LEACHING OF H-3 AND C-14 LABELED COMPOUNDS AT THE UNIVERSITY OF KANSAS RADIOACTIVE WASTE DISPOSAL SITE

by

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R. E. L.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Disposal of much of the radioactive waste generated at the University of Kansas Medical Center is by burial at the University of Kansas radioactive waste disposal site. This disposal site was established on the assumption that buried activity would not remain in the burial containers, but would leach through the soil. Based on this assumption, burial limits were established which prevent the leached activity from exceeding the maximum permissible concentrations (MPC) for water. This project is to quantitate the amount of leaching and to verify the safe operation of the burial site after approximately ten years of use.

Radioactive waste is buried in a 200' x 200' section of land located 907.3' South and 216' East of the Northwest corner of Section 13, Range 21E, in Johnson County, Kansas.[1] This location has been used for disposal of radioactive waste since 1965. Figure 1, page 3, shows the location of the disposal site in relation to Kansas City.

Trenches 1.5' wide, 6' to 8' deep, and 10' to 100' long are dug for burial of radioactive waste. The waste material is either stacked or thrown into the trenches until the trench is filled to a depth of 2' below ground level, after which the trench is backfilled plus an additional amount of extra soil is mounded over the top. Figure 2, page 4,

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[1]University of Kansas Medical Center - Radioactive Materials License 18-C054-02, 1974.

shows the burial location of waste as of November 18, 1976. The diagram is not drawn to scale.

Containers used to bury the waste are not selected to insure containment of the material after it is placed in the trench, and at no time during the burial procedure are precautions taken to prevent rupture of the containers. Examples of the types of containers used include plastic bags, plastic or glass vials, and cardboard boxes, and it would be logical to assume that many of the containers will rupture or deteriorate, during and after completion of a burial, thereby releasing radioactive waste.

Various isotopes and chemical compounds have been buried at the disposal site. However, due to the time which has elapsed since the burials were initiated plus the fact that most of the waste buried is H-3 and C-14, only these two isotopes have been studied in this project. Soil samples were taken in several locations and at various depths in and around the disposal site. The samples were counted in a liquid scintillation counter to determine whether carbon-14 (C-14) and hydrogen-3 (H-3) are present at levels exceeding those which naturally occur. Table 1, page 4, lists the decay characteristics[2] and the amount of activity which has been buried for these two isotopes. Tables 2 and 3, page 7, list some of the classes of compounds and specific chemical forms, most of them buried in a toluene or xylene base liquid scintillation fluid. This type of waste accounts for approximately 70% of the waste volume.

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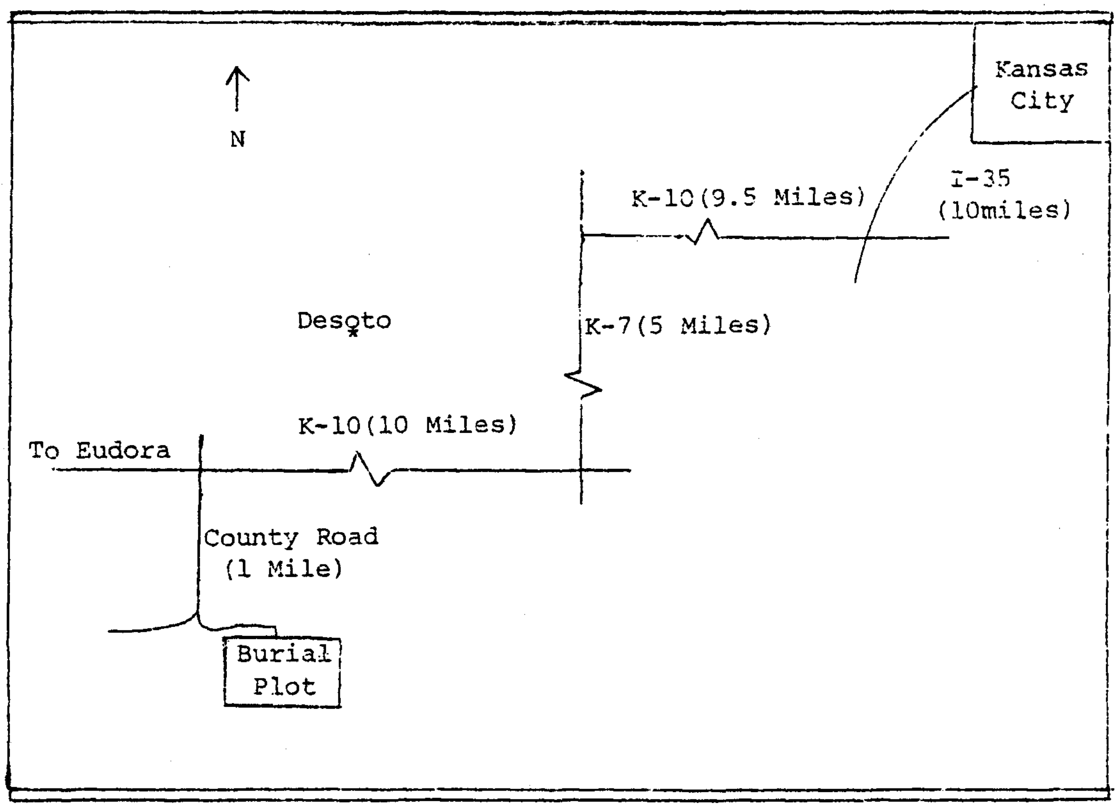
[2]Chemical Rubber Company. CRC Handbook of Radioactive Nuclides, 1969. The Chemical Rubber Company, Cleveland, Ohio, 1969, p. 34.

Geological Characteristics of the Disposal Site

The burial plot is composed of the following types of soil in distinct stratified layers: 1)the topsoil is a Pawnee clay loam, and this surface layer is approximately 24-32% clay and varies from 10-18" in depth; 2)the subsoil is 35-50% clay and is from 24-40" thick; 3)the substratum is variable in texture and is about 40-110" thick: 4)below this substratum is a layer of rock lake shale consisting of sandstone and sandy shale.[3] Figure 3, page 5, illustrates the vertical stratification and slope (4-6%) of the disposal site.

FIGURE 1

LOCATION OF THE DISPOSAL SITE



[3]Tom McLain. "Soil at KUMC Low Level Radioactive Waste Site in Johnson County, Kansas", Requested Report, 1976.

FIGURE 2

DISPOSAL SITE

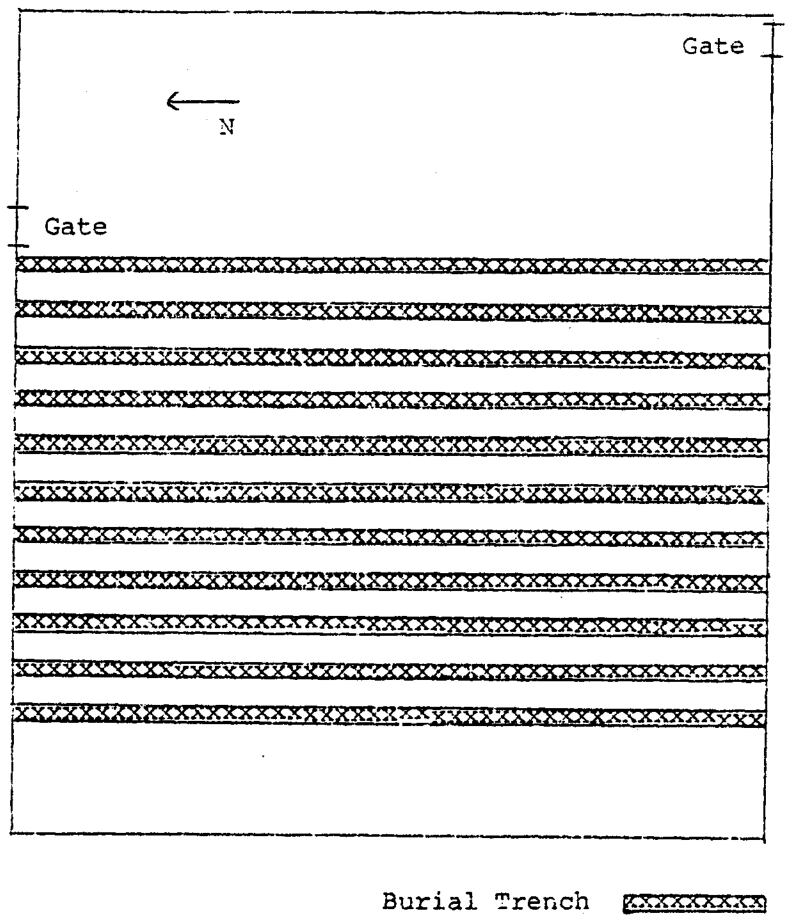


TABLE 1

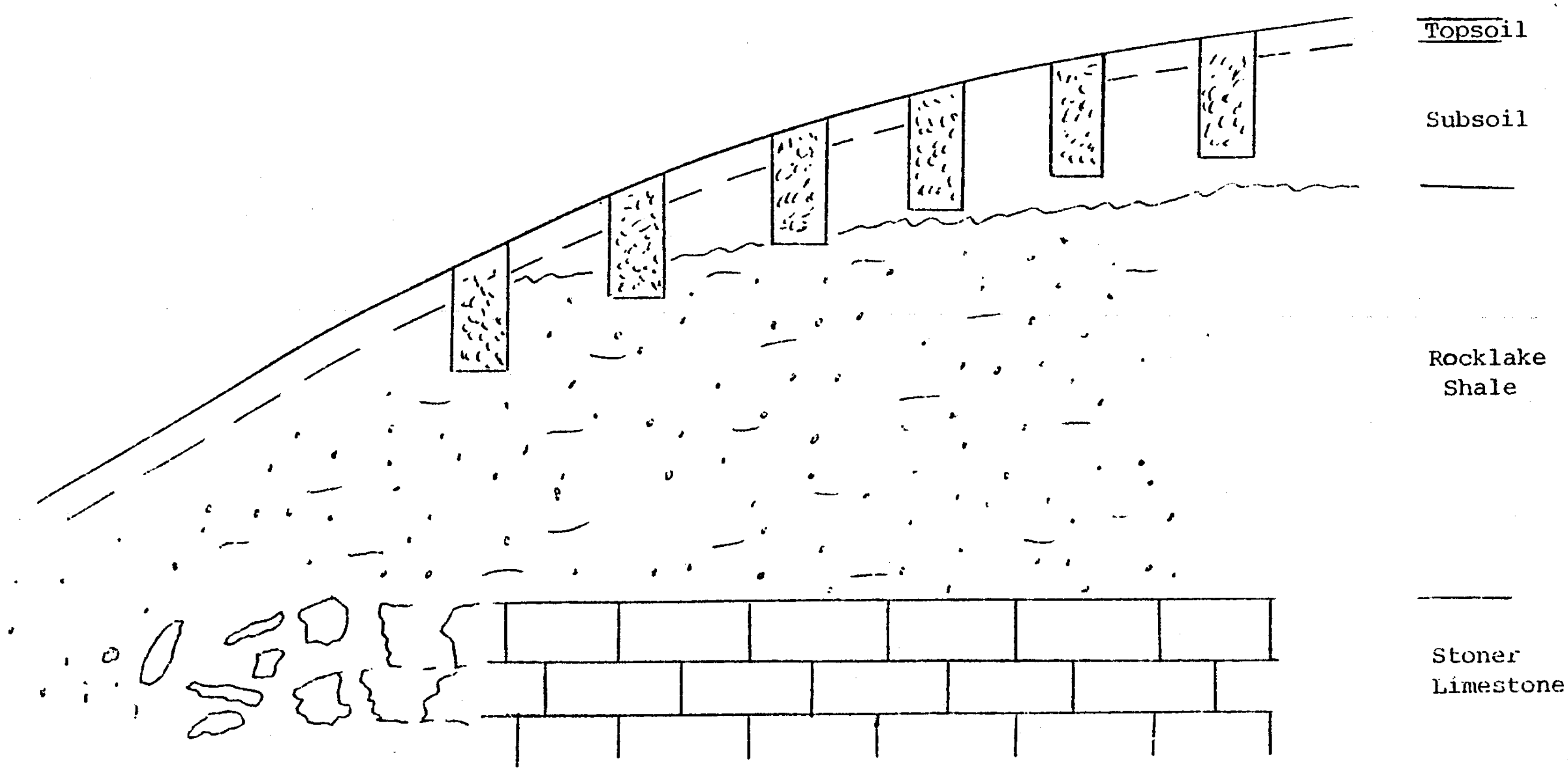
DECAY CHARACTERISTICS OF H-3 AND C-14

Isotope	T	Radiation Emitted	Activity Buried
H-3	12.3 years	β^- (.0186 MeV)	2,200,000 μCi
C-14	5730 years	β^- (.156 MeV)	300,000 μCi

FIGURE 3

Cross-Section of the Waste Disposal Site

(Diagram not to scale)



CHAPTER II

METHODS AND MATERIALS

In order to accomplish the objective of this project, it was necessary to divide the work into two major projects. The first required development of a method to extract radioactive material from soil obtained at the disposal site. The second involved collection of disposal site soil samples which were then analyzed by the technique developed in the first project to determine the amount of radioactive material attributable to the disposal site.

Project #1: Determining the Capability for Removal of Radioactive Material from Soil

To determine if radioactivity is leaching from the disposal site, it was necessary to develop a method to remove radioactive material from soil in a manner that would cause it to go into solution with the scintillation fluid and to eliminate as much as possible any quenching due to the soil sample. This was accomplished by adding labeled compounds to soil to simulate the presence of leached radioactive material and then using various agents (hereafter called strippers) to extract the activity. To reduce the quenching effect of the soil, samples were centrifuged to pack the soil on the bottom of the vial. Known amounts of labeled material were added to the soil, processed, and counted; then an internal standard was added to each sample so that the results could be related to the percent removal efficiency for each stripping agent.

The labeled compounds used in this research are representative of the major classes of compounds buried at the disposal site and are listed in Table 2, page 7. For each of the classes listed in Table 2, one labeled compound was used to study the class removal properties. The specific compounds and their radioactive label are listed in Table 3.

TABLE 2

CLASSES OF COMPOUNDS BURIED AT THE RADIOACTIVE WASTE DISPOSAL SITE

1.	Sugars
2.	Amino Acids
3.	Water
4.	Fatty Acids
5.	Organic Solvents

TABLE 3

LABELED COMPOUNDS USED FOR STUDYING REMOVAL PROPERTIES OF THE STRIPPING AGENTS

Class	Compound	Isotope Label
Sugars	Glucose	C-14
Amino Acids	A.A. Mixture*	C-14
Water	Water	H-3
Fatty Acids	Choesterol	C-14
Organic Solvents	Toluene	C-14

*A.A.: Amino Acid Mixture

The chemical classes and specific chemical forms used as stripping agents are listed in Table 4, page 8. The classes were chosen to reflect a broad spectrum of chemical reactions to determine which stripping agent had the best composite extraction efficiency for the labeled compounds listed in Table 3.

Samples were counted in a Packard Tri-Carb liquid scintillation counter set to operate in the balance point mode.[1] Packard Dimulume-30, a scintillation fluid containing a chemi-luminescence inhibitor, was used for the counting fluid.

TABLE 4

STRIPPING AGENTS

Class	Chemical Form
Acid	HCL (pH-1)
Base	Protosol
Organic Solvent	Liquid Scintillation Fluid
Water	Water
Chelating Agent	EDTA*

*Ethylenediamenetetraacetic Acid

It was calculated that 1.5 to 3.0 grams of soil would be needed to produce significant counts. The assumptions and calculations used to determine this value are contained in Appendix A.

Quenching effect of soil. Several techniques were considered to find some method of counting the soil samples without producing severe quenching due to the soil. An initial experiment indicated that the procedure developed by Joseph[2] could not be used in this project because of the quenching produced by suspending 1.5 to 3.0 grams of soil in each vial.

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[1]Nuclear Chicago Mark I Scintillation Counter Instrumentation Manual, Section 4, pp. 1-7.

[2]K. T. Joseph, "Radioactivity in the Rocks and Minerals of Kansas". Unpublished Masters Disertation, University of Kansas, 1972, pp. 17-18.

Table 6, page 25, shows the quenching effect of suspending various amounts of soil in a liquid scintillation fluid.

Other experiments included the use of filter papers to separate the soil from the strippers, separating funnels to remove the soil sediment from the strippers, and vacuum pumps to apply suction to the two above methods. These experiments resulted in very poor counting or extraction efficiencies and were discarded, and no data is contained in this thesis outlining these results since these experiments were very preliminary.

The procedure finally decided upon for separating the soil from the processed samples involved spinning the samples, each containing 15 ml of Dimulume-30 and 1.5 to 3.0 grams of soil for approximately 30 minutes, until the soil formed a solid layer on the bottom of the vial and until there were no visible soil particles floating in the scintillation fluid. This proved to be a satisfactory method since the sample vial is inserted between the detectors of the scintillation counter and the soil packed on the bottom of the vial does not add significantly to the quenching.

To determine the quenching effect of soil after centrifuging the samples, an increasing amount of soil was added to a series of vials and the vials centrifuged for 30 minutes. A known amount of C-14 toluene (8.7×10^3 ntpm*) was added to each vial, the samples counted, and the degree of quenching determined by dividing the net CPM by the ntpm added. This procedure was then repeated using H-3 toluene (5.6×10^4 ntpm).

<u>Chemical luminescence and quenching effects of the stripping solutions</u>. Prior to determining the extraction efficiencies of the stripping agents, their chemical luminescence and quenching properties were determined. The chemical luminescence properties were determined by pipetting 3 ml of the

*ntpm: nuclear transformations per minute stripper into 15 ml of Dimulume-30, allowing the solution adequate time to cool in the scintillation counter, and then counting each sample for 10 minutes. Two samples were used for each stripping agent. The results were compared with data obtained from samples containing only scintillation fluid.

The quenching effect of the stripping agents was determined by adding a known amount of activity (C-14 toluene, 6.4 x 10^4 ntpm) to a series of vials containing 15 ml of liquid scintillation fluid and then adding three ml of the stripper. Two vials were used for each stripper. The vials were placed in the counter to cool for 15 minutes and then were counted for two minutes. The quenching effect was determined by comparing the results obtained from the samples containing the strippers with the results from samples containing no strippers but with the same amount of activity.

Determining the extraction efficiencies of each stripper. For each labeled compound. The purpose of this experiment was to determine quantitatively the extraction efficiency of the strippers and then to decide which one gives the best overall extraction efficiency for the labeled compounds. Six vials were used for each stripping agent (total of 30 vials for each labeled compound). Into each series of vials, approximately two grams of soil and a known amount of labeled compound were added. To duplicate any binding that might occur during natural leaching, the vials were allowed to set overnight. Two ml of the stripper were then added and the samples processed to determine the extraction efficiency. The step-by-step procedure used to process the samples is contained in Appendix B.

Project #2: Determining Whether Radioactive Material is Leaching from the Disposal Site

Site preparation. Prior to collecting soil samples from the disposal site, the area was divided into four distinct sections: background, burial, lower level, and creek bottom. Background is approximately 300' North and across a gully from the burial site. Its purpose was to provide background data, assuming radioactivity would not leach across the gully and uphill and that soil samples collected from this section would be similar to those collected from the burial, lower level, and creek bottom except that possible radioactivity leaching from the burial site would not be present. The burial section is the area of the radioactive waste disposal site where waste is buried, and it constitutes an area of approximately 200' x 70'. The lower level section is located adjacent to and below the burial section. The last section is the creek bottom. If activity were found to be leaching from the burial site, samples would be collected from the creek to determine if activity is being carried in the stream. The nearest point of the creek is 150' from the bottom of the lower level. The sampling area is illustrated in Appendix C.

After the sections were outlined, wooden stakes were driven into the ground to indicate the sampling sites. There were five sites in the background section, ten in the burial, ten in the lower level, and six in the creek bottom. The sampling sites, (recorded in Appendix C), selected in the burial section were located between the burial trenches.

Sample collection. Wherever possible, samples were taken at depths of 3', 6', and bedrock in order to obtain a cross sectional representation of the disposal site. In the background and burial plots, samples were obtained at the specified depths. In the lower level plot, samples could only be taken at 3' and bedrock. The depth of the bedrock determined the sampling depth and thus the number of samples taken from each sampling site. The creek bottom samples were taken from 6" to 12" below the surface of the ground.

Two methods were used to obtain samples. Initially, a 4" auger was used to drill a hole to the desired sampling depth. The auger was then removed and a core barrel fastened in its place. The core barrel was lowered to the bottom of the hole and pushed into the soil to a depth of 4-10". The core barrel was pulled out and the soil sample removed. The auger was then replaced and the hole drilled to the next desired depth. This procedure was repeated for each sampling site in the area. The auger and core barrel equipment are shown in Figure 4, page 13. The removal of a soil sample from the core barrel is shown in Figure 5, page 14.

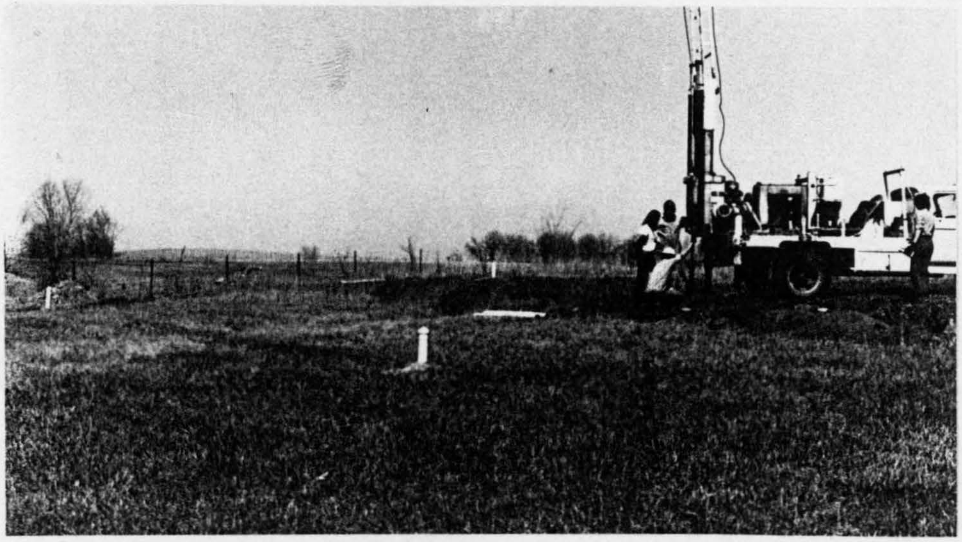
The second method used for obtaining core samples involved use of only the core barrel. In this method, the core barrel was pushed into the soil to the desired depth (3', 6', etc.), the barrel pulled out to remove the soil sample, and the barrel reinserted and pushed to the next desired depth. This method provided the same type of sample, but required less collection time.

To prevent cross contamination of the core samples, separate cloth bags were used for each soil sample. The bags were marked according to the sampling area, location within the area, and the sampling depth.

Sample preparation. Since the primary method of removing radioactivity from the soil was by direct contact with the scintillation fluid (determined from Experiment #1), it was necessary to have the soil surface area as large as possible. This was accomplished by pulverizing the core samples on a wire screen to produce a sample of sandy consistency.

FIGURE 4

AUGER AND CORE BARREL EQUIPMENT



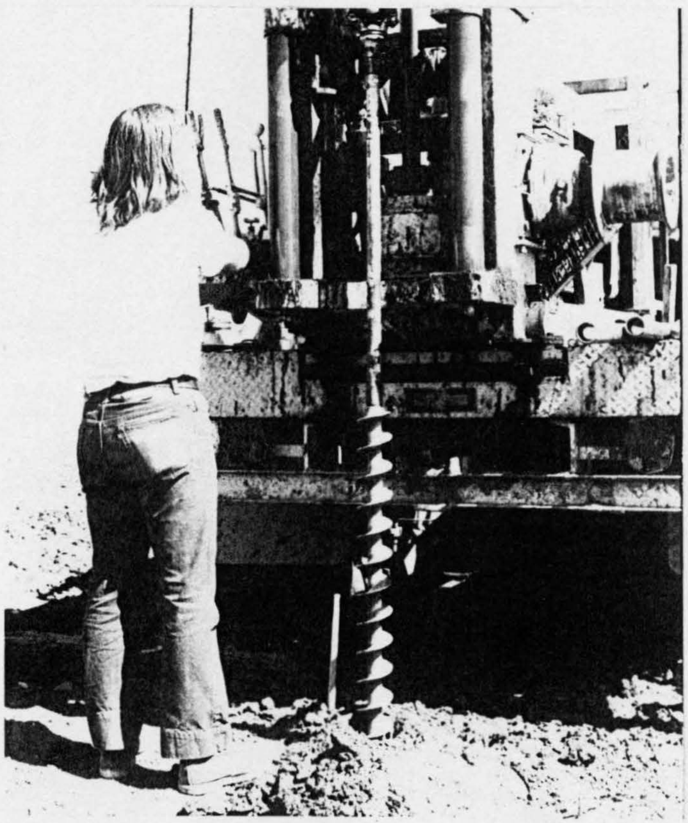


FIGURE 5

REMOVAL OF SOIL SAMPLE FROM CORE BARREL

After the core sample was pulverized, approximately two grams of soil were measured into a preweighed scintillation vial and the vial was reweighed to determine the exact weight of the soil added. Next, 15 ml of Dimulume-30 were added to the vial, the vial vortexed several times over a period of 20 to 30 minutes, and then allowed to stand overnight. Following the overnight soaking period, the samples were again vortexed several times and centrifuged until the soil formed a hard layer on the bottom of the vial. Figure 6, page 16, illustrates the appearance of the vials after adding the soil, vortexing, and finally centrifuging. The outside surface of the vials was cleaned with ethanol to remove any fingerprints or soil which might reduce light transmission through the glass. The samples were placed in a liquid scintillation counter for 10 to 15 hours to reduce any photo- or chemi-luminescence and then counted for 100 minutes each.

After all the samples from a particular area had been counted, a H-3 internal standard was added (100λ, H-3 toluene, 1.24×10^4 ntpm). The samples were then counted for two minutes and the above procedure repeated using C-14 toluene (1.0×10^4 ntpm).

The samples were counted on a Searle Mark III liquid scintillation counter. The counter was programmed to count in the dual label (H-3 and C-14) variable quench mode. In this mode, the instrument automatically shifts the window to center the spectrum peak thus maximizing the counting efficiency.[3] The step-by-step procedure used for processing the soil samples is contained in Appendix D.

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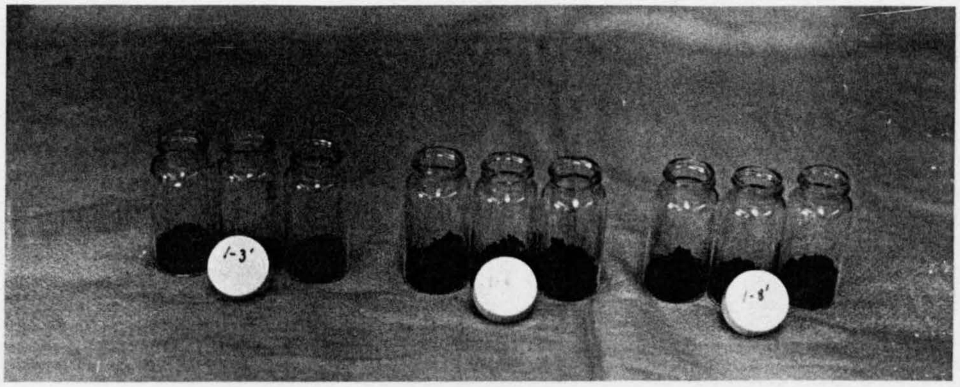
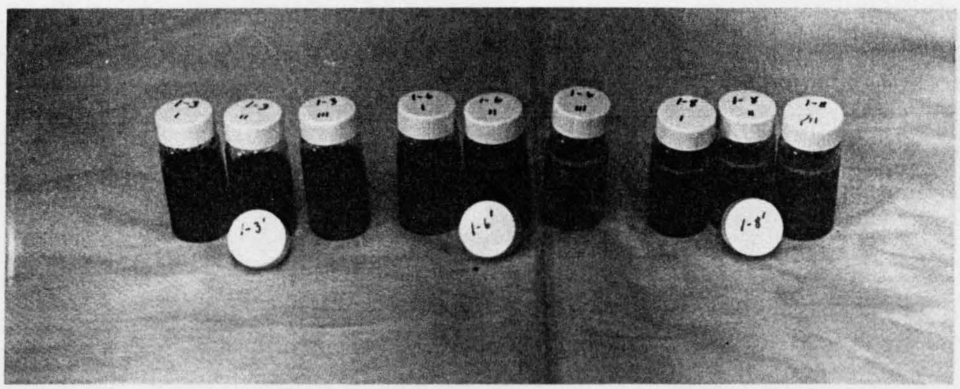
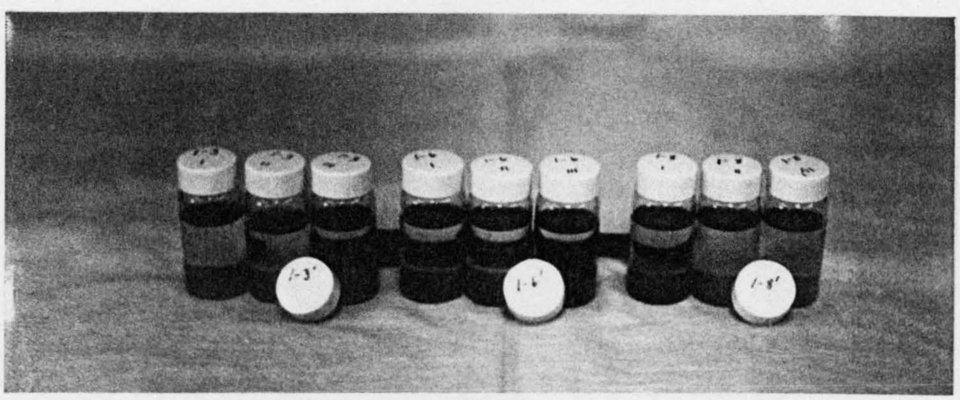
[3] Searle Mark III Scintillation Counter Instruction Manual, Section 5, pp. 5-42.

FIGURE 6

SAMPLE APPEARANCE







<u>Data analysis</u>. The data collected during the project is contained in Appendices E through H. Appendix E contains the data collected from the background plot, Appendix F contains the data collected from the burial plot, Appendix G contains data from the lower level, and Appendix H contains data from the creek bottom. A sample calculation is shown below. The information for this example was taken from Appendix F for positions 1-3.

<u>Legend</u>.

bkg:	background count from scintillation fluid and vial
BKG:	background count from soil
$\overline{M}$:	mean
CPM:	counts per minute
σ:	standard deviation
I.S.:	internal standard
ntpm:	nuclear transformations per minute
eff:	efficiency

A. Calculation of the mean ($\overline{M}$) sample CPM - bkg ± σ

1. Gross H-3 $\overline{M}$ CPM

   8250 cts/100 min.
   7653 cts/100 min.
   16079 cts/100 min.
   31982 cts/300 min. = 107 CPM

2. $\sigma = (107 \text{ CPM}/300 \text{ min})^{1/2} = .6$ cts.

3. Net H-3 $\overline{M}$ CPM ± σ = (gross CPM - bkg) ± σ

   $= (107 - 15) \pm \{(.6)^2 + (.16)^2\}^{1/2}$

   $= 92 \pm .6$

B. Calculation of sample ntpm ± σ

1. Gross $\overline{M}$ CPM ± σ (soil sample, I.S., bkg)

   6301 cts/2 min.
   6373 cts/2 min.
   6534 cts/2 min.
   19208 cts/6 min. = 3201 CPM ± 23.

2. Net I.S. CPM ± σ = {gross CPM(sample + I.S. + bkg) - net sample CPM - bkg} ± σ

   $= (3201 - 92 - 15) \pm \{(24)^2 + (.6)^2 + (1)^2\}^{\frac{1}{2}}$

   $= 3094 \pm 24$

3. $\text{I.S. eff.} \pm \sigma = \dfrac{\text{I.S. net CPM} \pm \sigma}{\text{I.S. ntpm} \pm \sigma}$

   a. I.S. σ = 5% calibration error + 3% pipetting error

   $= \{(.05)^2 + (.03)^2\}^{\frac{1}{2}}$

   $= .06$

   b. σ (net I.S. CPM) = 24/3094 = .008

   c. $\text{I.S. eff} \pm \sigma = \dfrac{3094 \pm .008}{1.24 \times 10^4 \pm .06}$

   $= 25 \pm \{(.06)^2 + (.008)^2\}^{\frac{1}{2}}$

   $= 25 \pm .06$

   $= 25 \pm 1.5$

4. $\text{Sample ntpm} \pm \sigma = \dfrac{\text{net sample CPM} \pm \sigma}{\text{I.S. eff} \pm \sigma}$

   $= \dfrac{92 \pm .06 \text{ CPM}}{.25 \pm 1.5\%}$

   $= \dfrac{92 \pm .007}{.25 \pm .06}$

   $= 368 \pm \{(.007)^2 + (.06)^2\}^{\frac{1}{2}}$

   $= 368 \pm .06$

   $= 368 \pm 22$ ntpm.

C. Calculation of ntpm/gram of soil

1. $\overline{M}$ soil wt (grams) per vial ± σ =

$$\begin{array}{l} 1.48 \pm .04 \text{ grams} \\ 1.99 \pm .04 \text{ grams} \\ \underline{1.74} \pm .035 \text{ grams} \\ 1.74 \pm .06 \text{ grams} \end{array}$$

$$\sigma = \{(.03)^2 + (.04)^2 + (.035)^2\}^{\frac{1}{2}} = .06$$

2. $$\text{ntpm/gram} \pm \sigma = \frac{\overline{M} \text{ sample ntpm} \pm \sigma}{\overline{M} \text{ sample weight} \pm \sigma \text{ (extraction eff.)}}$$

$$= \frac{368 \pm 22}{(1.7 \pm .06)\ (.49)}$$

$$= \frac{368 \pm .06}{(1.7 \pm .04)\ (.49)}$$

$$= 431 \pm \{(.05)^2 + (.04)^2\}^{\frac{1}{2}}$$

$$= 431 \pm .07$$

$$= 431 \pm 15 \text{ ntpm/gram.}$$

NOTE: Values in the "ntpm/gram" column in Appendices E-H must be divided by .49. The values indicated do not reflect the extraction efficiency for counting fluid.

CHAPTER III

RESULTS

Determining the Capability for Removal of Radioactivity from Soil

The results of this experiment are summarized in tabular and in graphical form. The counting efficiency obtained by the addition of increasing amounts of soil to the vials is tabulated in percent, counting efficiency versus grams of soil added. The values gathered for the chemical luminescence and quenching properties of the strippers are expressed as CPM above background. The extraction efficiencies are in percent and are listed as mean extraction efficiencies. For this part of the thesis, qualitative, not quantitative values are needed. For this reason, a statistical analysis was not performed.

The suspension of soil in a scintillation vial containing 15 ml of scintillation fluid and a known amount of activity reduces the counting efficiency as the amount of soil added increases. The suspension of .1 gm of soil decreased the H-3 and C-14 counting efficiency to 2% and 20% respectively (see Table 6, page 25). However, by centrifuging the samples to pack the soil on the bottom of the vials, this loss in counting efficiency can be reduced. Table 7, page 26, illustrates the changes in counting efficiency for H-3 and C-14 as the amount of soil in the centrifuged vials is increased. The H-3 efficiency drops from 51% with no soil added to 32% with 4.35 grams added. The C-14 efficiency ranged from 69%

with no soil added to 34% with 5.09 grams added. This reduction in efficiency is acceptable, especially when compared to the counting efficiency loss incurred if soil is suspended in the scintillation fluid.

Various compounds (strippers) were used to extract radioactive material from the soil samples. Prior to beginning the experiment to determine which of the stripping agents had the best overall extraction efficiency for the labeled compounds, their chemical and quenching properties were determined.

For cholesterol, the extraction efficiency of water, counting fluid, EDTA, acid and protosol was 92%, 96%, 88%, 73%, and 91% respectively. For toluene the extraction efficiency of water, counting fluid, EDTA, protosol, and acid was 88%, 87%, 86%, 82%, and 71% respectively. For amino acids, water had an extraction efficiency of 14%, EDTA 13%, counting fluid 11%, acid 11%, and protosol 9%. For glucose, the extraction efficiency of acid, water, EDTA, counting fluid, and protosol was 32%, 31%, 24%, 4%, and 4% respectively. For H-3 water, the extraction efficiency for counting fluid was 36%, and for water it was 38% (See Table 10 and Figure 7). Table 5, page 22, summarizes the ranges of extraction efficiencies of the various labeled compounds.

If the net sample CPM (LSF and Stripper) exceeded BKG (LSF)* + 3σ, the contribution from the stripper was considered significant. For the five stripping agents used, none exceeded this value. It was concluded that there was no significant contribution to the count rate due to chemical luminescence of the stripping agents.

A C-14 unquenched standard prepared from the same standard solution as that used for determining the quenching effect of the five stripping

*LSF: liquid scintillation fluid

agents exhibited a 72% counting efficiency. The efficiencies obtained after adding three ml of the stripping solutions ranged from 64% to 69%. This relates to a drop in counting efficiency of 9% to 4%. This information is tabulated in Table 9, page 27. Depending on the overall extraction efficiencies obtained for the various strippers, the degree of quenching may or may not be critical.

TABLE 5

RANGE OF EXTRACTION EFFICIENCIES

Labeled Compound	Range of Extraction Eff. (all strippers)	% Difference
Cholesterol	96% to 73%	24
Toluene	88% to 71%	20
A.A. Mixture	14% to 9%	31
Water	38% to 36%	4
Glucose	32% to 4%	88

Determining Whether Radioactive Material is Leaching from the Radioactive Waste Disposal Site

The results of this experiment are summarized in tabular and in graphical form. Final values for the soil data are listed as CPM above background $\pm\sigma$ and ntpm/gram $\pm\sigma$. It is assumed that the counts obtained in the H-3 and C-14 channels are from those respective isotopes and not other natural sources of radioactivity.

Background Plot. The mean net H-3 CPM for samples taken in the background plot is 2 ± .4 for samples taken at three feet, .7 ± .4 for samples taken at six feet, and 4 ± .4 for samples taken at nine feet. The mean net C-14 CPM for three, six, and nine feet is 2 ± .3, .3 ± .3, and .5 ± .3 respectively.

The information for the creek bottom is contained in Appendix H. See Tables 11 - 12 and Figures 7 - 8.

TABLE 6

QUENCHING EFFECT OF SOIL SUSPENDED IN A LIQUID SCINTILLATION FLUID

Sample #	Isotope	Soil Weight (grams)	Counting Eff. (%)
1	C-14	.2380	8
2	"	.2129	9
3	"	.1027	20
4	"	.0429	48
5	"	.0287	51
6	"	.0076	66
7	"	.0019	72
8	"	0.0000	73
9	H-3	.3071	.5
10	"	.2050	1
11	"	.1110	2
12	"	.0511	6
13	"	.0233	14
14	"	.0052	34
15	"	.0038	36
16	"	0.0000	45

TABLE 8

CHEMICAL LUMINESCENT PROPERTIES OF THE STRIPPING SOLUTIONS

Solution	Sample #	CPM	CPM-BKG
Water	1	32	0
	2	34	+2
Acid	1	38	+6
	2	41	+9
EDTA	1	28	-4
	2	36	+4
Protosol	1	35	+3
	2	46	+14
BKG (no stripper added)	1	29	
	2	35	$\overline{M}$ (mean)=32 CPM

TABLE 9

QUENCHING PROPERTIES OF THE STRIPPING SOLUTIONS

Solution	Sample #	CPM	CPM-BKG	Eff. (%)
Water	1	42645	42610	67
	2	42503	42468	66
Acid	1	40801	40766	64
	2	42433	42398	66
EDTA	1	43707	43672	68
	2	44454	44419	69
Protosol	1	44126	44091	69
	2	43970	43935	69
BKG (no stripper added)	1	33		
	2	37	$\overline{M}$ (mean) = 35 CPM	

TABLE 10

EXTRACTION EFFICIENCIES FOR THE STRIPPING AGENTS

Labeled Compounds	Stripping Agents				
	C.F.*	Prot.*	H_2O	EDTA	Acid
Amino acid mixture	11	9	14	13	11
Cholesterol	96	91	92	88	73
Glucose	4	4	31	29	32
Water	36	___	38	---	---
Toluene	87	82	87	86	71

*C.F. : Counting fluid

*Prot. : Protosol

FIGURE 7

EXTRACTION EFFICIENCIES FOR
EACH STRIPPER - EACH LABELED COMPOUND

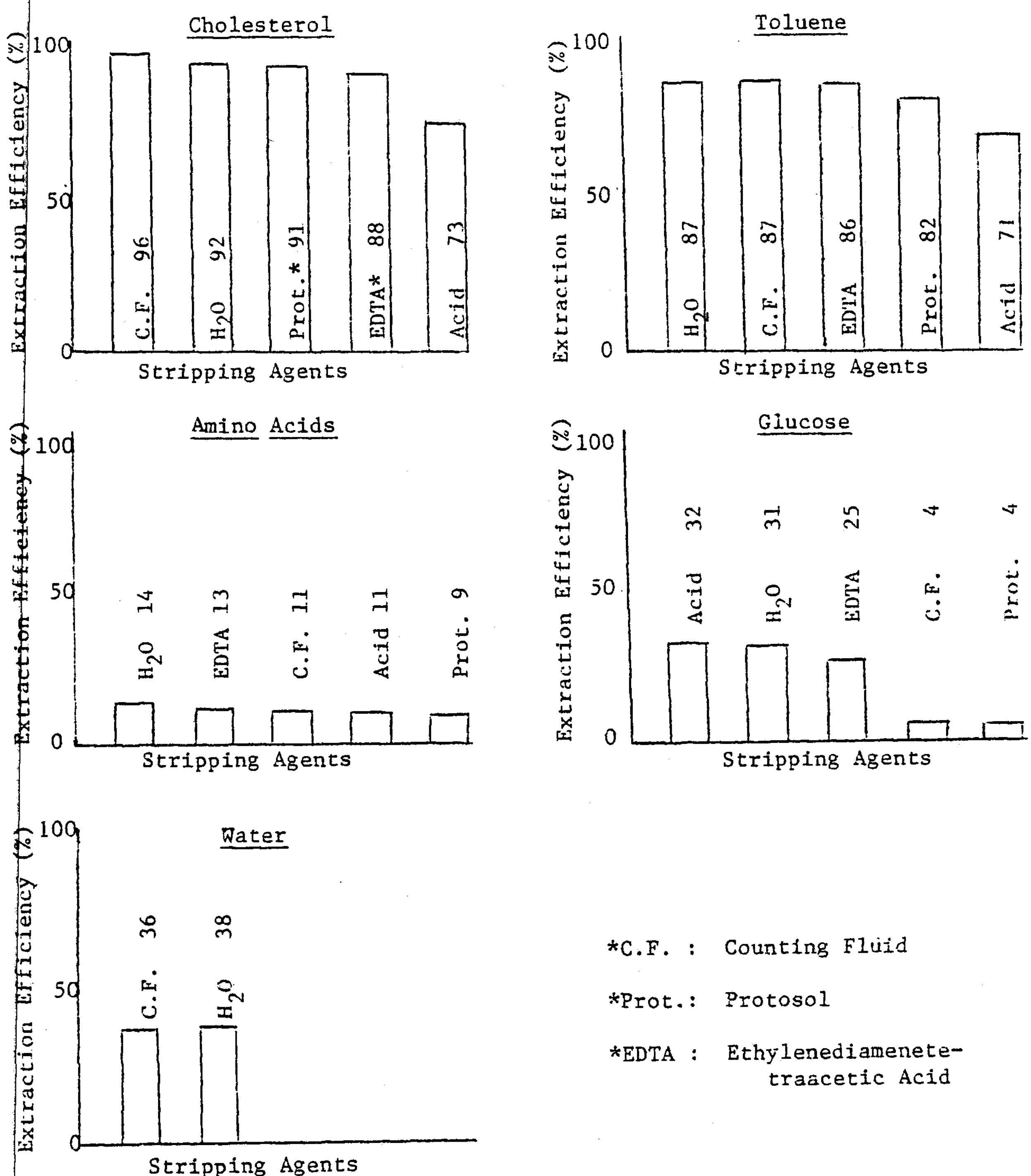
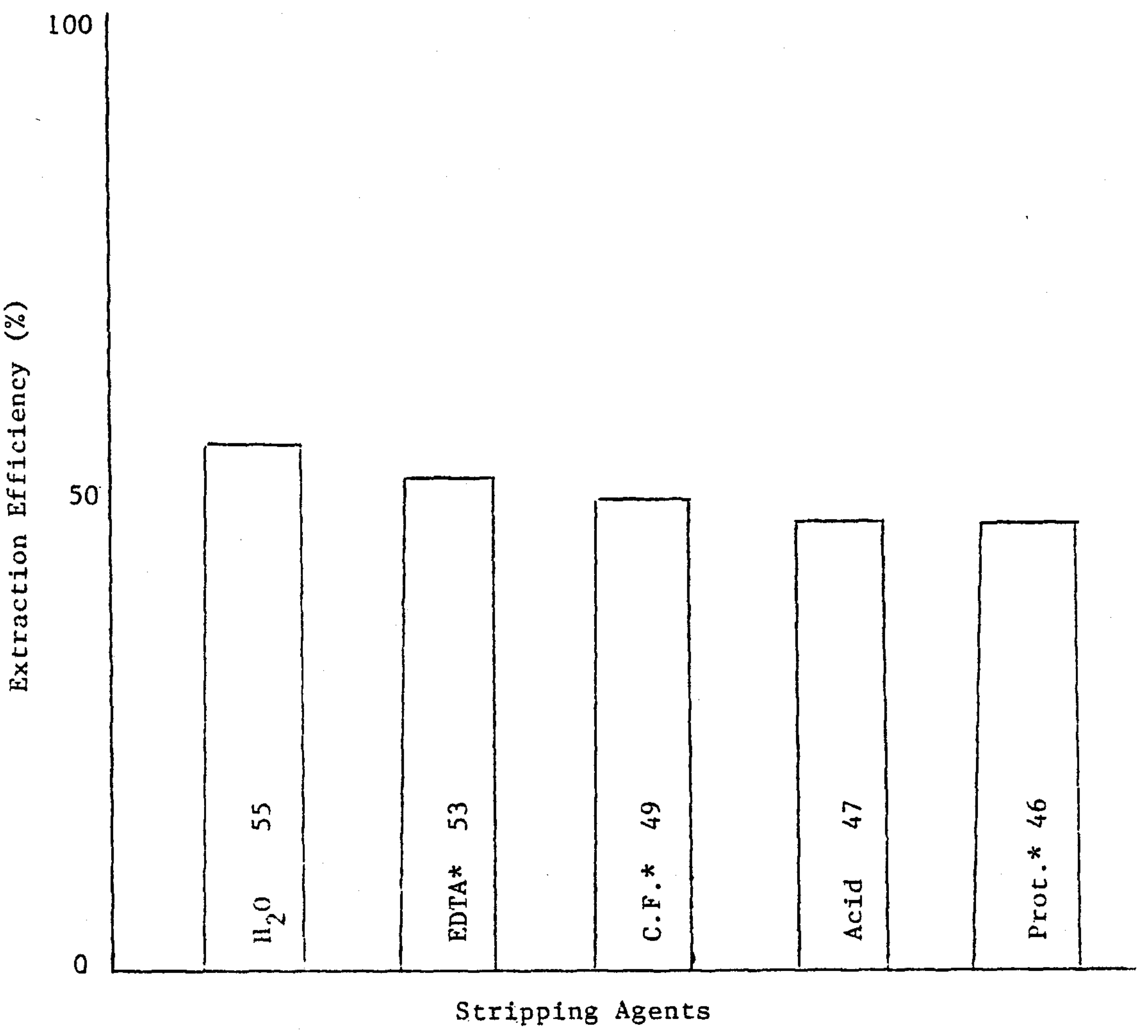


FIGURE 8

MEAN EXTRACTION EFFICIENCY FOR EACH STRIPPER



*EDTA: Ethylenedraminetetraacetic Acid

*C.F.: Counting Fluid

*Prot.: Protosol

TABLE 11

H-3 MEAN CPM ABOVE BACKGROUND OF SOIL SAMPLES

Depth	Background	Burial Plot	Lower Level	Creek Bottom
3'	.2 ± .4	31 ± 1	3 ± 1	-.02 ± .3(1)*
6'	.4 ± .4	111 ± 2	26 ± 1	-1 ± .3(2)*
9' (Btm)	4 ± .4	195 ± 2	26 ± 1	-.8 ± .3(3)*
				.4 ± .3(4)*
				.2 ± .3(5)*
				-.8 ± .3(6)*

*Sampling positions

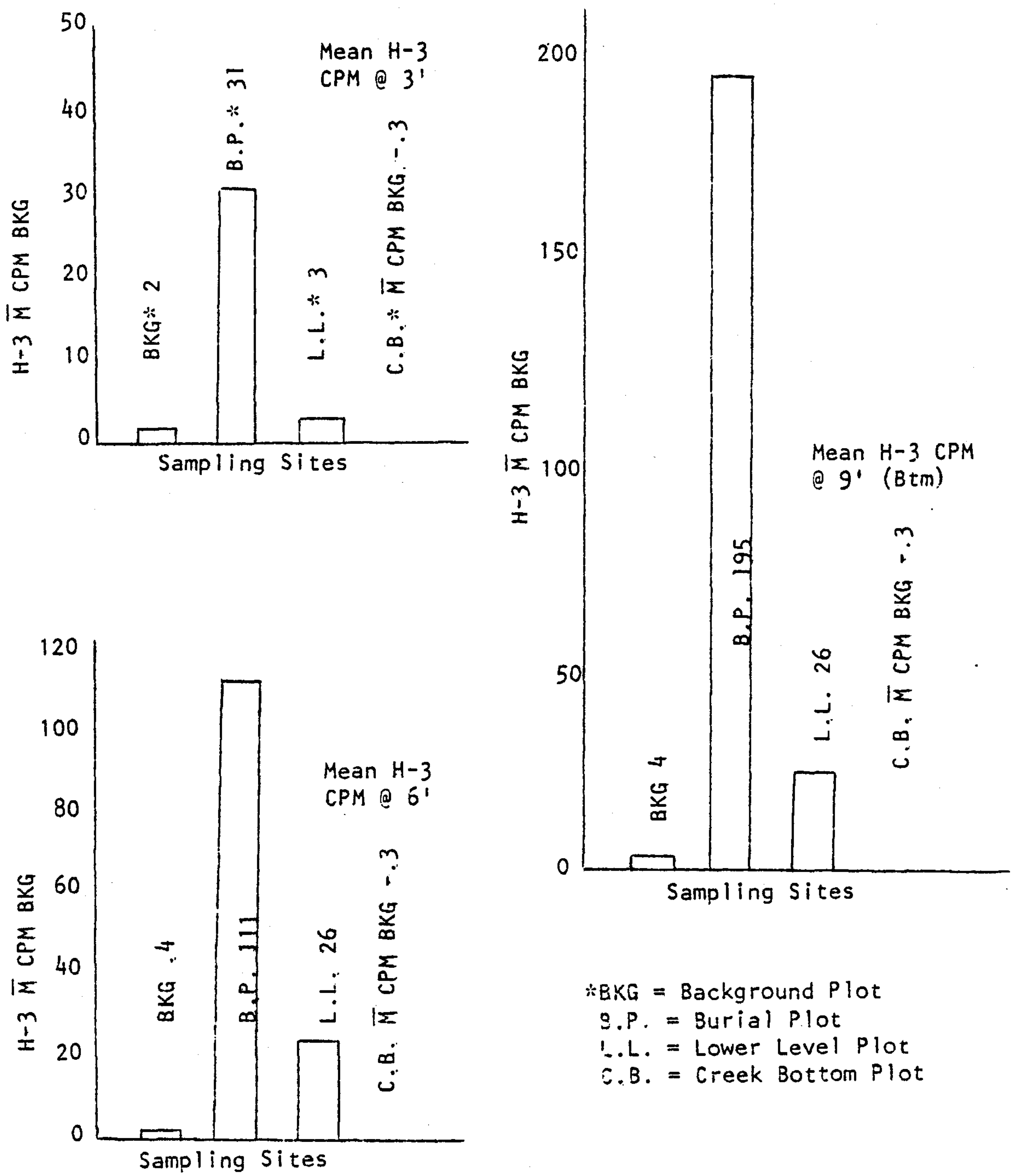
TABLE 12

H-3 MEAN ntpm/gram FOR SOIL SAMPLES

Depth	Background	Burial Plot	Lower Level
3'	2 ± .6	64 ± 15	6 ± 2
6'	.7 ± .5	224.16 ± 64.93	48 ± 14
9'	5 ± 1	415.01 ± 74.32	48 ± 14

FIGURE 9

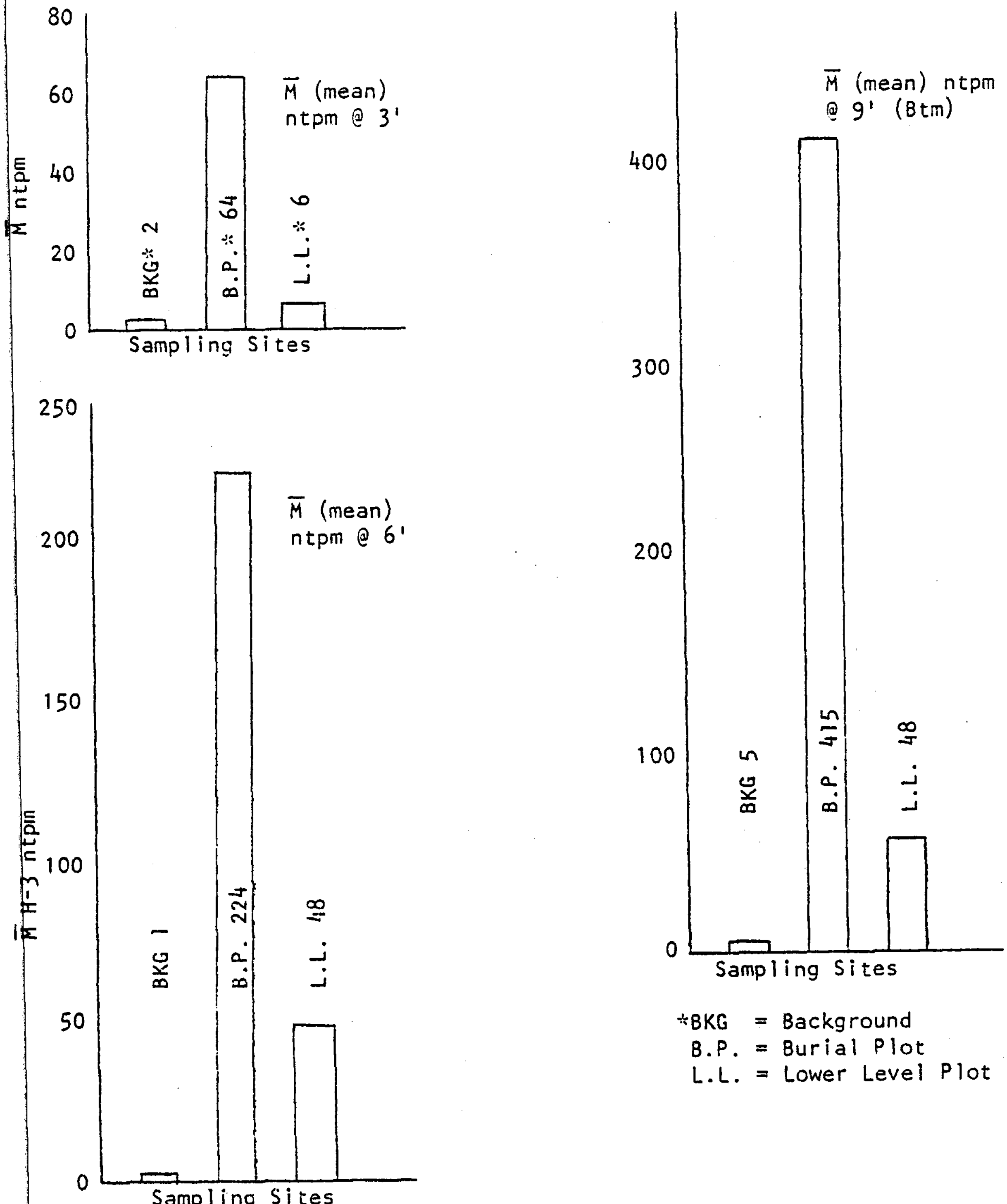
MEAN H-3 CPM ABOVE BACKGROUND
FOR THE SAMPLING SITES AT 3', 6', AND 9'



*BKG = Background Plot
B.P. = Burial Plot
L.L. = Lower Level Plot
C.B. = Creek Bottom Plot

FIGURE 10

MEAN H-3 ntpm FOR SAMPLING SITES AT 3', 6', AND 9'



CHAPTER IV

DISCUSSION

Project #1: Determining the Capability for Removal of Radioactivity from Soil

The procedure developed in project #1 for processing soil samples provides a method for removing radioactivity from soil. The stripping agents used produced data that indicated various labeled compounds, representative of the types buried at the disposal site, can be extracted.

The mean extraction efficiencies for the strippers ranged from 46-55 percent. If radioactive material is leaching from the disposal site, then from 46-55 percent of the leached activity could be removed. The actual percent extraction efficiency depends on the stripper used.

The original intention was to use the stripping agent which had the best overall extraction efficiency for removing leached radioactivity from soil. This was not followed for two reasons: 1)when three ml of water or a water base compound such as EDTA or acid is added to 15 ml of Dimulume-30, the scintillation fluid has a tendency to partially gel. When this occurs, the soil particles suspend in the gel and cannot be centrifuged down, thus increasing the amount of quenching produced by the soil. The problem can be solved by heating the vials in warm water to dissolve the gel, but this is a time-consuming process and often the fluid re-gels before centrifuging is complete; 2)the mean extraction efficiencies for water, EDTA, and C.F. are 55, 53, and 49 percent. When the drop in counting efficiency attributable to quenching of the strippers is considered (5% for water, 3% for EDTA), the overall efficiency of the extraction procedure (extraction and counting efficiency) for the three compounds becomes 50% for water, 50% for EDTA, and 49% for C.F.

Based on the tendency of the scintillation fluid to gel when a water/water base compound is used as a stripper and the fact that the overall efficiencies for the three best strippers are so close, counting fluid (C.F.) was chosen as the stripper of choice.

These extraction efficiencies, when extrapolated for the disposal site, did not take into consideration the many variables that might affect the leaching or binding of labeled material in soil (seasonal temperature changes, long term exposure to radiation, ground water movement, etc.). Because of the many variables possibly affecting the movement or binding of compounds to soil, it was assumed that if labeled compounds could be extracted from soil in the laboratory from simulated leaching, then the extraction procedure would work equally well for extracting activity from soil samples taken at the disposal site.

Project #2: Determining Whether Radioactive Material is Leaching from the Radioactive Waste Disposal Site

If radioactive material is leaching from the disposal site, one would 1)expect to see the burial plot and lower level plot CPM exceed the background plot CPM with increasing sampling depth and 2)expect the net CPM and ntpm/gram to be the lowest in the background plot, highest in the burial plot, and somewhere in the middle in the lower level plot. Except for the background plot at six feet, both of these expectations were correct. There was a drop in both the net H-3 CPM and the H-3 ntpm/gram between the three foot and six foot sampling depths in the background plot. However, the values were so close together that the differences are not statistically different.

<u>H-3 Samples</u>. The net H-3 CPM at three feet for the background, burial, and lower level plots was 2 ± .4, 31 ± 1, and 3 ± 1 respectively. At six feet, the values were .4 ± .4, 111 ± 2, and 26 ± 1. At nine feet they were 4 ± .4, 195 ± 2, and 26 ± 1.

The H-3 ntpm/gram followed the same pattern as the net CPM. The information for the net CPM and the ntpm/gram is contained in Tables 11 and 12, page 31.

Using the test criteria that data from the burial plot and lower level plot exceeding "background plot data (BKG) + 3σ" constitutes leaching with a 99 percent confidence level, the following results were collected: for the background plot at three, six, and nine feet, the net H-3 CPM (BKG) + 3σ is 3, 2, and 5; for all samples collected in the burial and lower level plot at three, six, and nine feet (bottom), these values are exceeded; for the burial plot, the values are 31, 111, and 195 net CPM and for the lower level they are 3, 26, and 26 net CPM (see Table 13, page 37).

For the background plot at three, six, and nine feet, the H-3 ntpm/gram + 3σ is 4, 2, and 9 respectively. For all samples collected in the burial and lower level plots at three, six, and nine feet (bottom), these values are exceeded: for the burial plot, the values are 64, 224, and 415 ntpm/gram and for the lower level, they are 6, 48, and 48 ntpm/gram (see Table 13, page 37).

TABLE 13

SUMMARY OF STATISTICAL ANALYSIS

Position	Net Counts/Minute			ntpm/gram		
	BKG* + 3σ	B.P.*	L.L.*	BKG + 3σ	B.P.	L.L.
3'	3	31	4	3	64	6
6'	2	111	26	2	224	48
9'	5	195	26	9	415	48

*BKG: Background plot
B.P: Burial plot
L.L: Lower level plot

From the above information, it can be stated with greater than 99% confidence that H-3 radioactive material is leaching from the radioactive waste disposal site.

C-14 Samples. From the data collected for analysis of C-14 labeled compounds, it is not possible to say that these compounds are leaching. In no case did the values calculated for C-14 net CPM exceed the values of C-14 background plot data (BKG) + 3σ. In four of the eight calculated values for net C-14 CPM, a negative value was obtained.

Because of the similarities between the H-3 and C-14 labeled compounds buried at the disposal site, it is logical to assume the C-14 labeled compounds are leaching similarly to the H-3 labeled compounds. The lack of data for C-14 was anticipated since the amount of soil added to each vial was less than that calculated for obtaining significant counts from the soil.

Since it has been determined that radioactivity is leaching from the disposal site, samples were taken in the creek bottom to determine whether the activity is being carried in the stream. From Table 11, the net CPM for the creek bottom ranged from -1 to .4. These values do not exceed the test criteria for establishing leaching and, in fact, are less than the net background plot CPM. The absence of activity in the stream can be explained by one of two theories: either the activity has been diluted to the point where it is below the minimum detectable level for the counter or the activity has not leached to the stream bed at this time. In either case, there does not appear to be any activity attributable to the disposal site in the creek bottom.

In Table 14, the μCi/gram of soil for the various sampling depths for the different plots has been calculated and summarized. This was done so that a comparison can be made between the levels of activity leaching and the maximum permissible concentrations for uncontrolled areas.

This comparison was between μCi/gram of soil and the μCi/ml for water. Water concentration levels were used since there are no concentration levels for soil and the movement of the leached activity through the soil is probably due to the movement of ground water.

The maximum permissible concentration for H-3 in water for uncontrolled areas is 3×10^{-3} μCi/ml. In the burial plot, the μCi/gram at three, six, and nine feet was 2.88×10^{-5}, 1.018×10^{-4}, and 1.88×10^{-4} respectively. In the lower level plot at three feet and bottom, the μCi/gram was 2.65×10^{-6} and 2.16×10^{-5}.

From the values above, it can be seen that the concentration in soil (μCi/gram) in the burial and lower level plots ranges from 16 to 1132 times less than the concentration levels allowed for water (uCi/ml).

The worst case situation would be the leaching of 1.88×10^{-4} uCi per gram of soil into the ground water over a period of one year. The H-3 concentration (uCi/ml) at the nearest accessible point on the creek then would be 8×10^{-6} uCi/ml. This value is less than the MPC for H-3 in water by a factor of 375, and is based on a drainage area 1400 feet by 1100 feet around the creek and disposal site and an annual rainfall of 34 inches. The calculated concentration (uCi/ml) one mile downstream from the disposal site is 1.7×10^{-6} uCi/ml or a factor of 1.7×10^{3} less than the MPC for tritium in water. These calculations are based on the assumption that the drainage area extends 700 feet on the side of the stream.

The Maximum Permissible Body Burden (MPBB) for H-3 is 2×10^{3} uCi. Using the above maximum activity of 1.88×10^{-4} uCi/gram of soil, one would need to ingest 1×10^{7} grams (23,000 pounds) of soil to reach the MPBB for H-3.

From the above discussion and comparisons, it would be safe to assume that people living and working in the area will not be exposed to radiation levels which are considered to be harmful and that the environmental hazard due to leaching of the compounds will be minimal.

TABLE 14

uCi/gram of Soil

Depth	Burial Plot	Lower Level Plot
3'	2.88×10^{-5}	2.65×10^{-6}
6'	1.01×10^{-4}	2.16×10^{-5}
9' (btm)	1.88×10^{-4}	2.16×10^{-5}

H-3 MPC for water: 3×10^{-3} uCi/ml

CHAPTER V

SUMMARY

A study was undertaken to verify the assumptions, made prior to establishing the disposal site, that buried radioactive waste would leach from the disposal site and that the disposal limits do not allow the leached radioactive material to exceed the MPC for uncontrolled areas. Samples were taken from four sections around the disposal area (background, burial, lower level, and creekbottom). At each sampling plot, soil samples were taken at levels of 3 feet, 6 feet, and 9 feet wherever possible. Counting was performed on a Searle Mark III liquid scintillation counter.

In Project #1, a method was developed for extracting leached radioactive material from soil samples. Extraction efficiency for the compounds, representative of those buried at the disposal site, ranged from 46% to 55%. This project determined that from 46% to 55% of the leached activity could be extracted if radioactivity were, in fact, leaching from the site.

Project #2 used the technique developed in the previous experiment to analyze soil samples taken from the disposal site. The data collected clearly indicate (99% confidence) that the radioactive waste at the disposal site is leaching. For samples collected in the burial and lower level plots, the activity per gram of soil ranged from 1.88×10^{-4} to 2.6×10^{-6} uCi/gram. Data collected for samples taken in the creekbottom indicate there is no radioactivity present which is attributable to the disposal site.

The H-3 soil concentration (uCi/gram) was less than the maximum permissible concentration for H-3 in water by a factor of 16 to 1000. Assuming the worst possible situation, the projected H-3 water concentration (uCi/ml) was from 375 to 1.7×10^3 times less than the maximum permissible concentration for water. To further indicate the minimal hazard associated with the leached radioactivity material, it was calculated that one would need to ingest 1×10^7 grams (23,000 pounds) of soil in order to exceed the maximum permissible body burden for H-3.

The estimated C-14 count rate associated with leaching of C-14 at the maximum permissible concentration is 890 counts per minute. By comparing this value to the minimum detectable C-14 activity determined in Appendix A, it can be seen that the counts per minute needed to indicate the presence of C-14 at the MPC level is 30 times greater than the minimum detectable level. Therefore, the lack of detectable C-14 counts indicates that if C-14 is leaching, it is less than the MPC by a factor of at least 30.

The results of this experiment indicate that the limits established by the Kansas Department of Health and Environment for burial of radioactive waste do not allow leaching to exceed the MPC values for tritium and carbon in water. At this time the amount of leakage does not appear to constitute any significant hazard to persons working or living near the disposal site, and it does not appear at present to pose a hazard to the environment of the area.

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APPENDIX A

Calculation of Optimum Soil Weight Needed for Significant Counts in Each Sample

I. Preliminary Information

A. Disposal area: 220' x 200'

B. Depth radioactive waste is buried below surface: 2'

C. Burial plot: 200' x 60'

D. H-3 activity buried: 2.2×10^6 μCi

E. C-14 activity buried: 3.0×10^5 μCi

F. Estimated values:

1. H-3 counting efficiency for soil samples: 35%

2. C-14 counting efficiency for soil samples: 60%

3. Mean extraction efficiency: 35%

4. Percent of buried activity leaching: 5%

5. H-3 background CPM: 25

6. C-14 background CPM: 20

G. Assumptions:

1. Distribution of leached activity:

a. activity is uniformly distributed over disposal site

b. activity is uniformly distributed over burial plot

2. Detectable limit is BKG + 3σ

3. Average depth of soil below 2' in the disposal site: 2.5'

4. Average depth of soil below 2' in the burial plot: 5'

II. Calculations

A. Minimum detectable activities

1. H-3

a. BKG = 25 CPM 3σ = 15 CPM

b. $$\frac{15 \text{ CPM}}{(.6)(.35)(2.2 \times 10^6 \text{ntpm}/\mu\text{Ci})} = 5.56 \times 10^{-5} \ \mu\text{Ci}$$

2. C-14

a. BKG = 20 CPM $\qquad 3\sigma = 13.42$

b. $$\frac{13.42}{(.6)(.35)(2.2 \times 10^{\circ} \text{ntpm}/\mu\text{Ci})} = 2.904 \times 10^{-5}\ \mu\text{Ci}$$

B. Mass of disposal site - burial plot

1. Disposal site

$$\frac{(200')(200')(2.5')(1.9 \text{ grams/cm}^3)}{3.53 \times 10^{-5} \text{ ft}^3/\text{cm}^3} = 5.38 \times 10^9 \text{ grams}$$

2. Burial plot

$$\frac{(200')(60')(5')(1.9 \text{ grams/cm}^3)}{3.53 \times 10^{-5} \text{ft}^3/\text{cm}^3} = 3.228 \times 10^9 \text{ grams}$$

C. Soil/vial needed to produce minimum detectable counts

1. H-3

a. Disposal site

$$\frac{5.56 \times 10^{-5}\ \mu\text{Ci(M.D. activity)}}{(2.2 \times 10^6\ \mu\text{Ci})(.05)/5.38 \times 10^9 \text{ grams}} = 2.72 \text{ grams}$$

b. Burial plot

$$\frac{5.56 \times 10^{-5}\ \mu\text{Ci}}{(2.2 \times 10^5)(.05)/(3.228 \times 10^9 \text{ grams})} = 1.63 \text{ grams}$$

2. C-14

a. Disposal site

$$\frac{2.904 \times 10^{-5}\ \mu\text{Ci}}{(3.0 \times 10^5\ \mu\text{Ci})(.05)/5.38 \times 10^9 \text{ grams}} = 10.42 \text{ grams}$$

b. Burial plot

$$\frac{2.904 \times 10^{-5}\ \mu\text{Ci}}{(3.0 \times 10^5\ \mu\text{Ci})(.05)/3.228 \times 10^9 \text{ grams}} = 6.25 \text{ grams}$$

APPENDIX B

Activity Extraction Procedure

1. Add approximately two grams of soil to each vial.
2. Pipette 100 lambda of the labeled compound into each vial.
3. Let the vial sit overnight.
4. Add two ml of the stripping agent to each vial.
5. Let the vial sit for one hour.
6. Add 15 ml of the liquid scintillation fluid.
7. Vortex sample several times over 15 - 20 minutes.
8. Let the vial sit overnight.
9. Vortex vial several times.
10. Spin the samples until soil forms a hard layer on bottom of the vial and no soil particles are visible floating in the liquid.
11. Wipe the outside of vials clean with ethanol.
12. Count samples for four minutes.
13. Remove samples and add an internal standard of the same isotope as the labeled compound.
14. Count the samples for one minute.
15. Determine the removal efficiency in the following manner:

    a. Internal Standard Efficiency =

    $$\frac{\{CPM(sample + I.S.) - BKG\} - \{CPM(sample) - BKG\}}{ntpm\ (I.S.)}$$

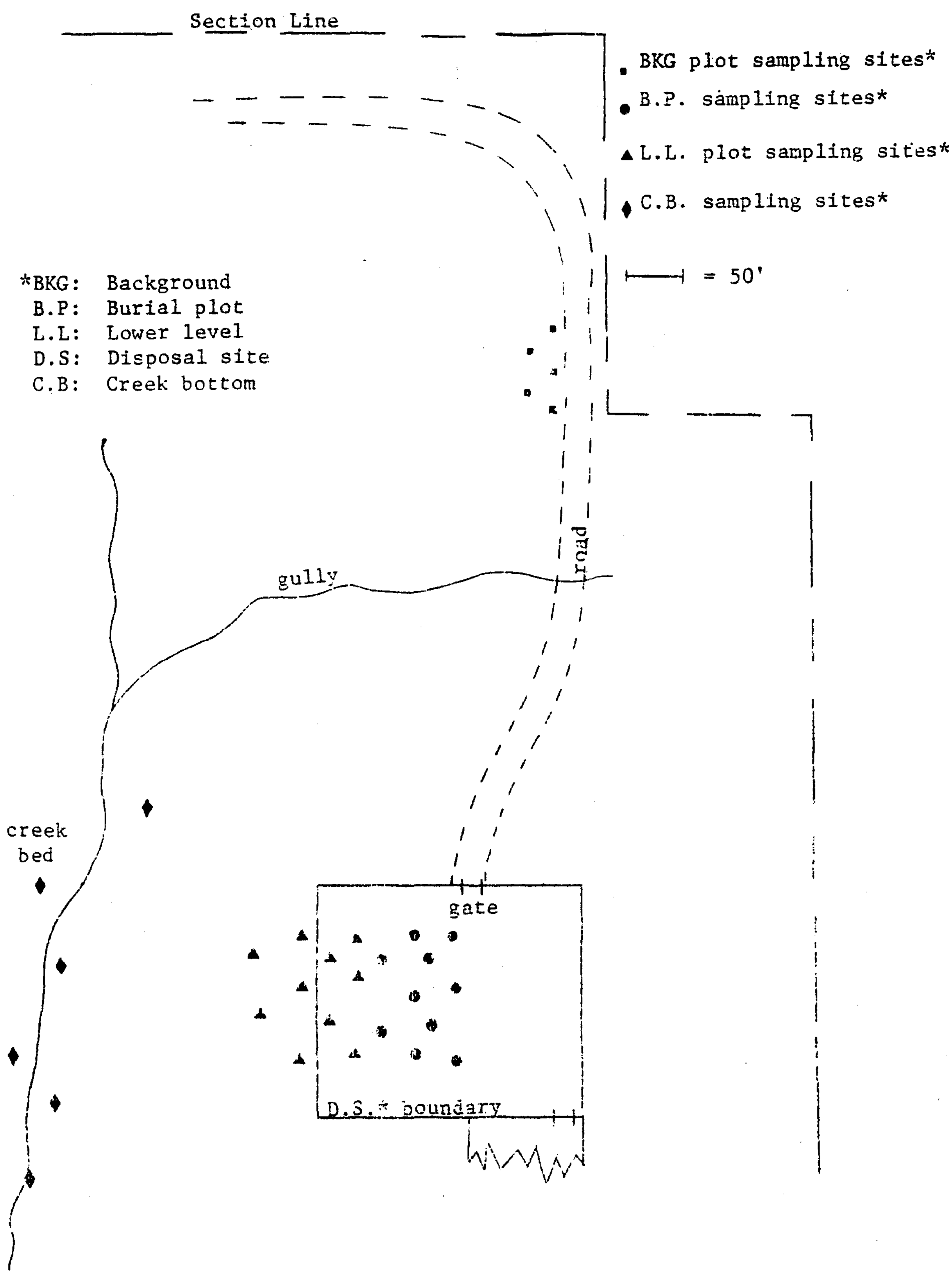
    b. Removal Efficiency =

    $$\frac{CPM(sample) - BKG}{\{I.S.\ eff. \times Sample\ ntpm\}}$$

APPENDIX C

Sampling Area

SOIL SAMPLING AREA



APPENDIX D

Soil Processing Procedure

1. Grate the core sample over wire screen.
2. Measure approximately two grams of soil into preweighed scintillation vial.
3. Reweigh the scintillation vial and determine exact weight of soil added.
4. Add 15 ml of Dimulume-30.
5. Vortex sample several times over 15 - 20 minutes.
6. Let the vials set overnight.
7. Vortex sample several times.
8. Spin samples in centrifuge until all soil is packed on the bottom.
9. Place sample in counter overnight to cool and dark adapt.
10. Count each sample for 100 minutes.
11. Add the H-3 internal standard.
12. Count each sample for two minutes.
13. Add the C-14 internal standard.
14. Count the sample for two minutes.

APPENDIX E

Background Plot Data

BACKGROUND DATA

H-3 and C-14 $\bar{M}$ CPM above Bkg ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\bar{M}$ cpm ± σ	H-3 $\bar{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\bar{M}$ cpm ± σ	C-14 $\bar{M}$ cpm-bkg ± σ
1 - 3	1	2080	19.66±.066	4.01±.071	1213	11.64±.039	1.99±.042
	2	1877			1095		
	3	1943			1184		
1 - 6	1	1671	16.19±.054	.547±.060	911	9.42±.031	-.227±.035
	2	1621			957		
	3	1566			959		
1 - B	1	2248	21.84±.073	6.19±.077	1004	9.93±.033	.280.037
	2	2103			987		
	3	2201			988		
2 - 3	1	1598	17.08±.057	1.437±.063	915	9.27±.031	-.377±.035
	2	1763			910		
	3	1764			957		
2 - 6	1	1676	16.88±.036	1.237±.062	971	9.44±.031	-.213±.035
	2	1689			974		
	3	1700			886		
2 - B	1	1782	15.63±.052	-.013±.058	881	8.79±.029	-.853±.033
	2	1454			875		
	3	1453			883		
3 - 3	1	1615	16.13±.054	.487±.060	920	9.05±.030	-.593±.034
	2	1638			892		
	3	1586			905		
3 - 6	1	1427	14.22±.047	-1.42±.054	937	9.38±.031	-.270±.035
	2	1391			928		
	3	1448			949		

BACKGROUND DATA

H-3 and C-14 $\overline{M}$ CPM above Bkg ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\overline{M}$ cpm ± σ	H-3 $\overline{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\overline{M}$ cpm ± σ	C-14 $\overline{M}$ cpm-bkg ± σ

Background H-3 standard: 382251

Background C-14 standard: 64419

BACKGROUND DATA

H-3 and C-14 $\overline{M}$ CPM above Bkg ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\overline{M}$ cpm ± σ	H-3 $\overline{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\overline{M}$ cpm ± σ	C-14 $\overline{M}$ cpm-bkg ± σ
3 - B	1	2432	23.44±.078	7.79±.082	1030	10.01±.033	.363±.037
	2	2345			952		
	3	2254			1021		
4 - 3	1	1454	14.56±.049	-1.83±.055	974	10.03±.033	.383±.037
	2	1423			1053		
	3	1493			983		
4 - 6	1	1730	18.19±.061	2.54±.066	931	9.26±.031	-.387±.035
	2	1853			962		
	3	1874			886		
4 - B	1	2225	23.16±.077	7.52±.081	1068	10.74±.036	1.087±.039
	2	2389			1088		
	3	2336			1065		
5 - 3	1	1998	20.62±.069	4.98±.074	863	8.77±.029	-.883±.033
	2	2197			868		
	3	1992			899		
5 - 6	1	1462	14.83±.049	-.807±.055	872	8.97±.030	-.680±.034
	2	1466			912		
	3	1523			907		
5 - B	1	1246	12.84±.043	-2.8±.050	937	9.34±.031	-.307±.035
	2	1328			924		
	3	1279			942		
Bkg	1	1640	15.64±.161		991		
	2	1584			1012		
	3	1654			1059		
	4	1502			967		
	5	1519			877		
	6	10187			884		

BACKGROUND DATA

H-3 DPM/Gram ± σ "H-3 I. S. added"

Position and Depth	Sample #	Cts/2 min	M CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	$\overline{M}$ sample wt.(grms) ± σ	DPM/gram ± σ
1 - 3	1	6716	3269±23.34	3248±23.38	26.2±1.54	15.27±.94	1.98±.040	2.07±.072	7.34±.519
	2	6446					1.91±.038		
	3	6451					2.31±.046		
1 - 6	1	6690	5301±23.46	3284±23.50	26.5±1.56	2.066±.26	2.42±.048	2.18±.075	.945±.123
	2	6542					1.91±.038		
	3	6576					2.20±.044		
1 - B	1	6342	3166±22.97	3143±23.01	25.3±1.49	24.42±1.47	2.21±.044	2.13±.073	11.46±.794
	2	6244					2.02±.040		
	3	6410					2.17±.043		
2 - 3	1	6463	3265±23.33	3247±23.37	26.2±1.54	5.49±.402	2.48±.050	2.25±.079	2.44±.198
	2	6629					2.14±.043		
	3	6501					2.13±.043		
2 - 6	1	6616	3322±23.53	3304±23.57	26.6±1.56	4.62±.36	2.12±.042	2.05±.071	2.25±.192
	2	6730					1.92±.038		
	3	6587					2.12±.042		
2 - B	1	6211	3014±22.41	2997±23.45	24.2±1.42	-.054±.2409	2.19±.044	2.15±.075	-.025±.112
	2	5800					2.07±.041		
	3	6074					2.18±.044		
3 - 3	1	6382	3223±23.18	3205±23.22	25.9±1.52	1.884±.113	2.04±.041	1.87±.065	1.01±.070
	2	6292					1.83±.037		
	3	6661					1.74±.035		
3 - 6	1	6658	3375±23.72	3358±23.76	27.1±1.59	-5.24±.366	2.25±.045	2.21±.076	-2.37±.185
	2	6738					2.06±.041		
	3	6855					2.31±.046		
3 - B	1	6380	3207±23.12	3183±23.16	25.7±1.51	30.35±1.81	2.20±.044	2.06±.071	14.73±1.02
	2	6447					2.01±.040		
	3	6414					1.96±.039		

BACKGROUND DATA

H-3 DPM/Gram ± σ   "H-3 I.S. added"

Position and Depth	Sample #	Cts/2 min	M CPM ± σ (sample + I.S.)	I.S. CPM ± σ	I.S. Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	M̄ sample wt. (grms) ± σ	DPM/gram ± σ
4 - 3	1	6476	3290±23.41	3275±23.45	26.4±1.55	-6.93±.46	1.71±.034	2.03±.071	-3.41±.256
	2	6631					2.23±.045		
	3	6630					2.14±.043		
4 - 6	1	6515	3232±23.21	3213±23.25	25.9±1.52	9.80±.629	2.24±.045	2.16±.075	4.54±.331
	2	6382					2.33±.047		
	3	6494					1.91±.038		
4 - B	1	6458	3151±22.92	3227±22.96	25.2±1.48	29.82±1.78	2.15±.043	2.14±.074	.832±.057
	2	6267					2.18±.044		
	3	6182					2.10±.042		
5 - 3	1	6213	3108±22.76	3086±22.80	24.9±1.46	20.008±1.21	2.31±.046	2.11±.073	.573±.040
	2	6051					1.81±.036		
	3	6385					2.20±.044		
5 - 6	1	6061	2939±22.13	2923±22.17	23.6±1.39	-3.42±.31	1.71±.034	1.95±.068	-1.75±.170
	2	5835					2.08±.042		
	3	5735					2.07±.041		
5 - B	1	6419	3085±22.67	3071±22.71	24.8±1.46	-11.31±.696	2.12±.042	2.37±.083	.294±.208
	2	6006					2.97±.039		
	3	6083					2.03±.041		
Bkg	1	36	16.67±1.39						
	2	39							
	3	31							
	4	43							
	5	28							
	6	23							

BACKGROUND DATA

C-14 DPM/Gram ± σ "C-14 I.S. added"

Position and Depth	Sample #	Cts/2 min	M CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	$\bar{M}$ sample wt.(grms) ± σ	DPM/gram ± σ
1 - 3	1	11643	5850±31.22	5837.63±31.24	58.4±3.42	3.409±.212	1.98±.040	2.07±.072	1.647±.117
	2	11809					1.91±.038		
	3	11645					2.31±.046		
1 - 6	1	11919	5978±31.56	5967±31.58	59.7±3.49	-.380±.063	2.42±.048	2.10±.075	-.174±.029
	2	11878					1.91±.038		
	3	12070					2.20±.044		
1 - B	1	11794	5915±31.39	5905±31.41	.591±3.46	-.638±.042	2.21±.044	2.13±.073	-.300±.044
	2	11762					2.02±.040		
	3	11933					2.17±.043		
2 - 3	1	12202	6095±31.87	6085±31.89	60.8±3.56	-.350±.038	2.48±.050	2.25±.079	-.156±.018
	2	12228					2.14±.043		
	3	12139					2.13±.043		
2 - 6	1	12300	6188±32.12	6179±32.14	61.8±3.62	-1.30±.241	2.12±.042	2.05±.071	-.673±.121
	2	12321					1.92±.038		
	3	12510					2.12±.042		
2 - B	1	11976	5961±31.52	5952±31.54	59.5±3.48	-1.433±.100	2.19±.044	2.15±.075	-.667±.052
	2	11924					2.07±.041		
	3	11867					2.18±.044		
3 - 3	1	12247	6036±31.71	6026±31.73	60.3±3.53	-.984±.081	2.04±.041	1.87±.065	-.526±.047
	2	12045					1.83±.037		
	3	11921					1.74±.035		
3 - 6	1	12161	6022±31.67	6012±31.70	60.1±3.52	-.449±.064	2.25±.045	2.27±.076	-.203±.030
	2	11813					2.06±.041		
	3	12158					2.31±.046		
3 - B	1	11566	5930±31.44	5919±31.44	59.2±3.47	.613±.073	2.20±.044	2.06±.071	.298±.036
	2	11978					2.01±.040		
	3	12034					1.96±.039		

BACKGROUND DATA

C-14 DPM/Gram ± σ   "C-14 I.S. added"

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S. CPM ± σ	I.S. Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	$\overline{M}$ sample wt. (grms) ± σ	DPM/gram ± σ
4 - 3	1	11583	6007±31.64	5996±31.66	60.0±3.51	.630±.072	1.71±.034	2.03±.071	.315±.037
	2	12072					2.23±.045		
	3	12386					2.14±.043		
4 - 6	1	12301	6036±31.72	6026±31.74	60.3±3.53	-.642±.049	2.24±.045	2.16±.075	-.297±.034
	2	11940					2.33±.047		
	3	11973					1.91±.038		
4 - B	1	12063	5921±31.41	5910±31.43	59.0±3.45	1.84±.126	2.15±.043	2.14±.074	.859±.066
	2	11963					2.18±.044		
	3	11501					2.10±.042		
5 - 3	1	11508	5852±31.23	5843±31.23	58.4±3.41	-1.51±.105	2.31±.046	2.11±.073	-.716±.056
	2	11936					1.81±.036		
	3	11669					2.20±.044		
5 - 6	1	11808	5552±30.42	5543±30.44	55.4±3.24	-1.23±.095	1.71±.034	1.95±.068	-.629±.053
	2	11354					2.08±.042		
	3	10151					2.07±.041		
5 - B	1	11885	6063±31.79	6054±31.81	60.5±3.54	-.507±.063	2.12±.042	2.37±.083	-.214±.028
	2	12476					2.97±.039		
	3	12019					2.03±.041		
Bkg	1	21							
	2	18							
	3	19							
	4	21							

BACKGROUND DATA
DEPENDENCE OF CPM ABOVE BACKGROUND ON SAMPLING POSITION AND DEPTH

Position and Depth	H-3 CPM above Bkg ± σ	C-14 CPM above Bkg ± σ	H-3 M CPM above Bkg ± σ	C-14 M CPM above Bkg ± σ
1 - 3	4.01±.174	1.99±.133		1.706±.293
2 - 3	1.44±.171	-.377±.131	1.817±.387	
3 - 3	.487±.170	.593±.131		
4 - 3	-1.83±.175	.383±.131		
5 - 3	4.98±.175	-.883±.130		
1 - 6	.547±.170	-.227±.131		-.270±.292
2 - 6	1.237±.170	.213±.131	.742±.376	
3 - 6	-1.42±.168	-.270±.131		
4 - 6	2.54±.172	-.387±.131		
5 - 6	-.807±.160	-.68 ±.130		
1 - B	6.19±.177	.280±.131		.452±.293
2 - B	-.013±.167	.853±.130	3.725±.389	
3 - B	7.79±.179	.363±.131		
4 - B	7.52±.178	1.087±.132		
5 - B	-2.8 ±.167	-.307±.131		

BACKGROUND DATA

DEPENDENCE OF DPM/GRAM ON POSITION AND DEPTH

Position and Depth	$\frac{DPM}{gram} \pm \sigma$	Position and Depth	$\frac{DPM}{gram} \pm \sigma$	Position and Depth	$\frac{DPM}{gram} \pm \sigma$
1 - 3	1.34±.519	1 - 6	.945±.123	1 - B	11.46±.794
2 - 3	2.44±.198	2 - 6	2.25±.192	2 - B	- .025±.112
3 - 3	1.01±.070	3 - 6	-2.37±.185	3 - B	14.73±1.02
4 - 3	-3.41±.256	4 - 6	4.54±.331	4 - B	.832±.057
5 - 3	.573±.040	5 - 6	-1.75±.170	5 - B	.294±.208

APPENDIX F

Burial Plot Data

BURIAL PLOT DATA
H-3 and C-14 $\overline{M}$ CPM above Bkg. ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\overline{M}$ cpm ± σ	H-3 $\overline{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\overline{M}$ cpm ± σ	C-14 $\overline{M}$ cpm-bkg ± σ
1 - 3	1	8250	106.61±.60	91.84±.62	1135	11.42±.20	.22±.24
	2	7653			1048		
	3	16079			1243		
1 - 6	1	13498	140.47±.68	125.90±.70	1003	9.82±.18	-1.38±.23
	2	14522			927		
	3	14122			1016		
1 - 8	1	11660	126.66±.65	111.89±.67	1272	12.27±.20	1.07±.14
	2	13289			1167		
	3	13048			1241		
2 - 3	1	4410	43.90±.38	29.13±.41	985	10.34±.19	-.86±.24
	2	3947			1057		
	3	4812			1061		
2 - 6	1	37790	393.16±1.31	378.23±1.32	1154	11.57±.20	.37±.24
	2	39938			1129		
	3	40220			1188		
2 - 7	1	36103	369.26±1.11	354.49±1.12	1500	14.67±.22	3.47±.26
	2	38333			1435		
	3	36342			1465		
3 - 3	1	2217	22.66±.27	7.89±.31	1139	10.96±.19	-.24±.24
	2	2294			1029		
	3	2287			1122		
3 - 6	1	9180	88.33±.54	73.56±.56	1014	10.17±.18	-1.03±.23
	2	8801			1021		
	3	8517			1017		

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\bar{M}$ cpm ± σ	H-3 $\bar{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\bar{M}$ cpm ± σ	C-14 $\bar{M}$ cpm-bkg ± σ
4 - 3	1	4169	40.23±.37	25.46±.40	923	9.43±.18	-1.77±.23
	2	3990			953		
	3	3909			952		
4 - 6	1	6134	69.71±.48	54.94±.51	1283	12.93±.21	1.73±.25
	2	6896			1309		
	3	7883			1286		
4 - 8	1	9911	100.21±.58	85.44±.60	1057	10.71±.19	-.49±.24
	2	10049			1102		
	3	10103			1059		
5 - 3	1	5534	55.27±.43	37.50±.46	1050	10.79±.19	-.41±.24
	2	5720			1099		
	3	5326			1082		
5 - 7	1	20852	200.47±.82	185.70±.84	1203	11.54±.20	.34±.24
	2	20671			1098		
	3	18618			1162		
6 - 3	1	2440	25.15±.29	10.38±.33	1035	10.43±.19	-.77±.24
	2	2531			1008		
	3	2573			1086		
6 - 7	1	5478	58.36±.44	43.59±.47	1035	10.12±.18	-1.08±.23
	2	6137			979		
	3	5893			1022		
7 - 3	1	3415	33.91±.34	19.14±.38	1145	11.23±.19	.03±.24
	2	3417			1131		
	3	3341			1093		
7 - 6	1	5928	57.89±.44	43.12±.47	1962	10.12±.18	-1.08±.23
	2	5969			1022		
	3	5471			1053		
7 - 9	1	7139	68.62±.48	53.85±.51	1072	10.77±.19	-.43±.24
	2	7318			1085		
	3	6130			1074		

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\bar{M}$ cpm ± σ	H-3 $\bar{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\bar{M}$ cpm ± σ	C-14 $\bar{M}$ cpm-bkg ± σ
8 - 3	1	5144	49.31±.41	34.54±.44	1051	10.53±.19	-.67±.24
	2	5567			1005		
	3	4083			1102		
8 - 6	1	13124	123.35±.64	108.58±.66	909	9.17±.17	-2.03±.22
	2	12153			996		
	3	11727			846		
8 - 8	1	47953	385.21±1.13	370.44±1.14	1423	16.58±.24	5.38±.28
	2	39747			1927		
	3	27864			1623		
9 - 3	1	3883	36.72±.35	21.95±.38	1005	9.92@.18	-1.28±.23
	2	3389			977		
	3	3746			995		
9 - 6	1	5105	47.41±.40	32.64±.43	1114	11.29±.19	.09±.24
	2	4497			1139		
	3	4621			1135		
10 - 3	1	4223	38.83±.36	24.06±.39	1049	10.44±.19	-.76±.24
	2	3744			983		
	3	3582			1101		
10 - 6	1	7423	79.16±.51	64.39±.53	1002	10.04±.18	-1.16±.23
	2	8792			954		
	3	7533			1057		
Bkg	1	1407	14.77±.16		1128	11.20±.14	
	2	1535			1108		
	3	1499			1105		
	4	1487			1109		
	5	1462			1176		
	6	1470			1092		

Pack. H-3 Std: 376052 cpm
Pack. C-14 Std: 62337 cpm

BURIAL PLOT DATA

H-3 DPM/Gram ± σ "H-3 I. S. added"

Position and Depth	Sample #	Cts/2 min	M̄ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	M̄ sample wt.(grms) ± σ	DPM/gram ± σ
1 - 3	1	6301	3201±23.09	3094.57±23.12	25.0± 1.47	368±21.78	1.48±0.30	1.74±.061	211.49±14.55
	2	6373					1.99±.040		
	3	6534					1.74±.035		
1 - 6	1	6234	3130±22.84	2989.34±22.88	24.1± 1.42	522±30.89	2.39±.048	2.55±.088	204.71±14.02
	2	6391					2.69±.054		
	3	6156					2.56±.051		
1 - 8	1	3778	1892±17.76	1765.36±17.81	14.2± .84	786±46.73	2.52±.050	2.85±.099	275.79±18.99
	2	3857					2.99±.060		
	3	3718					3.05±.061		
2 - 3	1	6068	3096±22.72	3052.61±22.75	24.6± 1.45	118±7.15	2.58±.052	2.35±.082	50.21±3.51
	2	6301					2.03±.041		
	3	6211					2.44±.049		
2 - 6	1	6836	3409±23.84	3016±23.87	24.3± 1.43	1554±91.58	1.96±.039	2.04±.071	761.76±52.14
	2	6810					1.97±.039		
	3	6808					2.18±.044		
2 - 7	1	4480	2169±19.01	1800±19.08	14.5± .86	2438±144.80	2.35±.047	2.39±.083	1020.08±70.182
	2	4478					2.29±.046		
	3	4056					2.52±.050		
3 - 3	1	6500	3227±23.2	3205±23.23	25.8±1.52 1.52	30.52±2.16	2.24±.045	2.32±.081	13.16±1.037
	2	6367					2.52±.050		
	3	6500					2.20±.044		
3 - 6	1	6156	3085±22.68	2997±22.71	24.2± 1.42	304±17.99	1.76±.035	1.80±.062	168.89±11.59
	2	6059					1.84±.037		
	3	6299					1.81±.036		
4 - 3	1	6292	3180±23.02	3140±23.05	25.3±1.49 1.49	100±6.10	1.93±.039	1.99±.069	50.25±3.53
	2	6414					1.99±.040		
	3	6378					2.06±.041		

Position and Depth	Sample #	Cts/2 min	$\bar{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± (sample)	Sample wt. (grams)	$\bar{M}$ sample wt. (grms)	DPM/gram ± σ
4 - 6	1	5953	2985±22.30	2915±22.33	23.5± 1.35	234±13.91	1.38±.028	1.47±.051	159.18±10.96
	2	5919					1.50±.030		
	3	6038					1.53±.031		
4 - 8	1	5842	2854±21.81	2754±21.85	22.2± 1.31	385±22.88	2.21±.044	2.30±.080	167.39±11.12
	2	5771					2.27±.045		
	3	5516					2.41±.048		
5 - 3	1	6081	3058±22.57	3005±22.60	24.2± 1.42	155±9.29	1.95±.039	1.94±.067	79.90±5.53
	2	6129					2.07±.041		
	3	6136					1.80±.036		
5 - 7	1	6483	3247±23.27	3047±23.31	24.6± 1.45	756±44.69	2.37±.047	2.49±.086	303.61±20.82
	2	6537					2.64±.053		
	3	6467					2.47±.049		
6 - 3	1	6367	3124±22.82	3099±22.86	25.0± 1.47	41.53±2.78	1.44±.029	1.48±.051	28.06±2.11
	2	6197					1.58±.032		
	3	6183					1.41±.028		
6 - 7	1	6249	3096±22.71	3037±22.74	24.5± 1.44	178±10.64	2.13±.043	2.31±.050	77.06±5.33
	2	6179					2.42±.048		
	3	6151					2.39±.048		
7 - 3	1	6255	3189±23.05	3154±23.08	25.4± 1.49	75±4.64	2.09±.042	2.07±.072	36.23±2.57
	2	6341					2.01±.040		
	3	6538					2.12±.042		
7 - 6	1	6015	2964±22.23	2906±22.26	23.4± 1.38	184±11.04	1.74±.035	2.20±.077	83.64±5.81
	2	5885					2.42±.048		
	3	5885					2.45±.049		

Position and Depth	Sample #	Cts/2 min	$\bar{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± (sample)	Sample wt. (grams)	$\bar{M}$ sample wt.(grms)	DPM/gram ± σ
7 - 9	1	3718	1785±17.25	1717±17.29	13.8±	389±23.41	2.51±.050	2.53±.088	153.75@10.68
	2	3449			.82		2.60±.052		
	3	3548					2.48±.090		
8 - 3	1	6193	3088±22.69	3039±22.72	24.5±	141±8.48	2.54±.051	2.05±.072	68.78±4.79
	2	5908			1.44		1.70±.034		
	3	6432					1.92±.038		
8 - 6	1	4866	2741±21.38	2618±21.42	21.1±	514±30.37	1.20±.024	1.61±.057	319.25±21.98
	2	6094			1.24		2.01±.040		
	3	5491					1.62±.032		
8 - 8	1	8701	4214±26.54	38.29±26.59	30.9±	122±70.39	2.09±.042	2.62±.092	458.02±31.29
	2	8425			1.81		2.85±.057		
	3	8163					2.92±.058		
9 - 3	1	5931	2988±22.32	2951±22.35	23.8±	92±5.64	2.60±.052	2.00±.071	46±3.26
	2	6114			1.40		1.89±.038		
	3	5883					1.51±.030		
9 - 6	1	6057	3110±22.77	3062±22.80	24.7±	132±7.94	1.96±.039	2.12±.074	62.26±4.33
	2	6362			1.45		2.33±.047		
	3	6241					2.08±.042		
10 - 3	1	6355	3087±32.69	304832.71	24.6±	98±6.03	2.07±.041	1.92±.067	51.04±3.61
	2	6190			1.46		1.96±.039		
	3	5981					1.74±.035		
10 - 6	1	6411	3209±23.13	3130±23.16	25.2±	255±15.12	2.61±.052	2.52±.087	101.19±6.95
	2	6307			1.48		2.50±.030		
	3	6538					2.46±.049		

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± (sample)	Sample wt. (grams)	$\overline{M}$ sample wt.(grms)	DPM/grams ± σ
BKG	1	32	14.92±1.11						
	2	32							
	3	26							
	4	22							
	5	46							
	6	21							

H-3 Pack Std 378095 CPM

BURIAL PLOT DATA

C-14 DPM ± σ "C-14 I.S. added"

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (Sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± σ (sample)
1 - 3	1	9294	4753±28.15	4741±28.19	47.4±2.83	.46±.50
	2	9738				
	3	9490				
1 - 6	1	9520	4760±28.16	4749±28.20	47.5±2.84	
	2	9545				
	3	9500				
1 - 8	1	8030	3935±25.61	3921±28.65	39.2±2.35	2.73±.39
	2	7831				
	3					
2 - 3	1	9320	4747±28.13	4734±28.17	47.34±2.83	0 - 0
	2	9677				
	3	9465				
2 - 6	1	9256	4669±27.9	4656±27.94	46.6±2.79	.795±.52
	2	9524				
	3	9235				
2 - 7	1	8086	3857±25.36	3841±25.40	38.41±2.30	9.03±.87
	2	7860				
	3	7199				
3 - 3	1	9815	4910±28.61	4897±28.65	48.97±2.87	0 - 0
	2	9821				
	3	9825				
3 - 6	1	9706	4884±28.53	4871±28.57	48.8±2.86	0 - 0
	2	10225				
	3	9375				
4 - 3	1	10110	4935±28.68	4922±28.72	49.22±2.88	0 - 0
	2	9699				
	3	9801				
4 - 6	1	9635	4731±28.08	4716±28.12	47.22.76	3.67
	2	9265				
	3	9486				
4 - 8	1	9614	4839±28.40	4826±28.44	48.26±2.83	
	2	10222				
	3	9200				
5 - 3	1	9194	4722±28.05	4709±28.09	47.1±2.76	
	2	9608				
	3	9532				

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± σ (sample)
5 - 7	1	9730	4769±28.19	4756±28.23	47.6±2.79	.715
	2	9756				
	3	9612				
6 - 3	1	9478	4674±27.9	4662±27.94	4.62±2.73	
	2	9444				
	3	9127				
6 - 7	1	9945	4803±20.29	4790±28.33	47.9±2.81	
	2	9277				
	3	9598				
7 - 3	1	9203	4660±27.86	4647±27.90	46.5±2.72	.065
	2	9213				
	3	9544				
7 - 6	1	9155	4600±27.69	4587±27.73	45.9±3.69	
	2	9353				
	3	9094				
7 - 9	1	6624	3620±24.56	3608±24.60	36.1±2.12	
	2	7508				
	3	7591				
8 - 3	1	9218	4638±27.8	4625±27.84	46.3±2.71	
	2	9411				
	3	9199				
8 - 6	1	8276	4164±26.35	4152±26.39	41.52±2.43	
	2	8682				
	3	8030				
8 - 8	1	9651	4678±27.92	4660±27.96	46.6±2.73	11.54
	2	8939				
	3	9480				
9 - 3	1	9565	4603±27.70	4590±27.74	45.9±2.69	
	2	9487				
	3	8566				
9 - 6	1	9324	4774±28.21	4761±28.25	47.62.79	.189
	2	9740				
	3	9583				
10 - 3	1	9245	4626±27.76	4661±27.80	46.1±2.70	
	2	9077				
	3	9435				

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S.Eff ± σ	DPM ± σ (sample)
10 - 6	1	9606	4855±28.45	4842±28.49	48.42±2.84	
	2	9795				
	3	9732				
BKG	1	22	12.67±1.45			
	2	25				
	3	29				

BURIAL PLOT DATA
DEPENDENCE OF CPM ABOVE BACKGROUND ON SAMPLING POSITION AND DEPTH.

Position and Depth	H-3 CPM above BKG ± σ	C-14 CPM above BKG ± σ	H-3 M CPM above BKG ± σ	C-14 M CPM above BKG ± σ
1 - 3	91.84±.62	0.22±.24		
2 - 3	29.13±.91	-0.86±.24	31.29±1.33	
3 - 3	7.89±.31	-0.24±.24		
4 - 3	25.46±.40	-1.77±.23		
5 - 3	37.50±.46	-0.41@.24		
6 - 3	10.38±.33	-0.77±.24		
7 - 3	19.14±.38	0.03±.24		
8 - 3	35.54±.44	-0.67±.24		
9 - 3	21.95±.38	-1.28±.23		
10 - 3	24.06±.39	-0.76±.24		
1 - 6	125.70±.70	-1.38±.23		
2 - 6	378.23±1.22	0.37±.24		
3 - 6	73.56±.56	-1.03±.23	111.06±2.14	
4 - 6	54.94±.51	1.73±.25		
5 - 7	185.70±.84	0.34±.24		
6 - 7	43.59±.47	-1.08±.23		
7 - 6	43.12±.47	-1.08±.23		
8 - 6	108.58±.66	-2.03±.22		
9 - 6	32.64±.43	0.09±.24		
10 - 6	64.39±.53	-1.16±.23		
1 - 8	111.89±.67	1.07±.14		
2 - 7	354.49±1.12	3.47±.26	195.22±1.90	
4 - 8	85.44±.60	-0.49±.24		
7 - 9	53.85±.51	-0.43±.24		
8 - 8	370.44±1.14	5.38±.28		

BURIAL PLOT DATA
DEPENDENCE OF DPM/GRAM ON POSITION AND DEPTH

Position and Depth	$\frac{DPM}{gram} \pm \sigma$	Position and Depth	$\frac{DPM}{gram} \pm \sigma$	Position and Depth	$\frac{DPM}{gram} \pm \sigma$
1 - 3	211.49±11.45	1 - 6	204.71±14.02	1 - 8	275.79±18.99
2 - 3	50.21± 3.51	2 - 6	761.76±52.14	2 - 7	1020.08±70.182
3 - 3	13.16±1.037	3 0 6	168.89±11.59	4 - 8	167.39±11.12
4 - 3	50.35±3.53	4 - 6	159.18±10.96	7 - 9	153.75±10.68
5 - 3	79.90±5.53	5 - 7	303.61±20.82	8 - 8	458.01±31.29
6 - 3	28.06±2.11	6 - 7	77.06@5.33	$\overline{M}$	415.01
7 - 3	36.23±2.57	7 - 6	83.64±5.81		
8 - 3	68.78±4.79	8 - 6	319.25±21.98		
9 - 3	46.00±3.26	9 - 6	62.26±4.33		
10- 3	51.04±3.61	10 -6	101.19±6.95		
$\overline{M}$	63.51	$\overline{M}$	224.16		

APPENDIX G

Lower Level Plot Data

LOWER LEVEL PLOT DATA
H-3 and C-14 $\overline{M}$ CPM ABOVE BKG ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\overline{M}$ CPM ± σ	H-3 $\overline{M}$ CPM-BKG ± σ	C-14 cts / 100 min	C-14 $\overline{M}$ CPM ± σ	C-14 $\overline{M}$ CPM-BKG ± σ
1 - 3	1	1668	16.18±.23	1.61±.28	1152	11.44±.20	.14±.24
	2	1576			1179		
	3	1609			1101		
1 - 6	1	6367	57.70±.44	43.13±.47	1107	11.28±.19	-.02±.24
	2	5573			1133		
	3	5369			1143		
2 - 3	1	1342	14.05±.22	-.52	1065	10.82±.19	-.48±.24
	2	1424			1059		
	3	1450			1123		
2 - 6	1	7522	77.15±.51	62.58±.53	1163	11.54±.20	.24±.24
	2	7492			1121		
	3	8130			1171		
3 - 3	1	1928	20.01±.26	5.44±.31	1093	11.03±.19	-.27±.24
	2	1942			1117		
	3	2134			1100		
3 - 6	1	6636	66.23±.47	51.66±.50	1145	11.66±.20	.36±.24
	2	6634			1180		
	3	6599			1172		
4 - 3	1	2088	21.27±.27	6.70±.31	1135	11.37±.19	.07±.24
	2	2169			1149		
	3	2124			1127		
4 - 6	1	4045	38.79±.36	24.22±.39	1317	13.57±.21	2.27±.25
	2	3800			1416		
	3	3792			1337		

LOWER LEVEL PLOT DATA
H-3 and C-14 $\overline{M}$ CPM ABOVE BKG ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\overline{M}$ CPM ± σ	H-3 $\overline{M}$ CPM-BKG ± σ	C-14 cts / 100 min	C-14 $\overline{M}$ CPM ± σ	C-14 $\overline{M}$ CPM-BKG ± σ
5 - 3	1	1790	18.44±.25	3.87±.30	1252	12.00±.20	.7±.24
	2	1870			1193		
	3	1873			1154		
5 - 6	1	6251	58.57±.44	44.00±.47	1335	11.62±.20	.32±.24
	2	5457			1074		
	3	5863			1095		
6 - 3	1	1642	15.98±.23	1.41±.28	1096	11.32±.19	.02±.24
	2	1538			1208		
	3	1613			1093		
6 - 6	1	1759	18.78±.25	4.21±.30	1119	11.22±.19	-.08±.24
	2	1960			1119		
	3	1915			1127		
7 - 3	1	1455	15.09±.22	.52±.27	1177	11.07±.19	-.23±.24
	2	1562			1001		
	3	1509			1142		
7 - 6	1	1567	15.55±.23	.98±.28	1102	11.07±.19	-.25±.24
	2	1583			1133		
	3	1515			1087		
8 - 3	1	1932	17.93±.24	3.36±.29	1079	11.34±.19	.04±.24
	2	1731			1128		
	3	1716			1196		
8 - 6	1	2450	23.85±.28	9.28±.28	1147	11.80±.20	.50±.24
	2	2305			1207		
	3	2400			1187		
9 - 3	1	2488	25.97±.29	11.40±.33	1335	11.68±.20	.38±.24
	2	2620			1074		
	3	2684			1095		

LOWER LEVEL PLOT DATA
H-3 and C-14 $\overline{M}$ CPM ABOVE BKG ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\overline{M}$ CPM ± σ	H-3 $\overline{M}$ CPM-BKG ± σ	C-14 cts / 100 min	C-14 $\overline{M}$ CPM ± σ	C-14 $\overline{M}$ CPM-BKG ± σ
9 - 6	1	1694	16.50±.23	1.93±.28	1072	10.63±.19	-.67±.24
	2	1674			1041		
	3	1581			1077		
10 - 3	1	1243	13.21±.21	-1.36	905	10.09±.18	-1.21±.23
	2	1309			1065		
	3	1410			1058		
10 - 6	1	3766	35.00±.34	20.43±.38	1091	11.47±.20	.17±.24
	2	3629			1189		
	3	3104			1160		
BKG	1	1524	14.57±.16		1093	11.30±.14	
	2	1488			1125		
	3	1414			1138		
	4	1492			1177		
	5	1409			1096		
	6	1456			1152		

LOWER LEVEL PLOT DATA

H-3 DPM/Gram ± "H-3 I. S. added"

Position and Depth	Sample#	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S. Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	$\overline{M}$ sample wt.(grms) ± σ	DPM/gram ± σ
1 - 3	1.	6569	3338±23.59	3316±23.66	26.7±1.57	6.02±1.11	2.30±.046	2.1 ±.073	2.87±.539
	2	6796					1.88±.038		
	3	6664					2.11±.042		
1 - 6	1	6227	3229±23.20	3166±23.28	25.5±1.50	168.91±10.10	2.68±.054	2.26±.079	74.74±5.18
	2	6542					2.15±.043		
	3	6607					1.94±.039		
2 - 3	1	6524	3223±23.18	3203±23.25	25.8±1.52		2.25±.045	2.07±.072	
	2	6190					2.11±.042		
	3						1.84±.037		
2 - 6	1	6276	3184±23.04	3102±23.12	25.0±1.47	250.18±14.86	2.21±.044	2.21±.077	113.20±7.76
	2	6370					2.00±.040		
	3	6459					2.43±.049		
3 - 3	1	6358	3222±23.18	3196±23.25	25.8±1.52	21.10±1.73	2.18±.044	2.07±.072	10.19±.908
	2	6491					1.93±.039		
	3	6478					2.11±.042		
3 - 6	1	6210	3120±22.80	3048±22.88	24.6±1.45	210±12.55	2.11±.042	2.07±.072	101.51±7.106
	2	6296					2.00±.040		
	3	6215					2.09±.042		
4 - 3	1	6761	3311±23.49	3284±23.56	26.5±1.56	25.29±1.89	2.64±.053	2.79±.097	9.06±.747
	2	6597					3.00±.060		
	3	6513					2.74±.055		
4 - 6	1	6563	3359±23.73	3315±23.80	26.7±1.57	90.59±5.52	2.89±.058	2.71±.094	33.43±2.34
	2	6792					2.59±.052		
	3	6802					2.66±.053		
5 - 3	1	6661	3236±23.40	3262±23.47	26.3±1.54	14.71±1.43	1.45±.029	1.67±.058	8.81±.909
	2	6506					1.73±.035		
	3	6553					1.84±.037		

LOWER LEVEL PLOT DATA

H-3 DPM/Gram ± "H-3 I. S. added"

Position and Depth	Sample#	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S. Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	$\overline{M}$ sample wt.(grms) ± σ	DPM/gram ± σ
5 - 6	1	6371	3100±22.73	3036±22.81	24.5±1.45	179.67±10.81	2.19±.044	2.15±.074	83.58±5.79
	2	6167					2.08±.042		
	3	6066					2.17±.043		
6 - 3	1	6774	3350±23.63	3328±23.70	26.8±1.57	5.25±1.09	2.42±.048	2.01±.070	2.61±.549
	2	6738					1.66±.033		
	3	6591					1.95±.039		
6 - 6	1	5996	3031±22.48	3007±22.55	24.3±1.43	17.36±1.60	1.68±.034	1.76±.061	9.86±.971
	2	6158					1.66±.033		
	3	6035					1.94±.039		
7 - 3	1	6429	3201±23.01	3180±23.17	25.7±1.51	2.03±1.06	2.18±.044	2.49±.087	.82±.429
	2	6120					2.95±.059		
	3	6657					2.35±.047		
7 - 6	1	6462	3279±23.78	3258±23.45	26.3±1.54	3.73±1.09	2.08±.042	1.95±.068	1.91±.562
	2	6710					1.83±.037		
	3	6504					1.93±.039		
8 - 3	1	7043	3385±23.79	3372±23.86	27.2±1.6	12.36±1.29	2.49±.050	2.22±.077	5.57±.613
	2	6631					2.05±.041		
	3	6698					2.13±.043		
8 - 6	1	6691	3281±23.39	3252±23.46	26.2±1.54	35.38±2.41	1.99±.040	2.02±.070	17.51±1.33
	2	6448					1.97±.039		
	3	6551					2.10±.042		
9 - 3	1	6649	3283±23.39	3252±23.46	26.2±1.54	43.47±2.85	2.07±.041	2.37±.083	18.34±1.36
	2	6478					2.50±.050		
	3	6574					2.55±.051		
9 - 6	1	6514	3277±23.37	3255±23.44	26.3±1.54	7.35±1.15	1.70±.034	1.58±.055	4.65±.745
	2	6590					1.73±.035		
	3	6561					1.30±.026		

LOWER LEVEL PLOT DATA

H-3 DPM/Gram ± "H-3 I. S. added"

Position and Depth	Sample#	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S.CPM ± σ	I.S. Eff ± σ	DPM ± σ (sample)	Sample wt. (grams)	$\overline{M}$ sample wt.(grms) ± σ	DPM/gram ± σ
10 - 3	1	6333	3198±23.09	3198±23.16	25.6±1.50		2.24±.045	2.07±.072	
	2	6435					1.86±.037		
	3	6423					2.10±.042		
10 - 6	1	6560	3255±23.29	3215±23.36	25.9±1.52	78.80±4.85	2.44±.049	2.26±.079	34.87±2.46
	2	6505					2.43±.049		
	3	6466					1.90±.038		

Bkg 2.5 CPM Pack H-3 Std = 380800 CPM

17.5 CPM

19.0 CPM

LOWER LEVEL PLOT DATA
C-14 DPM/Gram ± σ "C-14 I.S. added"

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S. CPM ± σ	I.S. Eff ± σ
1 - 3	1	10306	5261±29.61	5247±29.61	52.47±3.07
	2	10758			
	3	10506			
1 - 6	1	10568	5225±29.51	5111±29.51	51.11±2.99
	2	10474			
	3	10308			
2 - 3	1	10368	5240±29.55	5226±29.55	52.26±3.06
	2	10548			
	3	10529			
2 - 6	1	10706	5363±29.90	5349±29.90	53.49±3.13
	2	10791			
	3	10682			
3 - 3	1	10569	5133±29.25	5119±29.29	51.19±2.99
	2	10251			
	3	9979			
3 - 6	1	10241	5175±29.37	5161±29.37	51.61±3.02
	2	10367			
	3	10447			
4 - 3	1	10216	5151±29.32	5143±29.32	51.43±3.01
	2	10431			
	3	10299			
4 - 6	1	10222	5043±28.99	5029±25.99	50.29±2.95
	2	10146			
	3	9890			
5 - 3	1	10196	5087±29.12	5073±29.12	50.73±2.97
	2	10130			
	3	10197			
5 - 6	1	9843	4911±28.61	4897±28.61	48.97±2.87
	2	9774			
	3	9854			
6 - 3	1	10145	5129±29.24	5115±29.24	51.15±3.00
	2	10298			
	3	10334			

LOWER LEVEL PLOT DATA
C-14 DPM/Gram ± σ "C-14 I.S. added"

Position and Depth	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S.)	I.S. CPM ± σ	I.S. Eff ± σ
6 - 6	1	10551	5087±29.12	5073±29.12	50.77±2.97
	2	9843			
	3	10132			
7 - 3	1	10272	5101±29.16	5087±29.16	50.87±2.98
	2	10413			
	3	9922			
7 - 6	1	10196	5170±29.36	5156±29.36	51.56±3.02
	2	10214			
	3	10612			
8 - 3	1	9964	5058±29.04	5044±29.04	50.44±2.95
	2	10060			
	3	10327			
8 - 6	1	10416	5148±29.29	5134±29.29	51.34±3.01
	2	10101			
	3	10375			
9 - 3	1	10290	5096±29.14	5082±29.14	50.82±2.98
	2	10086			
	3	10201			
9 - 6	1	9975	4767±28.19	4753±29.19	47.53±2.79
	2	9710			
	3	8920			
10 - 3	1	10147	5092±35.68	5078±35.68	50.78±2.48
	2	8718			
	3	10222			
10 - 6	1	10195	5015±28.91	5001±28.91	50.01±2.93
	2	10060			
	3	9837			
BKG	1	32	13.67±1.51		
	2	23			
	3	27			

LOWER LEVEL PLOT DATA
DEPENDENCE OF CPM ABOVE BACKGROUND ON SAMPLING POSITION AND DEPTH

Position and Depth	H-3 CPM above BKG ± σ	C-14 CPM above BKG ± σ	H-3 $\overline{M}$ CPM above BKG ± σ	C-14 $\overline{M}$ CPM above BKG ± σ
1 - 3	1.61 ± .28	.14	3.24 ± .91	
2 - 3	- .52	-.48		
3 - 3	5.44 ± .50	-.27		
4 - 3	6.70 ± .31	.07		
5 - 3	3.87 ± .30	.70		
6 - 3	1.41 ± .28	.02		
7 - 3	.52 ± .27	-.23		
8 - 3	3.36 ± .29	.04		
9 - 3	11.40 ± .28	.38		
10 - 3	-1.36 ±	-1.21		
1 - 6	43.13 ± .47	-.02	26.24 ± 1.27	
2 - 6	62.58 ± .53	.24		
3 - 6	51.66 ± .50	.36		
4 - 6	24.22 ± .39	2.27		
5 - 6	44.00 ± .47	.32		
6 - 6	4.21 ± .30	-.08		
7 - 6	.98 ± .28	-.23		
8 - 6	9.28 ± .32	.50		
9 - 6	1.93 ± .28	-.67		
10 - 6	20.43 ± .38	.17		

LOWER LEVEL PLOT DATA

DEPENDENCE OF DPM/GRAM ON POSITION AND DEPTH

Position and Depth	DPM/gram ± σ	Position and Depth	DPM/gram ± σ
1 - 3	2.87 ± .539	1 - 6	74.74 ± 5.18
2 - 3	-	2 - 6	113.20 ± 7.76
3 - 3	10.19 ± .908	3 - 6	101.51 ± 7.11
4 - 3	9.06 ± .747	4 - 6	33.43 ± 2.34
5 - 3	8.81 ± .909	5 - 6	83.58 ± 5.79
6 - 3	2.61 ± .549	6 - 6	9.86 ± .971
7 - 3	.82 ± .429	7 - 6	1.91 ± .562
8 - 3	5.57 ± .613	8 - 6	17.51 ± 1.34
9 - 3	18.34 ± 1.363	9 - 6	4.75 ± .745
10 - 3	-	10 - 6	34.87 ± 2.46

$\overline{M} = 5.83$ $\overline{M} = 47.53$

APPENDIX H

Creek Bottom Plot Data

CREEK BOTTOM DATA
H-3 and C-14 $\bar{M}$ CPM above Bkg ± σ

Position and Depth	Sample #	H-3 cts / 100 min	H-3 $\bar{M}$ cpm ± σ	H-3 $\bar{M}$ cpm-bkg ± σ	C-14 cts / 100 min	C-14 $\bar{M}$ cpm ± σ	C-14 $\bar{M}$ cpm-bkg ± σ
1	1	1373	13.41±.21	-.02±.30	1212	12.13±.20	.33±.28
	2	1354			1214		
	3	1295			1213		
2	1	1277	12.40±.20	-1.03±.29	1226	11.63±.20	-.17±.28
	2	1262			1106		
	3	1181			1156		
3	1	1303	12.61±.21	-.82±.30	1267	11.95±.20	.15±.28
	2	1214			1193		
	3	1265			1126		
4	1	1412	13.82±.21	.37±.30	1304	12.55±.20	.75±.28
	2	1429			1294		
	3	1306			1216		
5	1	1419	13.66±.21	.23±.30	1301	12.46±.20	.66±.28
	2	1312			1217		
	3	1367			1219		
6	1	1221	12.67±.21	-.76±.30	1132	11.70±.20	-.10±.28
	2	1317			1216		
	3	1264			1162		
Bkg	1	1391	13.43±.21		1176	11.80±.20	
	2	1253			1211		
	3	1385			1154		

CREEK BOTTOM DATA

C-14 DPM/Gram ± σ "C-14 I.S. added"

Position	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S)	I.S. CPM ± σ	I.S. Eff ± σ	Sample DPM ± σ	Sample weight (grams)	$\overline{M}$ sample weight (grams ± σ)
1	1	10217	5101±29.16	5089±29.27	50.89±2.98	.649		2.41
	2	10194						
	3	10196						
2	1	10028	4961±28.76	4949±28.88	49.5±2.9	-.343		2.13
	2	9647						
	3	10093						
3	1	9935	5000±28.86	4987±28.97	49.9±2.92	.301		2.08
	2	10064						
	3	10002						
4	1	10228	5118±29.20	5105±29.31	51.1±2.99	1.469		2.26
	2	10225						
	3	10258						
5	1	10110	5006±28.88	4993±28.99	49.9±2.93	1.322		2.15
	2	9869						
	3	10057						
6	1	10076	4974±28.79	4762±28.90	49.6±2.91	-.202		2.09
	2	9527						
	3	10245						
Bkg	1	24	12.33±2.56	Pack C-14 Std:	62764 CPM			
	2	30						
	3	20						

CREEK BOTTOM DATA

H-3 DPM/Gram ± σ "H-3 I.S. added"

Position	Sample #	Cts/2 min	$\overline{M}$ CPM ± σ (sample + I.S)	I.S. CPM ± σ	I.S. Eff ± σ	Sample DPM ± σ	Sample weight (grams)	$\overline{M}$ sample weight (grams ± σ)
1	1	5852	2965±22.23	2951±22.28	23.8±1.40	-.084	2.41	2.41
	2	6008					2.35	
	3	5932					2.47	
2	1	6167	3027±22.46	3015±22.51	24.3±1.43	-4.236	2.17	2.13
	2	5817					2.25	
	3	6183					1.96	
3	1	5772	2952±22.18	2939±22.23	23.7±1.39	-3.459	2.23	2.08
	2	6184					1.82	
	3	5761					2.19	
4	1	5428	2876±21.89	2861±21.95	23.1±1.36	1.691	2.49	2.26
	2	5894					2.18	
	3	5934					2.11	
5	1	6142	2964±22.23	2950±22.28	23.8±1.40	.967	1.98	2.15
	2	5677					2.48	
	3	5968					1.99	
6	1	5999	2902±21.99	2889±22.05	23.3±1.37	-3.262	2.52	2.09
	2	5383					1.77	
	3	6033					1.98	
Bkg	1	32	14.00±1.53		Pack H-3 Std: 375489 CPM			
	2	23						
	3	29						

CREEK BOTTOM DATA

Position vs. CPM † BKG

Position	H-3 CPM † BKG ± σ	C-14 CPM †BKG ± σ
1	- .02 ± .3	.33 ± .28
2	-1.03 ± .29	-.17 ± .28
3	- .82 ± .30	.15 ± .28
4	.39 ± .30	.75 ± .28
5	.23 ± .30	.66 ± .28
6	- .76 ± .30	.10 ± .28