WHC-EP-0253

Animal Intrusion Field Test Plan

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Date Published
April 1990

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

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P.O. Box 1970
Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Available from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

NTIS Price Codes:

Microfiche Copy: A01

Printed Copy:

Pages	Price Codes	Pages	Price Codes
001-025	A02	301-325	A14
026-050	A03	326-350	A15
051-075	A04	351-375	A16
076-100	A05	376-400	A17
101-125	A06	401-425	A18
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201-225	A10	501-525	A22
226-250	A11	526-550	A23
251-275	A12	551-575	A24
276-300	A13	576-600	A25

Printed in the United States of America

DISCLM-1.CHP (2-89)

ABSTRACT

The Protective Barrier and Warning Marker System Development Plan identified tasks that need to be completed in order to design a final protective barrier to implement in-place disposal. This report summarizes the animal intrusion tasks that have been conducted by Westinghouse Hanford Company in fiscal year 1988 and fiscal year 1989 with respect to small mammals and water infiltration.*

An animal intrusion lysimeter facility was constructed and installed in fiscal year 1988. The facility consists of two outer boxes buried at grade which serve as receptacles for six animal intrusion lysimeters. Small burrowing mammals common to the Hanford Site environs are introduced over a three to four month period and allowed to burrow. During the course of each test, supplemental precipitation is added to three of the lysimeters with a rainulator at a rate equivalent to a 100-yr storm. Soil moisture samples are taken before and after each test and soil moisture measurements are also taken with a hydroprobe during the test period.

Two tests have been completed and a third test is in progress. Preliminary results from the first test indicate that the additional water, which was supplemented by the rainulator to the plots with burrowing animals, is being removed. Mechanisms which might account for this include evaporation loss due to continuous soil turnover from burrow excavations and moisture loss from open burrows that probably allows some air circulation.

Data from the second test, which was conducted during the winter, indicate that all the plots (control and animal) gained water. Plots with animal burrows gained almost twice as much water as the control plots. Plots with greatest changes occurred at the 18-in. level in all the plots. Additional tests, scheduled to be conducted over the next few years, should substantiate or verify these preliminary observations.

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*Adams, M. R., and N. R. Wing, 1986, Protective Barrier and Warning Marker System Development Plan, RHO-RE-PL-35P, Rockwell Hanford Operations, Richland, Washington.

EXECUTIVE SUMMARY

The Interim Hanford Waste Management Technology Plan* stressed the need for prerequisite technology development in order to implement the disposal strategies proposed for Hanford Site waste. One technology under design is a protective barrier. However, several technical concerns in many disciplines need to be resolved before a final design for a protective barrier can be developed. One of the major issues of concern, which was identified in the Protective Barrier and Warning Marker System Development Plan**, focused on the need to develop a barrier resistant to animal intrusion.

This document, which was coauthored by Westinghouse Hanford Company and Pacific Northwest Laboratory, proposes five major tasks that are designed to resolve technical concerns relating to animal intrusion into a protective barrier.

There are several concerns related to animal intrusion. The first of these is the potential impact of animal burrowing on water infiltration relative to barrier design. Burrowing animals can influence infiltration directly by creating passages (burrows) for entry of water through the barrier and into the waste, thus increasing the potential for contaminant leaching.

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*DOE-RL, 1986, Interim Hanford Waste Management Technology Plan, U.S. Department of Energy-Richland Operations Office, Richland, Washington.

**Adams, M. R., and N. R. Wing, 1986, Protective Barrier and Warning Marker System Development Plan, RHO-RE-PL-35P, Rockwell Hanford Operations, Richland, Washington.

Secondly, loose soil cast to the surface during the burrowing process can accelerate natural wind and water erosion. Indirect effects may include loss of soil cover through accelerated erosion, loss of soil moisture storage capacity, and loss of plant cover. By accelerating erosion, animal burrowing has the potential to indirectly influence contaminant transport to groundwater.

Thirdly, animals which penetrate the barrier may enter the waste zone and carry waste products to the surface. This is particularly relevant considering minimum barrier-failure scenarios (not presuming massive barrier failure) that would permit animals to burrow through the barrier.

The approach to resolving these concerns is to evaluate the proposed barrier design using a combination of fieldwork and modeling strategies. An existing model that calculates quantities of soil moved, burrow volumes, and amount of contaminant transported by burrowing will allow comparison of expected long-term barrier performance with performance standards. This model is included in this document. Thus, the adequacy of barrier design will be evaluated relative to proposed standards for infiltration, soil erosion, and direct contaminant transport. This plan assumes some interaction with the infiltration modeling effort, the surface erosion evaluation effort, and the need for a contaminant transport standard for radioactive materials moved to the soil surface.

Predictive modeling is based on the species, population, and burrowing habits of animals likely to inhabit the facility over the design life.

Technical concerns will be resolved by the modeling effort based on data obtained from answering the following questions.

1. What are the effects of burrowing on water infiltration?

2. How much soil, brought to the surface by burrowing animals, becomes subject to wind and water erosion?

3. How deep do the various animals burrow?

4. How will the density and composition of animal species that occupy the barrier over long periods of time be affected by barrier components (disturbed soils, mounded structures, rock armoring, etc.) and climate changes?

5. How effective are the proposed barrier components as deterrents to burrowing?

6. What are the potential impacts if the barrier is breached by animals?

All of these tasks are scheduled for completion by the end of fiscal year (FY) 1994. Schedules and cost estimates accompany each task. The cost to accomplish all of the proposed tasks is approximately $2,079,000 based on FY 1989 functional dollars.

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ANIMAL INTRUSION FIELD TEST PLAN

1.0 INTRODUCTION

All strategies for final disposal of radioactive waste at the Hanford Site propose the use of protective barriers and warning markers. The Protective Barrier and Warning Marker System Development Plan (Adams and Wing 1986) identifies tasks that need to be completed in order to design a final protective barrier to implement in-place disposal. Some of these tasks (i.e., BIO-1, BIO-2) focus on the need to evaluate impacts burrowing animals could have on the integrity of a protective barrier system.

In many respects, the proper functioning of a protective barrier will depend on whether or not burrowing compromises the integrity of the barrier through encouraging infiltration, accelerating wind and water erosion, and moving contaminants. This document addresses the technical concerns that need to be resolved with regard to animal intrusion and describes tasks, which are designed to collect quantitative data, in order to resolve these technical concerns.

1.1 OBJECTIVE

The objective of this plan is to describe the animal intrusion field test identified in the Protective Barrier and Warning Marker System Development Plan (Adams and Wing 1986). The results of these studies will enable predictions to be made regarding long-term consequences of animal burrowing. These results will aid in the evaluation of proposed barrier designs relative to performance standards. Specific objectives are as follows.

- Determine the degree to which animal burrows affect water infiltration.
- Determine quantitative estimates of animal burrow parameters including depth, volume, number of burrows/species, and the estimated life of a burrow system.
- Determine species composition and density of animals which could impact barrier performance relevant to disturbed soils, rock armoring, and climate changes.
- Determine what specific barrier materials and configurations are effective in deterring animals from adversely affecting barrier performance.
- Predict burrow volumes, rates of soil movement, and quantities of contaminants that may be transported for existing and for future burrowing animal populations subsequent to climate change.

- Coordinate with run-off, erosion, and infiltration study tasks to ensure that research activities are coordinated and mutually supportive of the program goals and objectives.

1.2 SCOPE

This document presents technical concerns that need to be resolved regarding animal intrusion on protective barriers. Five tasks are identified, which support the objectives stated above, and permit resolution of the technical concerns. Task descriptions of proposed field tests with associated costs and schedules are provided. The relationship between technical tasks, required parameter measures, model results, and performance standards are shown in Figure 1. Safety and quality assurance sections have also been included.

2.0 TECHNICAL CONCERNS

There are three main concerns regarding the potential impacts of animals on protective barriers: water infiltration, erosion, and radionuclide transport.

The first concern is the potential impact of animal burrowing on water infiltration relative to barrier design. Burrowing animals can influence infiltration directly by creating passages (burrows) for entry of water through the barrier and into the waste, thus increasing the potential for contaminant leaching.

The second concern is soil erosion. Burrowing animals also cast loose soil to the surface where it is susceptible to wind and water erosion. The indirect effects may be loss of soil cover through accelerated erosion, and subsequent loss of soil moisture, storage capacity, and plant cover. Thus, animal burrowing can indirectly lead to contaminant leaching and groundwater contamination.

The third concern is plants and animals that may penetrate the barrier and transport radionuclides to the barrier surface. Although it is probable that the proposed barrier will retain its basic configuration, it is also probable that the fine soils will infiltrate the rock layer. In this occurrence, both animals and plant roots will compromise the effectiveness of the barrier.

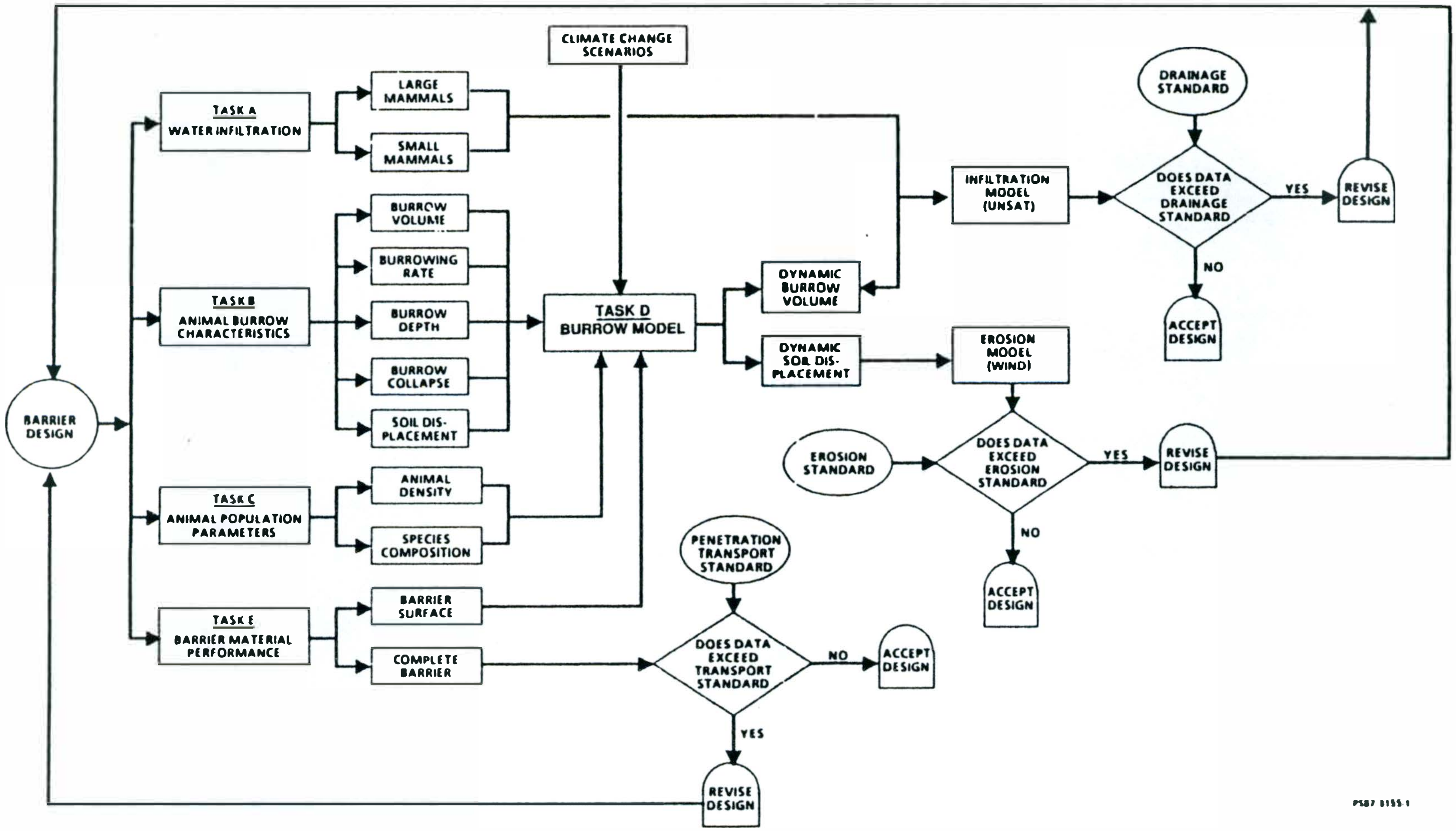

Figure 1. Overall Diagram of How the Animal Intrusion Work Activities are Related to the Protective Barrier Program.

In response to these three concerns, several technical questions have been identified that need to be answered in order to mitigate the effects that burrowing animals could have on a barrier. These technical issues are as follows.

1. What effect do burrow systems have on water infiltration? Do burrows act as direct conduits for water or are the burrows constructed in such a way that this pathway is insignificant?

2. What amount of soil, excavated and brought to the surface by burrowing animals, becomes subject to dispersal by wind and water erosion?

3. What are the expected volumes and depths for burrows of those animals common to the Hanford Site and those animals which may appear on the Hanford Site within the next 10,000 yr? What is the maximum number of animals and burrows that may occur on the barrier at any given time?

4. What is the current and future expected species composition and density of major burrowing animals on the barriers relative to altered habitat (disturbed soils and rock armoring), and climatic changes?

5. What specific barrier materials and configurations are effective in deterring animal encroachment and how might barrier designs be improved to minimize impacts from burrowing animals?

3.0 ANIMAL INTRUSION TEST PLAN

The following five tasks have been identified to resolve the technical concerns associated with animal intrusion, and meet the objectives of this document. Associated with each task are subtasks, schedules, and cost estimates. All cost estimates are scheduled for completion by fiscal year (FY) 1994. Figure 2 presents an overall schedule and Table 1 presents the associated costs for all identified tasks.

Tasks are presented in decreasing order of priority throughout the remainder of this document. All of the tasks address technical concerns that need to be completed. These tasks were prioritized based on current knowledge of each issue and need-to-know. However, all of these tasks are interrelated and any impact on one task will affect the results of the other tasks. A priority listing of the five tasks is presented below:

- Task A--Water Infiltration Study

- Task B--Animal Burrow Characteristics

- Task C--Population Response Study
- Task D--Prediction and Integration
- Task E--Barrier Performance Study.

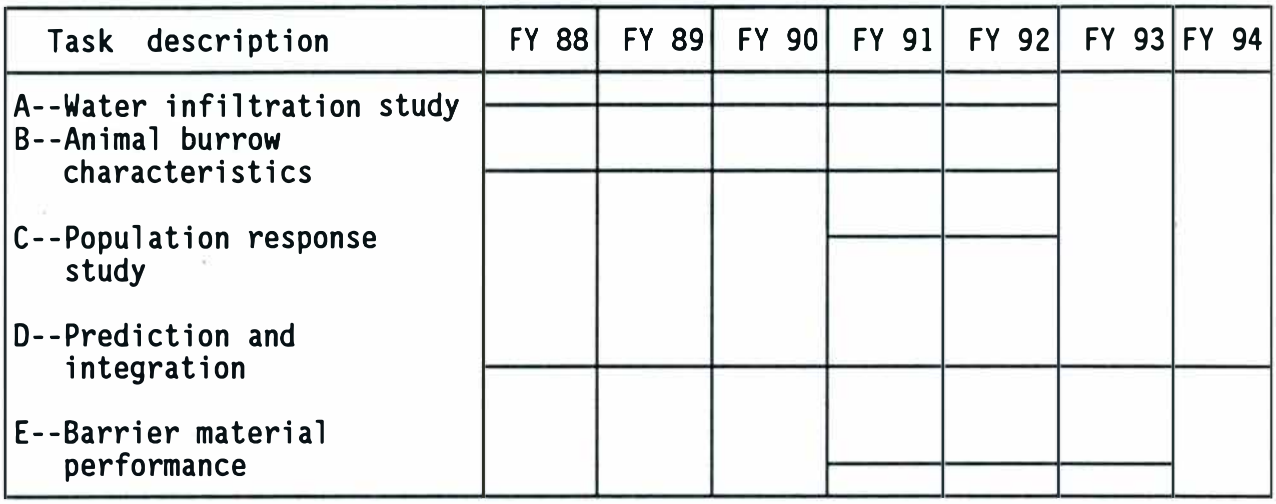

Figure 2. Overall Schedule for Animal Intrusion Test Plan.

Table 1. Total Cost Estimates for Materials and Manpower for the Animal Intrusion Test Plan.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	Total
Task A	119[a]	119	152	157	172	380	0	1099
Task B	86	45	181	110	40	0	0	462
Task C	0	0	0	86	85	0	0	171
Task D	3	10	20	30	50	50	75	208
Task E	0	0	0	56	46	37	0	139
Total								2,079

[a]Numbers in thousands of dollars. All totals include general and administrative/common support poll (G&A/CSP) (11.009%).

4.0 TASK A--WATER INFILTRATION STUDY

4.1 SUBTASK 1--WATER INFILTRATION IN RESPONSE TO SMALL BURROWING MAMMALS

4.1.1 Objective

Determine the degree to which small mammal burrow systems affect water infiltration.

4.1.2 Justification

The amount and rate at which water may penetrate the protective barrier and come into contact with the buried radioactive waste is of major concern. Since it is accepted that burrowing animals will eventually reside on the surface of any protective barrier, it is necessary to ascertain the effect these burrow systems will have on the downward movement of moisture. The pocket gopher (*Thomomys talpoides*) is an example of a burrowing mammal that may eventually reside on the protective barrier. Turner et al. (1973) concluded that pocket gophers cause patchy soil moisture conditions. There is increased infiltration where the gophers loosen the soil and produce depressions. However, where fine soil particles from soil casts seal the surface and where there is rapid run-off from mounds, there is decreased infiltration. There is some concern that burrow systems allow water to penetrate deeper than normal.

There is also evidence (Ellison 1946) that indicates burrowing activities may create favorable microenvironments for plant establishment. This would have the effect of reducing the deep penetration of water by plant transpiration.

Task A, subtask 1 will provide quantitative comparisons of moisture movement at depth in plots that have burrows and in plots with no burrows. Moisture will be measured at depth intervals (i.e., 6 in., 12 in., etc.) to determine the amount and extent of penetration.

4.1.3 Location

Task A, subtask 1 will be conducted at a study site adjacent to the Field Lysimeter Test Facility near the Hanford Meteorology Station, which is being used for several protective barrier studies. Soil will be obtained from the McGee Ranch, a site near the intersections of State Highways 24 and 240, where a soil characterization effort has indicated a fine silt loan in sufficient quantity to meet current estimates of future barrier construction requirements.

4.1.4 Experimental Design

Task A, subtask 1 will consist of the quantity and types of treatments summarized in Figure 3. The statistical design illustrated in Figure 3 is a three-factorial balanced incomplete block. Details of specific treatment combinations are given in succeeding sections.

A general overview of the procedures and methods of Task A, subtask 1 is provided below:

1. Construct and install animal lysimeters

2. Introduce animals and allow them to burrow over a 2- to 4-mo time period

3. Add water at a specified rate and intensity

4. Remove animals

5. Lift out lysimeters disassemble side panels in order to excavate and map burrow systems

4.1.4.1 Animal Lysimeters. The animal lysimeters, which will be used to test the various treatment combinations, will be constructed per approved drawings. The lysimeters consist of an outer box, inner box, and spreader beam assembly for lifting. The outer box will be placed 6 to 7 ft below grade. Three inner boxes will be placed inside each outer box so that they can be easily lifted out (Figure 4) at the end of each test period. The sides will be disassembled so that the burrow systems can be measured and examined. The inner boxes will consist of an outer iron frame with plywood sides. Each inner box will be lined with a watertight liner. The boxes are designed so that they can be reused to test different treatment combinations.

4.1.4.2 Test Animals. The animal species which will be used in Task A, subtask 1 are the Great Basin pocket mouse (*Perognathus parvus*), the Townsend ground squirrel (*Spermophilus townsendi*), northern pocket gopher (Thomomys talpoides) and a control (no animal). These are the burrowing animals of most concern that are currently present at the Hanford Site. Animals will be allowed to burrow 2 to 4 mo, after which excavation of the tests plots will take place. Food and water for the animals will be provided on a regular basis throughout the duration of the study.

4.1.4.3 Water Application. Two levels of water (control and 100-yr storm at 2.5-in. intensity) will be applied to the plots. Water will be added in a consistent manner to all plots using a rainulator. Water will be added once each month throughout the duration of the study, except in those cases where environmental conditions dictate otherwise (i.e., frozen soil). All plots will receive consistent water treatments so that meaningful comparisons can be made.

Treatments:

Water: 1) 2x water (WA)
2) Control (CO)

Animals: 1) Pocket mouse (PM)
2) Ground squirrel (GS)
3) Pocket gopher (PG)
4) Control (CO)

Seasons: 1) Spring (SP)
2) Summer (SU)
3) Fall (FA)

Spring 1987		Spring 1988		Spring 1989	
WAPMSP1	COPMSP1	WAPGSP1	COPGSP1	WAGSSP1	COGSSP1
WAPMSP2	COPMSP2	WAPGSP2	COPGSP2	WAGSSP2	COGSSP2
WACOSP1	COCOSP1	WACOSP1	COCOSP1	WACOSP1	COCOSP1
Summer 1987		**Summer 1988**		**Summer 1989**	
WAGSSU1	COGSSU1	WAPMSU1	COPMSU1	WAPGSU1	COPGSU1
WAGSSU2	COGSSU2	WAPMSU2	COPMSU2	WAPGSU2	COPGSU2
WACOSU1	COCOSU1	WACOSU1	COCOSU1	WACOSU1	COCOSU1
Fall 1987		**Fall 1988**		**Fall 1989**	
WAPGFA1	COPGFA1	WAGSFA1	COGSFA1	WAPMFA1	COPMFA1
WAPGFA2	COPGFA2	WAGSFA2	COGSFA2	WAPMFA2	COPMFA2
WACOFA1	COCOFA1	WACOFA1	COCOFA1	WACOFA1	COCOFA1

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Figure 3. Assignment of Animal and Water Treatments to the Six Lysimeters.

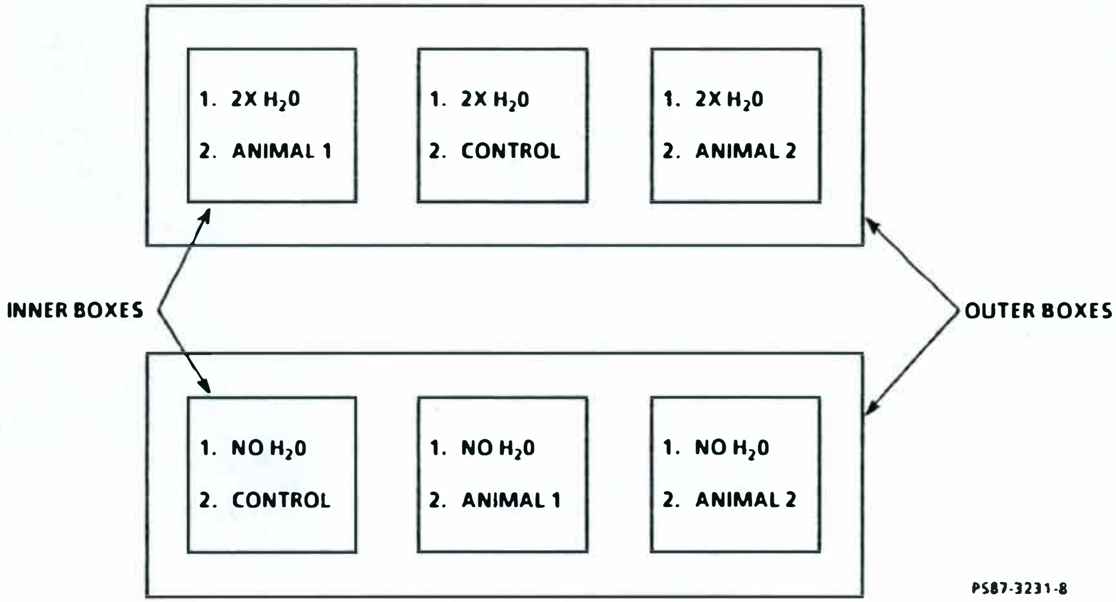

Figure 4. Animal Lysimeters With an Example of a Possible Treatment Combination.

4.1.4.4 Time. Burrowing activities are greatly influenced by the time of year; therefore, the year will be divided into three seasons. These seasons are spring (February--May), summer (June--September), and fall/winter (October--January). There may be some slight overlap of time depending on site support services and budget constraints.

4.1.4.5 Data Collection. Soil moisture data will be measured by neutron or conductance probes and by weighing soil cores. Core samples will be taken from every plot when they are initially installed, and before burrow excavation.

Statistical support for this three-way factorial design (balanced incomplete block design) is coordinated by Westinghouse Hanford Company (Westinghouse Hanford) statisticians using standard analysis of variance and multivariate analysis procedures (Table 2).

4.1.4.6 Other Details. During the initial stages of Task A, subtask 1, vegetation will not be allowed to grow on any of the lysimeters. However, based on future funding and barrier program needs, vegetation and/or various mulches could be introduced on the plots and water balance data could be collected. Nonvegetation conditions may represent worst-case conditions because of the lack of plant cover and high animal density. The actual barrier may be less stressed.

Table 2. The Analysis of Variance Table for a Balanced Incomplete Block Design.

Treatments	Degrees of freedom	Significant F at alpha = 0.05
	F(D1,D2) = Value	
Season (S)	2 = 3-1	F(2, 4) = 6.94
Year (Y)	2 = 3-1	F(2, 4) = 6.94
Blocking error	4 (by subtraction)	
Total for blocks	8 = 9-1	
Animal (A)	2 = 3-1	F(2, 22) = 3.44
Water (W)	1 = 2-1	F(1, 22) = 4.30
Animal-water interaction (AW)	2 = 2x1	F(2, 22) = 3.44
Error	22 (by subtraction)	
Total	35 = 36-1	

4.2 SCHEDULE

Description	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
Construct lysimeters	—					
Install lysimeters	—					
Collect field data	——	——	——	——	——	——
Reports	—	—	—	—	—	—

Figure 5. Task A Schedule for the Water Infiltration Study.

4.3 COSTS

Table 3. Task A--Water Infiltration Study Costs. (Sheet 1 of 2)

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
Subtask 1 Small Mammals						
Exempt manpower (Westinghouse Hanford manmonths)	6	6	10	10	10	10
Westinghouse Hanford						
Site services (mm)	4	4	4	4	4	4
Graphics		5	5	5	5	8
Travel			3	3	3	3
Materials	5	1	2	2	2	2
Statistics		3	3	3	3	3
Total (programatic $$)	69	69	102	102	102	105

Table 3. Task A--Water Infiltration Study Costs. (Sheet 2 of 2)

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
Subtask 2 Large Mammals						
Exempt manpower (Westinghouse Hanford manmonths)						
Exempt manpower (PNL)	19	19	28	30	30	
Nonexempt manpower (PNL)	21	21	21	20	30	
Materials	1	2	1	5	10	
Subtask 2 Total	50	50	50	55	70	275
Task Total (1 and 2)	119	119	152	157	172	380

4.4 SUBTASK 2--WATER INFILTRATION IN RESPONSE TO LARGE BURROWING MAMMALS

4.4.1 Objective

Determine the water infiltration response relative to large mammal burrowing.

4.4.2 Justification

Large burrowing mammals, most notably the badger (*Taxidea taxus*), are abundant on the Hanford Site. Badgers have the potential to significantly impact infiltration because they are aggressive burrowers, digging numerous burrows in search of prey species. Most burrows are dug for feeding rather than denning purposes and, once dug, are not plugged. Recent observations made during rainfall simulation at the Hanford Site suggest that the large volumes of soil displaced near the burrow entrances can serve as water dams that funnel water into the burrows. Since a large degree of badger burrowing is a result of hunting smaller burrowing mammals, there is also the potential for facilitation of water drainage through interconnections of badger/prey burrows. Due to their size, aggressive nature, and overall strength, it is not practical to include badgers in the animal lysimeter study from Task A, subtask 1.

4.4.3 Description

The objective of Task A, subtask 2 is to provide data to be used both directly (model parameters) and indirectly (concepts and validation) in a model evaluation of infiltration. To accomplish this objective, several questions concerning infiltration and animal burrowing must be answered. The questions include the following.

1. How much water will enter large-animal burrows during run-off generation events?

2. How rapidly will water that collects in holes infiltrate into the soil?

3. What is the water content distribution around and under burrows? Will water in the soil adjacent to burrows be preferentially removed by natural processes (e.g., evaporation and transpiration)?

4. To what extent will the water that enters the barrier through burrows break through the fine soil/gravel interface?

The sequence of events for predicting impacts from animal burrowing will be as follows:

1. Evaluate run-off (run-off/erosion task)

2. Relate water entering individual holes to run-off (this subtask)

3. Predict infiltration/distribution (unsaturated flow modeling)

4. Scale to entire barrier based on animal burrow density (burrowing characterization)

5. Compare to predictions of performance standards.

Subtask activities will be conducted for each of the four following objectives.

4.4.3.1 Objective Number 1. Quantify water intercepted by burrows relative to run-off for both vegetated and bare soil surfaces.

Soil moisture measurements obtained during FY 1988 at two study sites showed that water permeated below ground through large-mammal burrows subsequent to run-off, generating simulated rainfall. Visual observations suggested that run-off volumes were different at two field sites having substantially different vegetation composition but quantitative measurements have not been obtained.

The approach for objective No. 1 will be to use small replicated run-off plots that are established over large-mammal burrows and over nearby control areas without burrows. Quantities of rainfall sufficient to generate run-off will be applied to the plots, run-off will be measured, and the quantity of water entering holes will be obtained from the difference between rainfall and measured run-off. Control plots will be used to account for surface infiltration not associated with the burrows.

Since vegetative cover may have a substantial influence on run-off, and the quantity of water available to enter burrows, vegetative cover will be a treatment variable. The number of replicate treatments will be determined based on a preliminary analysis of variability from the initial runs.

The deliverable for objective No. 1 includes quantitative estimates of water interception relative to run-off for large-animal burrows (input parameter values) for use in the multidimensional unsaturated flow model evaluation of infiltration.

4.4.3.2 Objective Number 2. Quantify infiltration rates for large-animal burrows. To validate the infiltration model (compare model output with field data) measurements of infiltration rates for water that enters burrows are required.

A series of thoroughly characterized (size, shape, and depth) animal-dug or artificially constructed animal holes will be selected and filled with water. Water will be added to maintain a constant head, and the rate of water addition will be recorded. Measurements will be made until the infiltration rate stabilizes.

The deliverable for objective No. 2 is an estimated mean value for the infiltration rate through large-animal burrows for representative well-characterized animal burrows.

4.4.3.3 Objective Number 3. Determine changes in the distribution of water around large-animal burrows in response to infiltration and drying.

To validate the predictive infiltration model, it is necessary to confirm that water behaves (becomes distributed) similarly in the field as in the model. It is also necessary to determine the extent to which water that enters the soil through burrows is removed by natural processes (e.g., evaporation and transpiration). Gravimetric sampling results and hydroprobe measurements obtained during spring 1988 showed decreased water content in the vicinity of large-mammal burrows relative to control areas. These results suggest that assumptions on uniformity of soil moisture before infiltration may need to be revised.

The approach planned for objective No. 3 is to measure soil moisture over time around large-animal burrows subsequent to an infiltration event. Measurements will be made through two complete annual cycles. Study sites may be shared with the infiltration activity study sites (see objective No. 2).

The deliverable for objective No. 3 will be descriptive data defining the distribution of water around representative large-mammal burrows and an evaluation of the removal of soil water through time from the same or similar burrows.

4.4.3.4 Objective Number 4. Evaluate drainage from the fine soil layer of a barrier into the gravel layer subsequent to infiltration through animal burrows.

To validate the unsaturated flow model, it is necessary to have field data to compare barrier performance relative to model predictions. It is necessary to ascertain if the predicted quantity of water actually passing through a test barrier configuration confirms independent predictions.

The approach will be to construct small sections of the current preferred barrier design and apply water to simulated mammal burrows. The quantity of water, which passes through the barrier as drainage, will then be measured. Since this validation activity is planned late in the Task A, subtask 2, the test design will need to be completed at a later date. A minimum of three replicated test units are planned.

The deliverable of objective No. 4 will be a data set that relates drainage to the quantity of water entering the fine soil surface of the barrier through animal burrows.

4.5 SCHEDULE

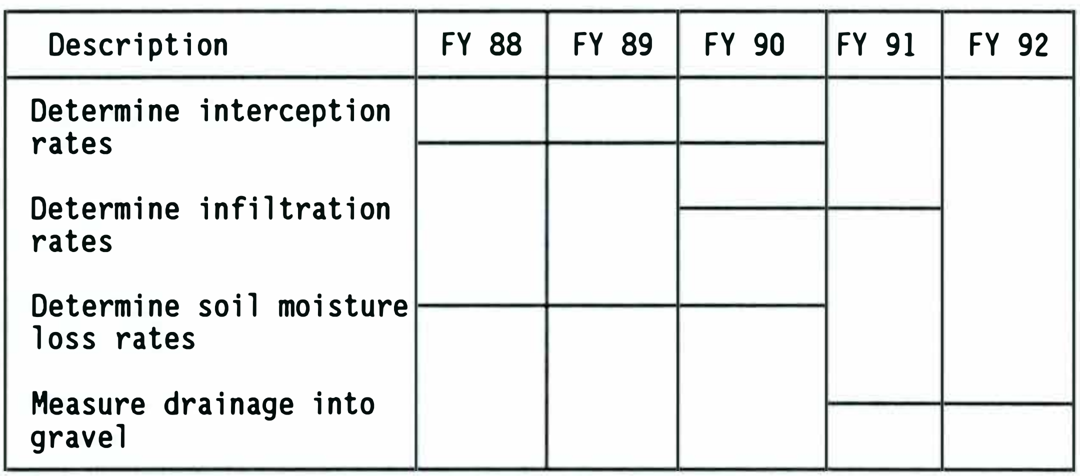

Figure 6. Schedule for Task A, Subtask 2 Activities.

4.6 COST

See Table 3.

5.0 TASK B--ANIMAL BURROW CHARACTERISTICS

5.1 OBJECTIVE

Obtain quantitative estimates of animal burrow parameters, including burrow depth, burrow volume, number of burrows created per individual species, amount of soil displaced to the surface per burrow, and the estimated life of a burrow. These burrow parameters will be estimated from literature, survey, or field study for major species of burrowing animals (vertebrates and invertebrates) likely to occur on the waste site over the next 10,000 yr.

5.2 JUSTIFICATION

The results from Task B, in addition to information on the density and change in animal species composition over time (Task C), are needed for input into the modeling task (Task D) in order to address the three major issues of concern (water infiltration, erosion of soil cap, and waste transport). Information on the depth to which resident animals burrow is necessary for estimating the rate of burrowing related to water infiltration into the barrier. When used in conjunction with the results of Task E (barrier resistance to animal burrowing), and estimated erosion rates, this information will assist in assessing the probability of animal intrusion into buried waste. Estimates of the total volume/burrow system and distribution of this volume by depth are needed as model inputs for estimating the rate of water infiltration (see Figure 1).

Estimates of the volume of soil displaced to the surface by burrowing animals are necessary for estimating source terms for easily erodible soil and thus, erosion of the soil cap, which in turn affects the depth of water penetration. Estimates of the number of burrows constructed per individual per unit time, and the expected life of these burrow systems, are needed. In addition, species density (Task C) is also needed to calculate total density of animal burrows in a given area/unit time. This will affect both the rate of soil erosion and the rate of water infiltration (Table 4).

5.3 DESCRIPTION

Anticipated field studies for Task B are described below. Both vertebrate and invertebrates will be studied in these subtasks. Initial species to be studied include the pocket mouse, kangaroo rat, pocket gopher, ground squirrel, prairie dog, badger, marmot, and western harvester ant. To the extent possible, fieldwork will be restricted to the type of soil and vegetative communities expected to occur on the barrier surface over the next 10,000 yr.

5.3.1 Subtask 1--Literature Review and Data Compilation

Task B, subtask 1 is an ongoing effort that includes an extensive review of the literature for information on animal burrowing characteristics and compilation of these data into a format suitable for modeling input (Task D). This effort and preliminary modeling will direct any additional fieldwork on animal burrowing characteristics (see following subtasks 2 through 6).

5.3.2 Subtask 2--Burrow Depth

An initial review of the literature indicates that considerable information exists on the burrowing depth of most species of interest except the badger, marmot, and harvester ant. Additional information on the burrowing depths of badgers will be obtained by direct measurement in the field. Fieldwork on marmots will be impractical because of their low densities and tendency to burrow in rocky hillsides. Fieldwork will be conducted on the burrowing depths of the western harvester ant, unless additional information is obtained from the literature in FY 1989. Harvester ants are likely to be an important species with respect to the transport of wastes because they may burrow to greater depths than the other species and may be capable of penetrating rock barriers.

Table 4. Relationship Between Animal Burrowing Characteristics and Major Technical Concerns.

	Technical concerns		
Animal burrow characteristic	Soil erosion	Water infiltration	Waste transport
Depth		IN	IN
Volume		IN	IN
Amount of soil displaced	IN	IN	
Number of individual burrows	IN		IN
Life of burrow		IN	

IN = Input needed to resolve technical concerns.

5.3.3 Subtask 3--Burrow Volume

Considerable information is also available on the burrowing volumes of all species except badgers, marmots, and western harvester ants. Information on the burrow volume of badgers will be obtained by direct measurement in the field. Fieldwork on marmots may be impractical because of their low densities and tendency to burrow in rocky hillsides. If fieldwork is impractical for a given species and there are no data available from the literature, burrow volumes will be estimated based on other species of similar size. Since burrow volumes of harvester ants are likely to be small, no fieldwork will be required for this species on this topic.

5.3.4 Subtask 4--Soil Displacement

Information is available on soil displacement for all species except badgers, marmots, and western harvester ants. Information on soil displacement by badgers may be obtained by direct measurement in the field. Fieldwork on marmots will be impractical because of their low densities and tendency to burrow in rocky hillsides. Estimates of soil displacement will be made in a manner similar to that for burrow volumes (see Section 5.3.3) if direct measurements cannot be made. No fieldwork will be required for soil displacement by harvester ants because little displacement is likely.

5.3.5 Subtask 5--Burrowing Rates and Spatial Distribution of Burrows

Literature on the number of burrows constructed per individual per time period and burrow spatial distribution is highly variable and does not exist for many species. Simulation runs will be conducted in the modeling task (Task D) using information available in the literature. If results from the modeling indicate that more refined estimates of the number of burrows constructed per individual and the spatial distribution of these burrows is required, then field studies will be conducted. During field studies, the following parameters would be measured on selected plots: number of burrows present, number of new burrows constructed per time period, and the number of burrowing animals present.

5.3.6 Subtask 6--Life and Fate of Burrow

Based on a cursory review of the published literature, almost no information is available on the estimated life of a burrow system for most species of burrowing animals. These data are needed for model input (Task D). Undoubtedly, a burrow dug by a badger persists for a much longer time period than does a burrow dug by a pocket mouse. Due to the expected long life of some of the larger burrow systems (e.g., badger), fieldwork on this aspect would be impractical. However, fieldwork on the life and fate of smaller burrow systems, such as those dug by mice and ground squirrels, is feasible and is being conducted. This fieldwork involves marking recently dug burrows and monitoring their fate over time.

5.4 SCHEDULE

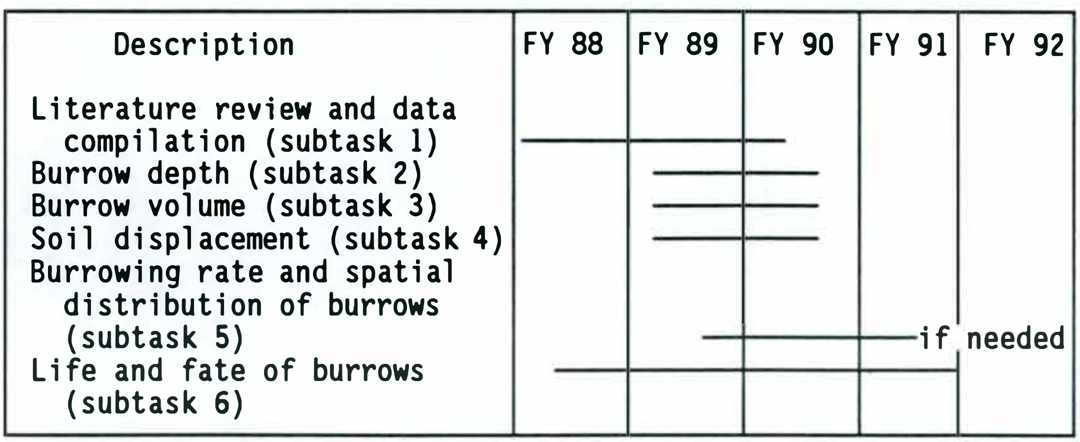

Figure 7. Schedule for Task B for Animal Burrow Characteristics.

5.5 COSTS

Table 5. Animal Burrow Characteristics Costs. (Sheet 1 of 2)

	FY 88	FY 89	FY 90	FY 91	FY 92	Total ($K)
General						
Exempt manpower (PNL)			15	28	30	
Nonexempt manpower (PNL)			7	7	7	
Travel				3	1	
Computer			2	1	2	
Library			1	1		
Subtotal			25	40	40	105
Literature review and data compilation (subtask 1)						
Exempt manpower (PNL)	30	15	9			
Nonexempt manpower (PNL)						
Materials						
Library	3	1	1			
Subtotal	33	16	10			59
Burrow depth (subtask 2)						
Exempt manpower (PNL)			10			
Nonexempt manpower (PNL)		3	10			
Materials			2			
Subtotal		3	22			25
Burrow volume (subtask 3)						
Exempt manpower (PNL)			10			
Nonexempt manpower (PNL)		3	10			
Materials			2			
Subtotal		3	22			25
Soil displacement (subtask 4)						
Exempt manpower (PNL)			10			
Nonexempt manpower (PNL)		3	10			
Materials			2			
Subtotal		3	22			25
Burrowing rate and spatial distribution of burrows (subtask 5)						
Exempt manpower (PNL)		5	40	30		
Nonexempt manpower (PNL)			20	20		
Materials			5	5		
Subtotal		5	65	55		125

Table 5. Animal Burrow Characteristics Costs. (Sheet 2 of 2)

	FY 88	FY 89	FY 90	FY 91	FY 92	Total ($K)
Life and fate of burrows (subtask 6)						
Exempt manpower (PNL)	10	5	5	5		
Nonexempt manpower (PNL)	40	10	10	10		
Materials	3					
Subtotal	53	15	15	15		98
Total (all tasks)	86	45	181	110	40	462

6.0 TASK C--POPULATION RESPONSE STUDY

6.1 OBJECTIVE

The objective of Task C is to evaluate the species composition and density of animals that could impact barrier performance through burrowing. These animals will be evaluated in relation to barrier components (soil, rock armor, admix), soil disturbance, and vegetation type as influenced by climate.

6.2 JUSTIFICATION

Numerous species of burrowing animals live throughout the Pacific Northwest. Their distribution, density, and composition are related to biotic and abiotic factors of the environment that they inhabit. The burrowing capabilities of each species is correlated with individual morphological adaptations. Clearly, a small rodent is not capable of displacing soil or rock to the same degree that a large, powerful animal can. To evaluate long-term burrowing impacts, information on species composition and probable densities are required for both vertebrate and invertebrates that may be attracted to the protective barriers.

A prediction needs to be formed concerning the types of animals that could establish residence in the basalt rock armoring or burrow into the disturbed soil or admix gravel over the next 10,000 yr. The prediction will need to consider present and past distributional and density data for a variety of climatic regimes that could occur at the Hanford Site in the future. Each species that is a potential candidate for future inhabitance of the Hanford Site will need to be considered in relationship to burrowing capabilities and ecological position. For instance, some species of animals may be attracted to the basalt armoring because it provides denning habitat. Other species may be attracted to the barrier because it provides food or other resources not available in the surrounding environment.

The data on species composition relative to habitat (reflecting both physical characteristics of barriers and climate change) are required as direct input to evaluate infiltration, accelerated soil erosion, and waste transport potential (see Figure 1).

6.3 DESCRIPTION

To determine the species of animals that are likely to impact the protective barrier over the next 10,000 yr, it will be necessary to consider climate change scenarios. With this input, regional plant communities and animal species that are known to exist under similar climate regimes can be identified. This will be accomplished through a literature review of the distribution and densities of burrowing animals currently known to occur in habitats that most resemble those predicted for the Hanford Site.

Consideration will also be given to proximity of animal populations to the Hanford Site in order to evaluate migration patterns and the probability of different species dispersing onto the Hanford Site. Data will also be gathered to characterize the potential effects of the ecotone (transition zone) which will become established at the toe of the barrier. The wide variety of plants growing in this area will likely attract a variety of animals that normally would not inhabit rocky areas.

Also as part of Task C, field observations will be conducted at various basalt rock outcrops in the Pasco Basin in order to identify species and characterize burrowing behavior. Animal and/or burrowing densities will be approximated by literature review and limited field observations, as appropriate.

6.4 SCHEDULE

Description	FY 88	FY 89	FY 90	FY 91	FY 92
Literature review				—	
Collect filed data				—	—
Data evaluation					—
Reports					—

Figure 8. Task C Schedule for Population Response Study.

6.5 COST

Table 6. Task C--Population Response Costs.

	FY 88	FY 89	FY 90	FY 91	FY 92	Total
Exempt manpower (PNL)	0[a]	0	0	51	51	
Nonexempt manpower (PNL)	0	0	0	21	21	
Travel	0	0	0	5	5	
Materials	0	0	0	1	0	
Subtotal	0	0	0	78	77	155
G&A/CSP				8	8	16
Total				86	85	171

[a]In thousands of dollars.

7.0 TASK D--PREDICTION AND INTEGRATION

7.1 OBJECTIVE

The objectives of Task D are twofold. The first objective is to apply an animal burrowing model (BURROW) to predict cumulative burrow volumes, soil displacement, and radioactive materials transport that result from animal burrowing for the 10,000-yr design life of the barrier. Data acquired in Task B (Animal Burrow Characteristics), Task C (Animal Population Parameters), and Task E (Barrier Material Performance) are required input to the model.

The second objective is to integrate model results into the barrier evaluation process. Model results for burrow volume estimates and data from Task A (Water Infiltration) need to be integrated to evaluate potential infiltration relative to any proposed barrier design. Cumulative soil displaced to the surface will provide a basis for evaluating accelerated erosion from burrowing. Thus, part of the second objective is to integrate animal-related accelerated erosion in the erosion evaluation task in order to evaluate the barrier relative to proposed erosion standards.

The integration objective also anticipates the need for a surface contamination standard, the basis for which is provided under allowable residual contamination levels (ARCL) methodology (Napier 1982). The objective is to compare estimates of burrowing-related radioactive material transport under probable barrier failure scenarios (DOE-RL 1986b) over the 10,000-yr design life to the standard to evaluate adequacy of barrier design.

7.2 JUSTIFICATION

It is necessary to predict barrier performance relative to future animal burrowing, animal densities, and population structures to design barriers that meet long-term performance standards. Two types of predictions will be required. For standards that impose an annual limit, such as the proposed water infiltration standard, infiltration must be predicted for the maximum year during the 10,000-yr period. For standards that impose a design life limit, such as soil cover remaining after 10,000 yr, cumulative erosion also must be predicted. Thus, estimates of changes in magnitude of animal burrowing activity through time are required, as are means for interpreting these changes relative to increased infiltration and accelerated erosion.

In addition to collecting appropriate field data and information from the literature, a model that predicts cumulative burrow formation and soil movement through time must be identified and applied, and predicted results must be integrated with the infiltration and erosion studies and their related modeling efforts.

7.3 DESCRIPTION

The need to predict long-term erosion and infiltration response of the design barrier to burrowing activity provided the basis for structuring Tasks A through C. A soil transport algorithm from an existing biotic transport model called BIOPORT/MAXI1 (McKenzie et al. 1985) served as a planning and organizing vehicle for a new code called BURROW. This new code will permit calculation of burrow volumes and quantities of soil moved through time as a result of changing animal populations. Figure 1 showed the data requirements for use in the BURROW code relative to specific animal intrusion tasks. Figure 1 also showed the application of the animal transport model results for predicting burrowing-related infiltration and erosion and the ultimate relationship to barrier design decisions. This coordinates the animal intrusion study and integrates study results into the evaluation and design of a final barrier.

Specifically, Task D will accomplish the following.

1. Coordinate Tasks A, B, and C to ensure that parameter values and units are suitable for predicting burrowing activity.

2. Modify the BURROW model as needed.

3. Develop population response algorithms of the BURROW model relative to climate change.

4. Calculate total burrow volumes and soil quantities moved to the surface of the barrier in response to changing climates and animal species and abundances.

5. Coordinate with infiltration and erosion studies to permit evaluation of burrowing-related infiltration and erosion relative to barrier design and performance evaluation.

6. Coordinate with the erosion study task to develop means for predicting animal burrowing impacts on accelerated soil erosion by wind and water.

5. Evaluate surface contamination resulting from animal intrusion into the waste zone.

7.4 SCHEDULE

Description	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94
Model initialization							
Model modifications and input							

Figure 9. Task D Schedule for Prediction and Integration.

7.5 COSTS

Table 7. Task D--Prediction and Integration Costs.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	Total ($K)
Exempt manpower (PNL)	3[a]	10	10	10	28	28	46	135
Nonexempt manpower (PNL)	0	0	0	0	22	22	28	72
Total	3	10	20	30	50	50	75	208

[a]In thousands of dollars.

8.0 TASK E--BARRIER MATERIAL PERFORMANCE

8.1 OBJECTIVE

Document the effectiveness of the barrier components and materials as a deterrent to burrowing.

8.2 JUSTIFICATION

Before the final barrier configuration is selected, it is necessary to determine how effective each barrier component (surface and subsurface) is against intrusion by burrowing animals. If it is determined that animals will indeed breach the barrier within the next 10,000 yr then estimates need to be made on how much waste may be brought to the surface and what the potential impacts to the environment might be. These dose estimates can then be compared against a radionuclide transport standard to determine if such a case would be acceptable.

8.3 DESCRIPTION

It is not known now what the specific components of the final barrier will be. Materials such as fine soils, cobble, pea gravel, geotextiles, asphalt, and others may be used. In most of the barrier designs, the cobble layer beneath the fine soil is considered the primary animal intrusion barrier. The amount of evaluation necessary will depend on the width of the cobble layer.

Task E is divided into two subtasks. Subtask 1 will evaluate the effectiveness of the basalt riprap shoulder and multilayer design as a deterrent to burrowing. Subtask 2 will evaluate how effective a surface admix gravel is as a deterrent to burrowing.

Some of the information that is needed for these two subtasks will be gathered from literature, and from information collected in Tasks B and C.

8.3.1 Subtask 1--Basalt Riprap and Multilayer

Much of the information needed to conduct Task E, Subtask 1, will be collected in Task C. Task C will indicate what kinds of animals will be expected to inhabit the basalt riprap areas and their burrowing characteristics. With this information, an evaluation can be made of the probability of a given animal to burrow and come into contact with the waste. The BURROW code and the radionuclide transport model BIOPORT/MAXI1 BURROW (McKenzie et al. 1985) can then be used to determine dose rates and impact upon the environment.

Task E, Subtask 1 could also test specific barrier components in manmade plots for short periods of time; however, this is most likely cost-prohibitive.

8.3.2 Subtask 2--Admix Gravel

The effort to assess the extent of intrusion into admix gravel layers will be divided into three separate studies.

- Study No. 1: monitor the burrowing activities of animals on the admix gravel study plots established at the McGee site.

- Study No. 2: document local burrowing activities on graveled sites.

- Study No. 3: collect information at selected natural analog sites similar to the barrier configurations under design.

8.3.2.1 Admix Gravel Study Plots. Several admix gravel study plots have been established at the McGee site with varying amounts of pea gravel mixed in to the soil. Since there are no animal exclusion barriers at these plots, it will be possible to monitor foraging and burrowing activities, and possibly determine whether the animals prefer certain plots over others.

8.3.2.2 Local Site Burrowing Activities. There are several graveled sites at the Hanford Site (natural analog sites not included) within the Pasco Basin that will be looked at with regard to animal burrowing. Examples of sites which could be evaluated include drill pads, graveled cribs, and disturbed sites where gravel has been put down. Sites with varying degrees of cobble size, cobble depth, and different ages will be evaluated as to the extent animals have encroached on these sites and established residence.

8.3.2.3 Natural Analog Studies. In conjunction with the natural analog studies that have been proposed, animal burrowing activities will also be documented at natural analog sites. These sites will provide data of animal activity on sites that have existed for thousands of years.

8.4 SCHEDULE

Description	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
Literature review						
Select study areas						
Collect and record data						

Figure 10. Task E Schedule for Barrier Material Performance.

8.5 COSTS

Table 8. Task E--Barrier Material Performance Costs.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	Total
Exempt manpower (PNL)	0[a]	0	0	56	46	37	139
Subtotal							
G&A/CSP							

[a]In thousands of dollars.

9.0 SAFETY

Standard plant safety procedures pertaining to the operation of heavy equipment will be followed.

Separate safety precautions must be followed when handling the animals. Only qualified personnel, those with experience trapping and handling animals, will be allowed to handle the animals using appropriate live trapping techniques.

10.0 QUALITY ASSURANCE

The following quality assurance requirements shall be in place for controlling work performed in this plan: Personnel Training and Qualification; Management Assessment, Procedures, Test Control, and QA Records.

- Personnel training and qualification
- Management assessment
- Procedures
- Test control
- Quality assurance records.

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