for Kelly

LA-11257-PR
Progress Report

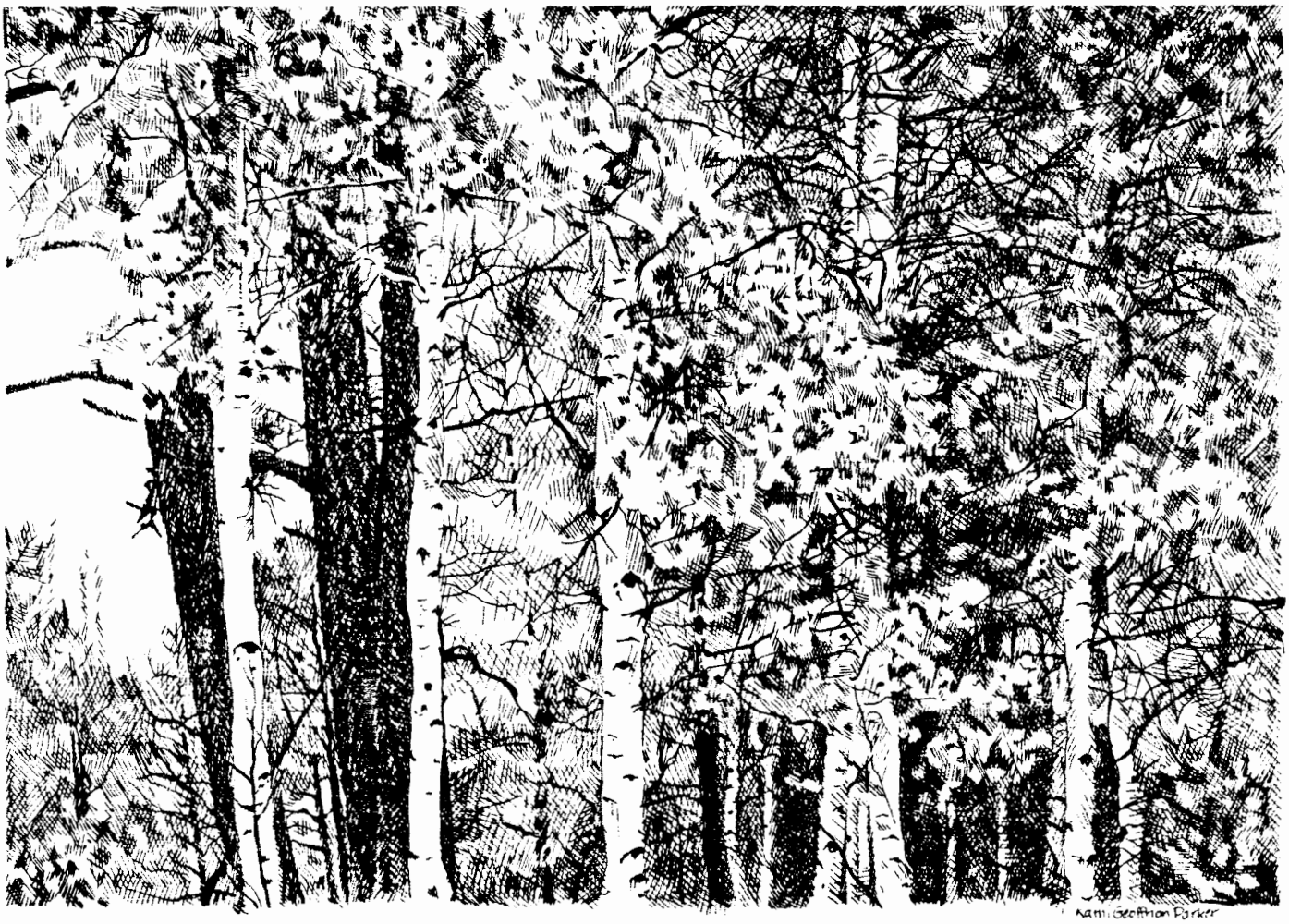
Report
8/29/89

Health, Safety, and Environment Division

Annual Report 1987

RECEIVED
AUG 29 1989

from Greg Mello



8016

Los Alamos

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

TL

Trench Cover Systems for Manipulating Water Balance on Low-Level Radioactive Waste Sites An Intermediate-Scale Demonstration Project

Authors: *[redacted] W. Nyhan (Principal Investigator), B. J. Drennon, J. L. Martinez, and T. E. Hakonson*
Group: *Environmental Science, HSE-12*
Cooperators: *USDA–Agricultural Research Service, Aridland Watershed Management Unit, Tucson, Arizona; and National Soil Erosion Laboratory, Purdue University*
DOE Office of Health and Environmental Research, Ecological Research Division
Colorado State University
Funding Organization: *DOE National Low-Level Radioactive Waste Management Program*

The Environmental Science Group at Los Alamos National Laboratory began studies of water balance on low-level waste trench caps in 1981 as the arid site for the DOE National Low-Level Radioactive Waste Management Program. Those studies were conducted in a 9-ha field site designated as the Los Alamos Experimental Engineered Test Facility[1] and relied on rainfall simulator technology[2] to evaluate the hydrologic response of a variety of trench cover designs. Large caissons (3-m diam by 6 m deep) were also used to investigate subsurface processes, including the influence of capillary barriers on percolation. Results of that work have been published in 138 journal papers, symposia proceedings, and government and Laboratory reports.

In 1984, the results from several previous studies were used to design and emplace a cover demonstration called the Low-Level Integrated Systems Test Project.[3] The purpose of the demonstration was to monitor and compare water balance[4] on a conventional trench cap design with that on an improved design. The latter design incorporated our best available knowledge on methods to control erosion,[5,6] percolation,[7-10] and biological intrusion.[7]

The demonstration plots were designed and instrumented so that a complete accounting of precipitation falling on the plots could be made. The plots, which were about 3 by 10 m, were constructed and instrumented (Figures 1 and 2) to provide measures of runoff and erosion, soil water storage, and seepage, as measured by leachate production at the various drains.[3] Only natural precipitation was added to the plots during the study.

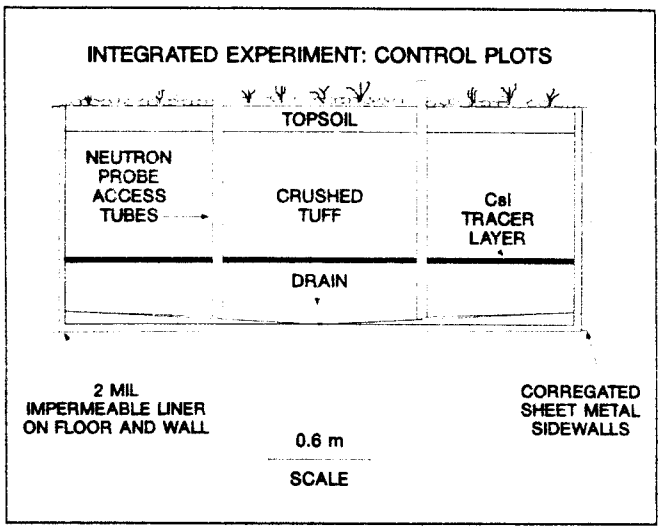


Figure 1. Conventional trench cap design on the Integrated Systems Test plots. Instrumentation for measuring soil water also includes thermocouple psychrometers and tensiometers. The CsI tracer was used to indicate plant root intrusion. The surface had a 0.5% downslope gradient and a 60% to 70% gravel mulch and grass cover.

The technology for controlling erosion on the plots consisted of applying a 60% to 70% cover of gravel (2-cm diam) and a plant cover of blue gramma (*Bouteloua gracilis*) and western wheat grass (*Agropyron smithii*) to a mild slope of 0.5%. Experimental results leading to this erosion control design were developed from rainfall simulator studies at Los Alamos[6,11] and at the Nevada Test Site where the influence of the natural

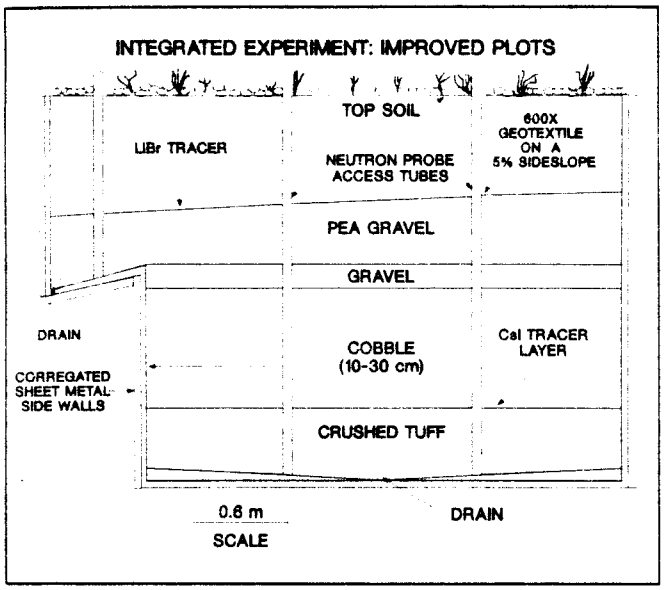


Figure 2. Improved trench cap design on the Integrated Systems Test plots. Instrumentation for soil water also includes thermocouple psychrometers and tensiometers. The CsI and LiBr were used to indicate direction of water flow and plant root intrusion. The surface had a 0.5% downslope gradient and a 60% to 70% gravel mulch and grass cover.

erosion pavement, which covers the soil surface in the northern Mojave Desert, on water balance has been extensively studied.[12-14]

Percolation or seepage control uses the pea gravel portion of the layered rock component (Figure 2) of the trench cap to provide a capillary barrier to downward water flow.[3,13] The difference in saturated hydraulic conductivities of the rock and the overlying soil causes downward water flow to be impeded at the soil-rock interface. A 5% lateral slope on the interface between the soil and gravel allows gravity to convert the downward flow to a lateral flow component. Lateral flows can then be diverted away from the trench, precluding the movement of water through the cover into the trench. The integrity of the soil-rock interface is maintained with a geotextile fabric (Figure 2) (MIRAFI Inc., 22672 Lambert Street, Suite 602, El Toro, CA 92630). Failure of the capillary barrier can occur when the soil at the interface becomes saturated with water. The objective, then, is to keep soil overlying the capillary barrier as dry as possible by maximizing evapotranspiration losses.

The cobble layer underlying the gravel layer prevents plant root and animal intrusion and was designed on the basis of the results of several field tests at the Experimental Engineered Test Facility and at several low-level waste sites at Los Alamos.[7] It prevents or minimizes plant root intrusion because the spaces between the cobble are relatively free of soil and water. As long as a limited source of nutrients and water is in the cobble, plant root penetration into this zone will be minimized. The cobble also prevents most burrowing animals from digging through the waste simply because the stones are too heavy to move.

Three years of data have been collected on the Low-Level Integrated Systems Test plots. During that time we have demonstrated that with the improved cover design we can eliminate or reduce erosion, percolation, and biointrusion over that measured on the conventional cover design. From May 1984 to March 1987, a total of 210 cm of precipitation fell on the plots, which on an annual basis greatly exceeds the average annual precipitation of about 46 cm for Los Alamos. In the winter and spring of 1984–1985, Los Alamos had 250% above the annual snowfall of 130 cm. During the winter of 1986–1987, 335 cm of snow fell on the plots, which broke the existing snowfall record of 312 cm at Los Alamos.

Leachate production from the various drains are summarized in Table 1. Over the three-year period, the conventional cover design produced drainage on two occasions, both of which followed large snowfall. On the first occasion (April–May 1985), 161 L of leachate were produced amounting to about 0.66% of the precipitation that had fallen on these plots. The second period of drainage in November 1986 to March 1987 followed a heavy snowfall of 137 cm and produced 3047L of leachate, amounting to 5% of the total precipitation incident on the plots to that time.

The improved design (Figure 2) performed considerably better than the conventional design in controlling percolation during the two episodes of drainage. During the first period of April–May 1985, there was no drainage from the bottom of the improved cover designs. However, a lateral flow totaling 335L did occur and represented about 1% of the accumulative precipitation. During the second drainage episode in November 1986 to March 1987, both the lateral and bottom drains generated leachate. The lateral flow generated 500 L, representing about 0.69% of the accumulative precipitation, while the bottom drain generated 769 L, representing 1.1% of the total precipitation that fell on the plots.

Altogether, about 1.2% of the precipitation falling on the plots from May 1984 to March 1987 was diverted laterally through the soil above the capillary barrier, reducing the amount of percolation to deeper zones in the cover profile by over half. The improved cover design also reduced the bottom drainage or leachate production by a factor of 4 over the conventional design (769 L vs 3208 L, Table I).

The light covering of gravel (60% to 70% cover to a depth of about 2 cm), gentle slope (<1%), and dense cover (70% to 80%) of native grasses effectively eliminated runoff and erosion over three years despite the occurrence of several intense rainstorms. Likewise, the use of a combination capillary wick-biointrusion barrier reduced percolation by a factor of 4 over the conventional cover design and diverted a significant amount of percolating water laterally, reducing the amount of deep percolation by a factor of over 2. The cobble component of the rock barrier also completely prevented plant root intrusion through the cover into a simulated waste.

Table I. Leachate Production from the Los Alamos Integrated Systems Test Plot Trench Cover Designs from May 1984 to March 1987

Treatment	Date	Drainage (L)	% Total Precipitation to Date Drainage Stopped
Conventional Design (Figure 1)			
	April–May 1985	161	0.60[a]
	Nov. 1986–April 1987	3047	4.6[b]
	Total	3208	4.9
Improved Design (Figure 2)			
Lateral drain above capillary barrier	March–May 1985	335	1.1[c]
Bottom drain below capillary barrier	March–May 1985	0	0[c]
Lateral drain above capillary barrier	February–April 1987	500	0.63[d]
Bottom drain below capillary barrier	March 1987	769	0.97
Total			
Lateral drain		835	1.1
Bottom drain		769	0.97

[a]Total precipitation on conventional cover design when drainage stopped was 26,700 L.
[b]Total precipitation on conventional cover design when drainage stopped was 66,150 L.
[c]Total precipitation on modified cover design when drainage stopped was 32,040 L.
[d]Total precipitation on modified cover design when drainage stopped was 79,380 L.

References

1. G. L. DePoorter, "The Los Alamos Experimental Engineered Waste Burial Facility: Design Consideration and Preliminary Experimental Plan," in *Waste Management '81*, R. G. Post and M. E. Wacks, Eds. (University of Arizona Press, 1981), pp.667-886.
2. K. G. Renard, "Rainfall Simulators and USDA Erosion Research: History, Perspective, and Future," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, Tucson, Arizona, January 14-15, 1985, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4 (1986), pp. 3-6.
3. W. V. Abeele, J. W. Nyhan, T. E. Hakonson, B. J. Drennon, et al., "Low-Level Integrated System Test," Los Alamos National Laboratory report LA-10572-MS (1986).
4. T. E. Hakonson, L. J. Lane, J. G. Steger, and G. L. DePoorter, "Some Interactive Factors Affecting Trench Cover Integrity of Low-Level Waste Sites," in *Proceedings of Low-Level Waste Disposal: Site Characterization and Monitoring*, Arlington, Virginia, June 16-17, 1982, NUREG/CP-0028, CONF-820674, Vol. 2 (1982), pp. 377-400.
5. J. W. Nyhan and L. J. Lane, "Erosion Control Technology: A User's Guide to the Use of the Universal Soil Loss Equation at Waste Burial Sites," Los Alamos National Laboratory report LA-10262-M (1986), p. 67.
6. J. W. Nyhan and L. J. Lane, "Rainfall Simulator Studies of Earth Covers Used in Shallow Land Burial at Los Alamos, New Mexico," in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4.
7. T. E. Hakonson, "Evaluation of Geologic Materials to Limit Biological Intrusion into Low-Level Radioactive Waste Disposal Sites," Los Alamos National Laboratory report LA-10286-MS (1986), p. 91.
8. L. J. Lane, "Surface Water Management: A User's Guide to Calculate a Water Balance Using the CREAMS Model," Los Alamos National Laboratory report LA-10177-M (1984), p. 49.
9. L. J. Lane and J. W. Nyhan, "Water and Contaminant Movement: Migration Barriers," Los Alamos National Laboratory report LA-10242-MS (1984).
10. J. W. Nyhan and L. J. Lane, "Use of a State of the Art Model" in "Generic Designs of Shallow Land Repositories for Low-Level Waste," in *Waste Management '82*, R. G. Post, Ed. (University of Arizona Press, Tucson, Arizona, 1982), pp. 235-244.
11. J. W. Nyhan, G. L. DePoorter, B. J. Drennon, J. R. Simanton, and G. R. Foster, "Erosion on Earth Covers Used in Shallow Land Burial at Los Alamos, New Mexico," *Journal of Environmental Quality* **13**, 361-366 (1984).
12. J. R. Simanton, C. W. Johnson, J. W. Nyhan, and E. M. Romney, "Rainfall Simulation on Rangeland Erosion Plots," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4 (1986).
13. T. E. Hakonson, L. J. Lane, G. R. Foster, and J. W. Nyhan, "An Overview of Los Alamos Research on Soil and Water Processes in Arid and Semi-arid Ecosystems," L. J. Lane, Ed., in Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN: 0-9603692-4-4, 7-10 (1986), pp. 7-10.
14. E. M. Romney, R. B. Hunter, and A. Wallace, "Shrub Use of Water from Simulated Rainfall in the Mojave Desert," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4 (1986), pp. 25-29.

Waste-Site Closure Demonstration—A Field-Scale Study

Authors: *F. J. Barnes (Co-Principal Investigator), J. Warren (Co-Principal Investigator, HSE-7), P. M. Rich, E. A. Lopez, W. J. Herrera, and E. J. Antonio*
Group: *Environmental Science, HSE-12*
Cooperators: *P. R. Kemp, New Mexico Museum of History*
Funding Organization: *DOE Defense TRU Waste Management Program*

The overall goal of the Waste-Site Closure Demonstration is to apply and evaluate a cost-effective and efficient waste-site closure methodology for Los Alamos that maximizes surface stability and minimizes site maintenance. In the initial phase of the project (FY87–89), the objective is to modify a pre-existing closure study at Area B so as to demonstrate the effects of gravel mulches on soil erosion, plant biomass, and soil water storage under natural precipitation regimes. The following phase will involve design and application of an optimization cover to Area E (FY90) and follow-up monitoring of that site to assess cover performance (FY91-92).

Previous studies at Los Alamos have demonstrated that the closure methods and design of a trench cap are highly correlated with subsequent site stability and integrity. Water and soil dynamics, as influenced by physical and biological factors, account for most of the performance-related problems. For example, erosion associated with surface runoff can breach the trench cap relatively quickly and expose waste. Soil profile depth and soil layer characteristics can greatly influence plant growth, storage of soil water after precipitation events, and hence the likelihood of precipitation percolating below the trench cap and into the waste.

The installation of the closure demonstration at AreaB was largely completed in FY87. The demonstration consists of twelve plots, four in each of three clusters, on the Area B closed waste site (Figure 1). Two clusters (east control and west control) have soil profiles similar to the standard trench cap cover profile used at Los Alamos (15-cm soil over 75-cm crushed tuff). The central cluster has a profile consisting of 15-cm soil and 45-cm crushed tuff over a gravel-cobble layer designed to act as a barrier to biointrusion by plants and animals, as well as a barrier to capillary moisture flow. Soil moisture measuring devices were installed on each plot. Soil moisture was measured every two weeks by two different methods. Plant biomass or ground cover was estimated by several different methods with varying success. A meteorological weather station was also installed and data collected daily. Runoff from natural precipitation from each plot was collected after each rainfall and sediment load transport determined.

When runoff (as percent of total precipitation) is averaged over all events for each plot (Table I), a definite trend is immediately obvious. The plots with gravel mulch in addition to the vegetation have much lower runoff rates than those with only a grass or shrub cover. Thus, the gravel plots have much higher water infiltration rates than the nongravel plots. The higher amount of available water resulted in greater vegetation growth and higher plant survival rates on the gravel plots.

The wide range in runoff on all plots and between plots with the same treatment is the result of the many factors not accounted for in this brief summary. In particular, runoff was affected greater by storm intensity and antecedent moisture conditions (that is, whether rain had occurred in the couple of days preceding the event). Within treatments, soil profiles differ among plots with results particularly noticeable between the biobarrier plots (5, 6, 7, and 8) and the others. Slopes and extent of plant cover also differed among plots. These factors will all be used in analysis of the results as the project continues.

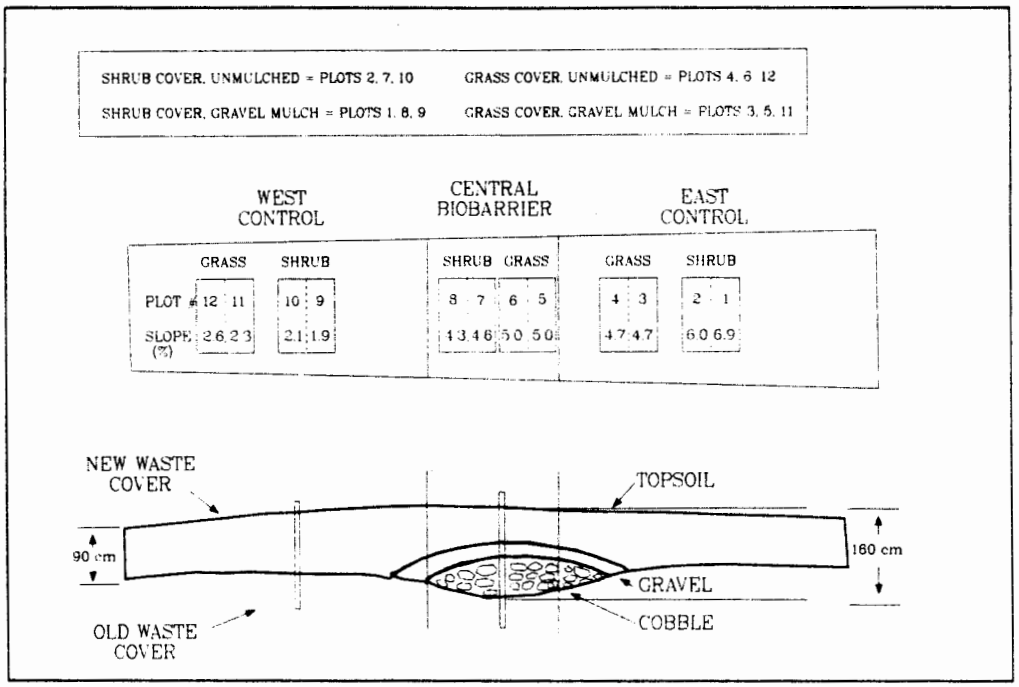


Figure 1. Area B–low-level waste site.

Table I. Runoff on Demonstration Plots in 1987

Treatment	Plot	Mean Runoff[a]	Runoff Range[a]
Shrub + gravel	1	3.89	0.09-11.53
	8	0.77	0.05-1.59
	9	4.53	0.54-10.69
Grass + gravel	3	8.81	1.20-27.53
	5	0.69	0.19-1.29
	11	8.27	0.16-44.87
Grass	4	23.25	0.34-50.24
	6	1.05	0.50-1.65
	12	18.77	0.46-48.78
Shrub	2	32.14	1.45-63.65
	7	29.31	1.00-68.10
	10	20.27	1.59-48.78

[a]Runoff as percent of total precipitation.

Development of an Arid-Site Closure Plan—A Modeling Study

Authors: *J. W. Nyhan (Principal Investigator) and F. J. Barnes*
Group: *HSE-12*
Funding Organization: *DOE National Low-Level Radioactive Waste Management Program*

Federal regulations stipulate that landfill cover technology ensures the long-term stability and integrity of a hazardous waste landfill system. Specific guidance for achieving compliance with these regulations requires cover designs that manage the water balance on the landfill site. Special attention must be given to the design of the soil profile and the establishment of a stable vegetative cover to minimize erosion of the surface soils and the percolation of water into the waste. Recommendations for a specific landfill must be based on a combination of field and laboratory data and on computer modeling of water balance to assess specific design scenarios. The purpose of this study was to investigate the utility of two hydrologic models (CREAMS and HELP) for assisting in the design of landfill cover systems that are stable and free of maintenance requirements.

Results of the modeling study suggest that, overall, CREAMS performs more satisfactorily than HELP in accurately predicting the soil water storage in the soil profile, although more detailed calibration of HELP will probably improve model performance. Although relative estimates of runoff, deep percolation, and evapotranspiration are useful for comparing different cover designs, absolute quantitative estimates of these values are subject to considerable error. Choice of values for soil parameters requires more experience and more detailed data than is indicated by the documentation for either model. The results of this study have demonstrated unequivocally that the role of native vegetation in determining site stability and integrity must be evaluated and considered in designing a hazardous waste landfill cover system.

It is apparent that native species are much hardier than cultivated species. Given sufficient time with no human interference (that is, no maintenance), native species will invade and colonize a landfill site, and some sequence of succession will proceed thereafter. Unfortunately, these processes are not well documented, especially for severely disturbed sites or on constructed soil profiles.

The use of simple hydrologic models to simulate the water balance of landfill cover systems can assist the process of designing soil and vegetative systems for site closure. Two models (CREAMS and HELP) were used to simulate eight experimental cover designs on a landfill site at Los Alamos, New Mexico. Careful parameterization of the models was a key to successful simulation. Few data exist for leaf area indices and rooting depths of native plant species. Values of hydrologic parameters of soils may be quite different in the constructed soil profiles of landfill covers than under laboratory or natural conditions. These areas are in critical need of further research.

Modeling of Radionuclide Transport at An Inactive-Material Disposal Area

Author: M. A. Devaurs (Principal Investigator)
Group: Environmental Science, HSE-12
Funding Organization: Department of Energy, Los Alamos National Laboratory Comprehensive Environmental Restoration Program

Site TA-21 was chosen as one of the sites for Phase 2 follow-up under the Environmental Restoration Program. Area T is an inactive-material disposal area at TA-21, designated for further site characterization work.

In 1943, Los Alamos National Laboratory constructed four adsorption beds filled with gravel and cobble for disposal of radioactive liquid wastes. About 98% of the estimated 10 Ci of plutonium discharged to the adsorption beds was added between 1945 and 1952. At infrequent intervals after 1952 until 1967, a few hundred gallons of wastes were discharged to the adsorption beds, after which waste treatment operations shifted to a new treatment plant. The results of a 1953 study undertaken by the USGS at this site determined that vertical migration of plutonium occurred within 6 m of the surface of the beds. In 1959 another study was undertaken to document vertical distribution at 12 sampling points spaced at 61-cm intervals along the depth of a caisson drilled near one of the beds. As a result of information from these studies, researchers attempted to change the distribution of plutonium beneath the beds by adding 10.8 m of effluent containing plutonium in July 1961 and 9.7 m of tap water a month later. In 1978, a major field study was undertaken to determine the vertical distribution of americium-241, plutonium, and water beneath the beds by drilling and sampling to a depth of 30.5 m through two of the beds.

The objective of this study was to use existing data to estimate radionuclide movement by estimating the (1)vertical extent of contamination and (2) potential for contaminant migration. Adsorption bed 1, where tap water was added in 1961, was used as a "worst case" of potential migration of radioactive waste contaminants. The goal is to use existing data to extract meaningful information on radionuclide movement to assist in design of future studies. Recommendations are made on how this information could guide further drilling/sampling for contamination at Area T.

Spatial moment methodology is used to obtain estimates of plume mass, location, movement, dilution, and spreading for plutonium and americium. Spatial moment analysis predictions are input into a one-dimensional convective dispersive solute transport equation for solute movement prediction.

Preliminary results indicate that moment-predicted velocities and dispersion coefficients are greater for bed 1 where water was added, resulting in model predictions of radionuclide movement to a greater depth in bed 1. This agrees with 1978 observed data. Varying estimates of plutonium input concentration give different estimates of when plutonium would reach ground water at a 350-m depth. The most conservative estimate is year 2397. The best example of plutonium concentration predicted by the convective dispersive equation compared with observed 1978 data is given in Figure 1. Further modeling estimates of radionuclide movement below adsorption beds and recommendations for further drilling/sampling activities are currently being developed.

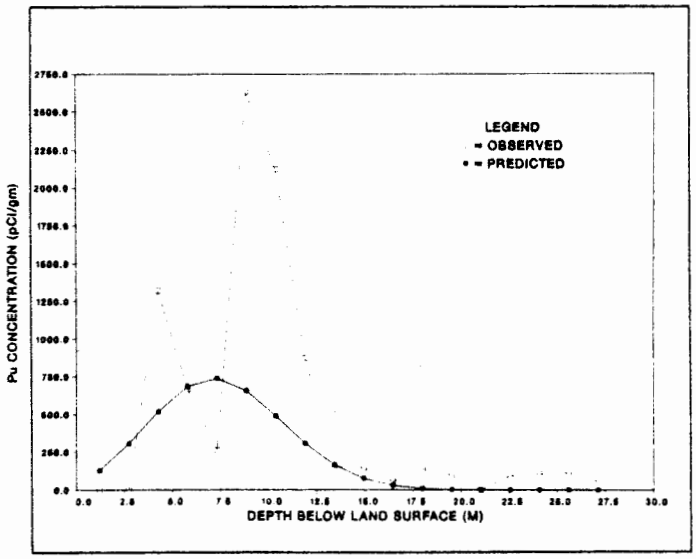


Figure 1. Comparison between observed and model-predicted (0.10598-mg/L initial concentration) plutonium concentrations in 1978.