIERS

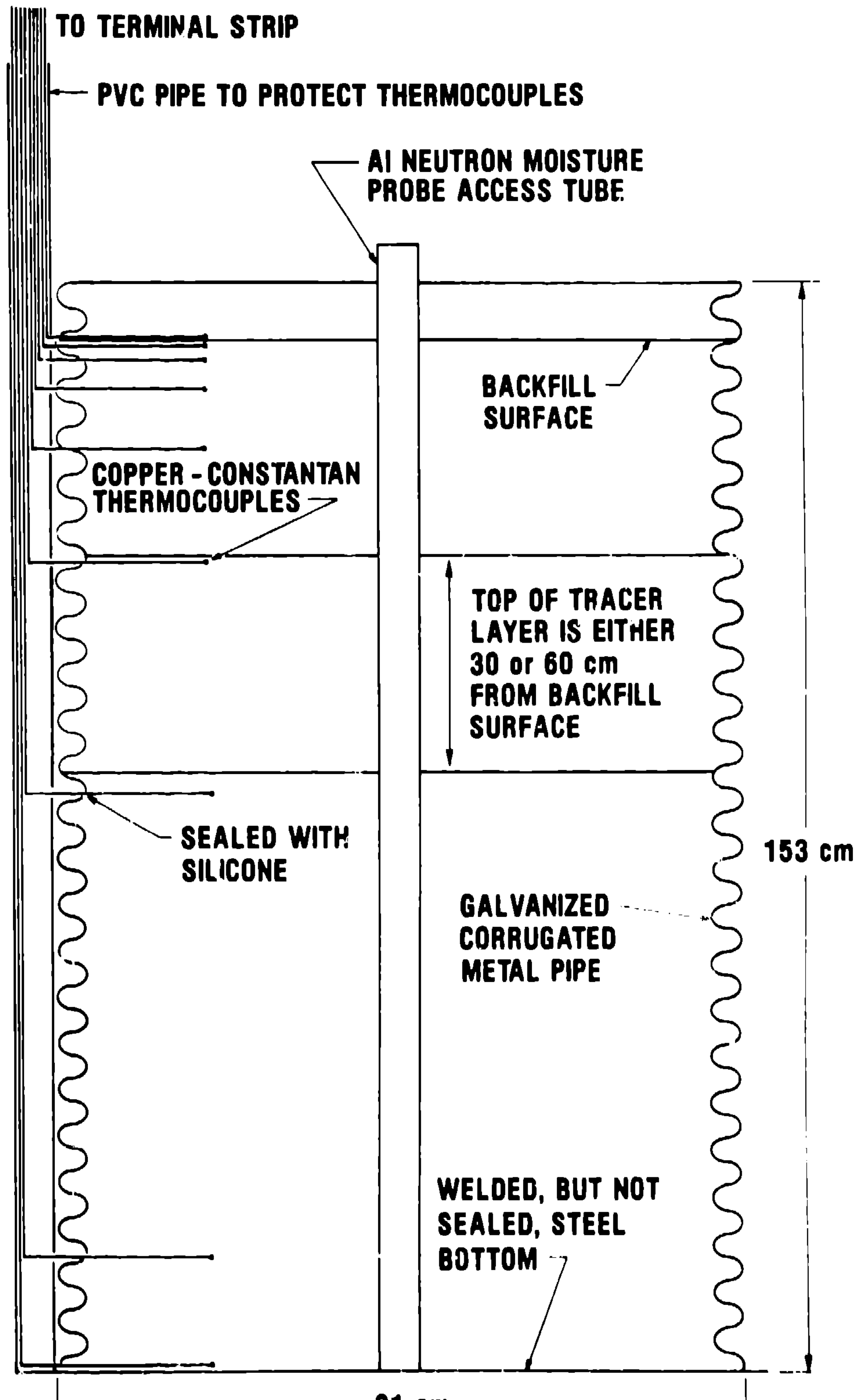


FIGURE 8

MOISTURE CYCLING EXPERIMENTAL UNIT

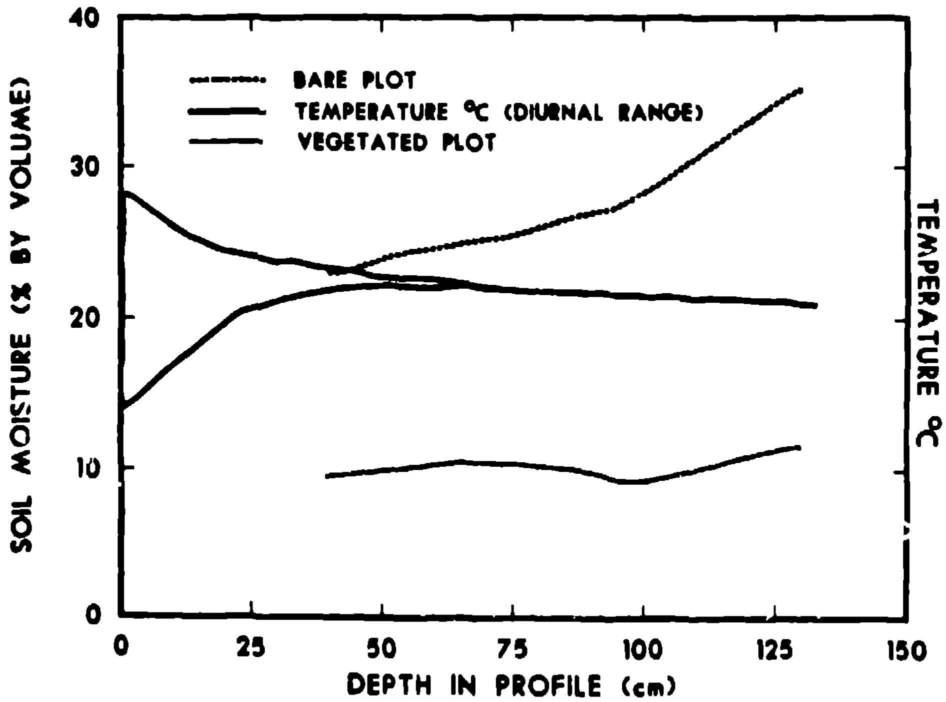


FIGURE 9

SOIL MOISTURE ON 7/20/82

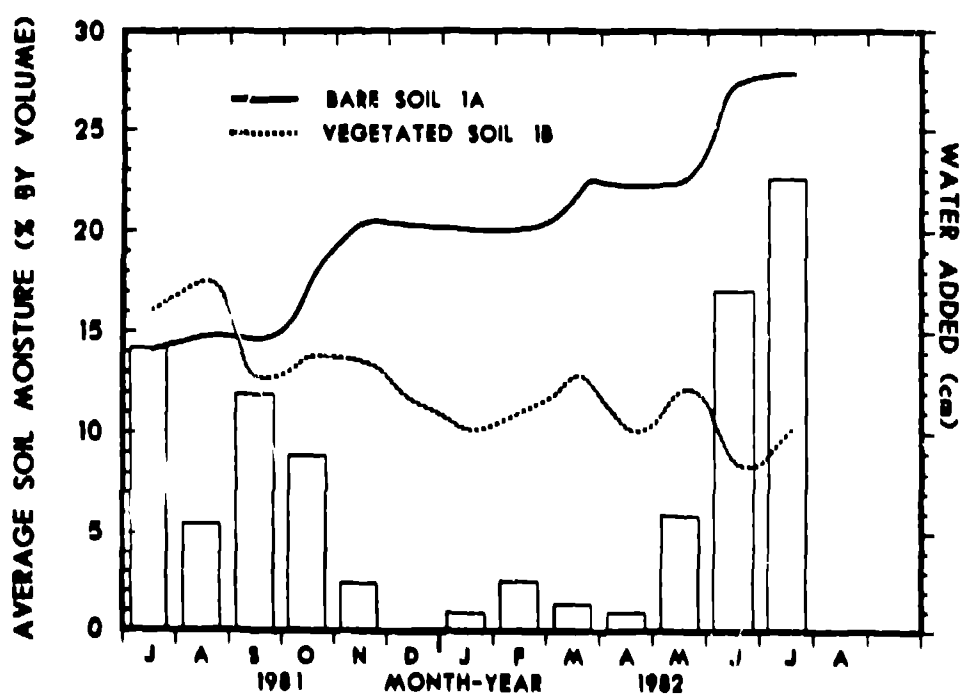
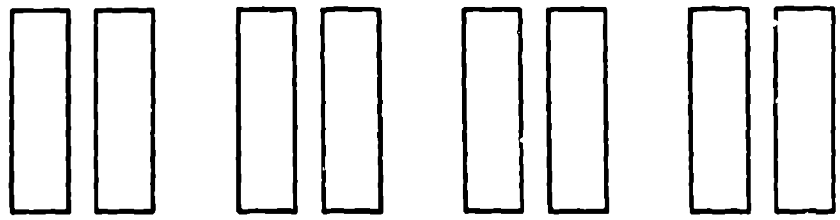


FIGURE 10

BEHAVIOR OF WATER IN BARE AND VEGETATED SOIL PROFILES

1. Emplace 4 pairs of 35 x 10 foot erosion plots:



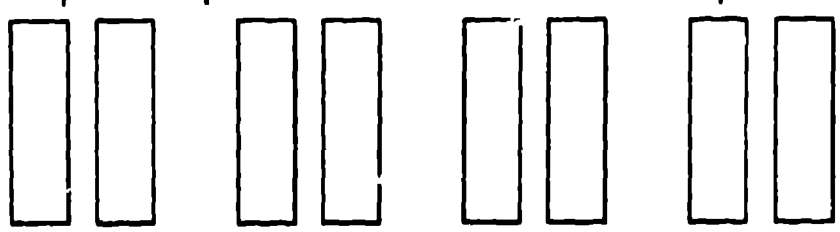
2. Plot treatments:
   A. 4 plots to determine soil erodibility factor for bare soil covers:
      2 plots: standard SLB configuration
      2 plots: tilled surface

   B. 4 plots to determine cover management factor:
      2 plots: sparse barley cover
      2 plots: dense barley cover

FIGURE 11

FY82 EROSION FIELD EXPERIMENTS

1. Emplace 4 pairs of 35 x 10 foot erosion plots



2. Plot treatments:
   A. 4 plots to determine soil erodibility and cover management factors for profiles containing biobarriers or wicks

   B. 4 plots to determine the cover management factor for natural range grass cover to compare with the fy82 barley cover data

   C. 4 plots to determine the cover management factor for fy82 plots with gravel-riprap added

FIGURE 12

FY83 EROSION FIELD EXPERIMENTS