RIO TINTO

ENERGY AMERICA

PR 20, 30, 40, 50, 70 and 72
(73FR03811)

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ADJUDICATIONS STAFF

6 May 2008

Secretary
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001
ATTN: Rulemakings and Adjudications Staff

Gentlemen:

Subject: Kennecott Uranium Company - Comments on 10 CFR Parts 20, 30, 40, et al. Decommissioning Planning; Proposed Rule Federal Register / Vol. 73, No. 14 / Tuesday, January 22, 2008 / Proposed Rules pages 3912 to 3846

Kennecott Uranium Company is a uranium recovery licensee (SUA-1350) in the State of Wyoming. It manages the Sweetwater Uranium Project, which contains the last remaining conventional uranium mill in Wyoming. This facility is located in Sweetwater County, Wyoming. Kennecott Uranium Company has reviewed the Proposed Rule regarding 10 CFR Parts 20, 30, 40 et al. Decommissioning Planning, Proposed Rule Federal Register / Vol. 73, No. 14 / Tuesday, January 22, 2008, and has the following comments.

The document *Regulatory Analysis for Proposed Rulemaking - Decommissioning Planning* dated December 2007 states in part:

NRC staff concludes that the uranium mills, ISL facilities and sewage treatment plants will not be affected by the proposed amendments to 10 CFR 20.1406(c) and 20.1501.

It is interesting to note in light of the above, that the preamble to the proposed rule states:

There have been instances of previously unidentified soil and ground water contamination at uranium recovery and rare earth sites undergoing decommissioning in several states, notably Colorado and Pennsylvania.

While this supplemental document states that the key provisions of the proposed rule will not likely apply to uranium recovery operations, the proposed rule itself fails to make such a distinction. If this is the conclusion of Staff then Kennecott Uranium Company requests that uranium recovery facilities (conventional mills, in-situ uranium recovery facilities and heap leach facilities (should any be constructed)) be categorically excluded from coverage under the proposed amendments to 10 CFR 20.1406(c) and 20.1501 in the final rule itself.

If this will not be the case then Kennecott Uranium Company has the following comments on the proposed rule should it apply to uranium recovery facilities:

General Comments on the Proposed Rule

The proposed rule incorporates the existing term *Residual Radioactivity* as set forth in 10 CFR 20.1003:

> *''Residual radioactivity means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the licensee's control. This includes radioactivity from all licensed and unlicensed sources used by the licensee, but excludes background radiation. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.''*

into 10 CFR 20.1501 by changing that section to state:

Template - SECY-067 SECY-02

§ 20.1501 General.
(a) Each licensee shall make or cause to be made, surveys of areas, including the subsurface, that—

(2) are reasonable under the circumstances to evaluate —
(ii) Concentrations or quantities of residual radioactivity; and
(iii) The potential radiological hazards of the radiation levels and residual radioactivity detected.
(b) Records from surveys describing the location and amount of subsurface residual radioactivity identified at the site must be kept with records important for decommissioning.

In addition the proposed rule also incorporates the term residual radioactivity into 10 CFR Part 20.1406 when it states:

§ 20.1406 Minimization of contamination.

(c) Licensees shall, to the extent practical, conduct operations to minimize the introduction of residual radioactivity into the site, including the subsurface, in accordance with the existing radiation protection requirements in Subpart B and radiological criteria for license termination in Subpart E of this part.

These proposed changes impact licensed source material recovery operations especially conventional mills. The Commission acknowledges this fact when in the Preamble it states:

There have been instances of previously unidentified soil and ground-water contamination at uranium recovery and rare earth sites undergoing decommissioning in several states, notably Colorado and Pennsylvania.

In addition, the Preamble states:

Associating these events with knowledge of currently operating sites provided a means for NRC staff to evaluate the potential for future subsurface contamination at currently operating facilities. This risk-informed approach concluded that the sites with a higher likelihood of becoming legacy sites shared the following characteristics: ***relatively large volumes of low specific activity radioactively contaminated liquids; large volumes of long-lived radionuclides; large throughput; liquid processes; or processes that involve large quantities of solid radioactive material stored outdoors.*** *The study identified a number of events that could increase decommissioning costs by increasing the possibility of soil or ground-water contamination, and termination.* **(Bold inserted by Kennecott Uranium Company)**

The phrase *relatively large volumes of low specific activity radioactively contaminated liquids; large volumes of long-lived radionuclides; large throughput; liquid processes; or processes that involve large quantities of solid radioactive material stored outdoors* describes conventional uranium mills. Tailings fluids and process fluids in conventional source material processing facilities are *low specific activity radioactively contaminated liquids.* Source material processing facilities (in the case of uranium processing facilities) process radionuclides from the Uranium-238 and Uranium-235 decay chains. Both of these decay chains contain very long-lived radionuclides such as Uranium-238 (4.51 billion years, Uranium-234 (247,000 years), Thorium-230 (80,000 years), Uranium-235 (710 million years) and Protactinium-231 (32,500 years). Source material processing facilities involve large volumes of material that contain long-lived radionuclides.

Source material by definition (*Source material means--*
(1) Uranium or thorium or any combination of uranium and thorium in any physical or chemical form; or
(2) Ores that contain, by weight, one-twentieth of 1 percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.)
includes thorium. While there are no thorium mills at present (though there may well be in the future if the thorium fuel cycle is considered) the Thorium-232 decay chain has one (1) long lived radionuclide, Thorium-232 at 14.1 billion years.

These decay chains are shown in the following three (3) tables:

Table 1 – Uranium-238 Decay Chain					
Element	**Atomic Mass**	**Fraction of Isotope Present**	**Half Life**		**Specific Activity (Curies per gram)**
Uranium	238	1	4.5100E+09	Years	3.333E-07
Thorium	234	1	24.1	Days	2.316E+04
Protactinium - M	234	1	1.17	Minutes	6.867E+08
Protactinium	234	0.0013	6.75	Hours	1.984E+06
Uranium	234	1	2.4700E+05	Years	6.191E-03
Thorium	230	1	8.00E+04	Years	1.945E-02
Radium	226	1	1602	Years	9.883E-01
Radon	222	1	3.823	Days	1.539E+05
Polonium	218	1	3.05	minutes	2.827E+08
Lead	214	0.9998	26.8	minutes	3.278E+07
Astatine	218	0.0002	2	seconds	2.587E+10
Bismuth	214	1	19.7	minutes	4.459E+07
Polonium	214	0.9998	1.64E-04	seconds	3.214E+14
Thallium	210	0.0002	1.32	minutes	6.782E+08
Lead	210	1	21	years	8.113E+01
Bismuth	210	1	5.013	Days	1.241E+05
Polonium	210	0.9999987	138.4	Days	4.494E+03
Thallium	206	0.0000013	4.19	minutes	2.178E+08
Lead	206	STABLE			
Notes:		Splits in the decay chain with split fractions.			
	Most widely used half-life used. Some isotopes have multiple half-lives cited in the literature.				

Table 2 – Uranium-235 Decay Chain					
Element	**Atomic Mass**	**Fraction of Isotope Present**	**Half Life**		**Specific Activity (Curies per gram)**
Uranium	235	1	7.1000E+08	Years	2.144E-06
Thorium	231	1	25.5	Hours	5.320E+05
Protactinium	231	1	3.25E+04	Years	4.766E-02
Actinium	227	1	21.6	Years	7.297E+01
Francium	223	0.014	22	Minutes	3.832E+07
Thorium	227	0.986	18.2	Days	3.161E+04
Radium	223	1	11.43	Days	5.124E+04
Radon	219	1	4	seconds	1.288E+10
Polonium	215	1	1.78E-03	seconds	2.947E+13
Lead	211	0.9999977	36.1	minutes	2.468E+07
Astatine	215	0.0000023	1.00E-04	seconds	5.247E+14
Bismuth	211	1	2.15	minutes	4.144E+08
Polonium	211	0.0028	0.52	seconds	1.028E+11
Thallium	207	0.9972	4.79	minutes	1.896E+08
Lead	207	STABLE			
Notes:		Splits in the decay chain with split fractions.			
	Most widely used half-life used. Some isotopes have multiple half-lives cited in the literature.				

Table 3 – Thorium-232 Decay Chain					
Element	**Atomic Mass**	**Fraction of Isotope Present**	**Half Life**		**Specific Activity (Curies per gram)**
Thorium	232	1	1.4100E+10	Years	1.100E-07
Radium	228	1	6.7	Years	2.700E+02
Actinium	228	1	6.13	Hours	2.200E+06
Thorium	228	1	1.91	Years	8.200E+02
Radium	224	1	3.6400E+00	Days	1.600E+05
Radon	220	1	5.50E+01	Seconds	9.322E+08
Polonium	216	1	0.15	Seconds	3.481E+11
Lead	212	1	10.64	Hours	1.400E+06
Bismuth	212	1	60.6	minutes	1.500E+07
Polonium	212	0.64	3.04E-07	seconds	1.750E+17
Thallium	208	0.36	3.1	Minutes	2.916E+08
Lead	208	STABLE			
Notes:		Splits in the decay chain with split fractions.			
	Most widely used half-life used. Some isotopes have multiple half-lives cited in the literature.				

Conventional uranium mills involve large throughputs. In the case of the Sweetwater Uranium Project the design capacity of the mill is 3,000 tons per day. Conventional uranium mills also involve large quantities of radioactive materials stored out of doors specifically the mill tailings (11(e).2 byproduct material) that is stored in the tailings impoundment until the impoundment is filled and ultimately reclaimed.

It is clear from the above discussion that conventional uranium mills fit the Commission's description of sites that have *the potential for future subsurface contamination.*

The proposed rule's Preamble states:

Based on past NRC experience, significant concentrations or quantities of undetected and unmonitored contamination, caused primarily by subsurface migration or ground water, has been a major contributor to a site becoming a legacy site and a potential radiological hazard.

The issue of groundwater contamination and groundwater monitoring at uranium recovery sites (both conventional and in-situ recovery) has been well addressed by the Commission and the industry as groundwater monitoring at in-situ uranium recovery sites has been an integral part of the process since its use began and is an integral part of conventional uranium mills as well. Groundwater protection standards for uranium an d thorium mill tailings are incorporated in 40 CFR Part 192 – Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, and in 10 CFR Part 40 Appendix A.

Kennecott Uranium Company would also like to emphasize that in-situ uranium recovery operations operate within an aquifer exemption issued by the Environmental Protection Agency (EPA) under 40 CFR Part 146 and that once exempted this area is permanently exempted.

The Preamble also states:

One or more of the licensees affected by this proposed rulemaking may find that compliance with the monitoring requirements will mean the installation of ground water monitoring wells and surface monitoring devices at their sites. The installation of these monitoring devices and wells is generally expected to result in small environmental impacts due to their very localized nature.

Kennecott Uranium Company agrees with this statement

The Preamble states:

During sampling and testing, the proposed rule introduces the potential for a small amount of increased occupational exposures. These exposures are expected to remain within 10 CFR part 20 limits and to be ALARA. If subsurface contamination is detected, licensees may choose to remediate when contamination levels are lower and more manageable, which could result in reduced future occupational exposure rates than if the contamination conditions were allowed to remain and become increasingly more hazardous. Licensees may alternatively choose to provide adequate funding in response to their knowledge of the extent of any subsurface contamination, which will better ensure that the area is remediated following decommissioning to a degree that supports public health and safety,

In Kennecott Uranium Company's experience with a major residual radioactivity excavation at its site occupational exposure rates were inconsequential. The real risks associated with the remediation of subsurface contamination were the ones associated with any large excavation/open pit mining operation such as interactions with personnel and equipment, exposure of personnel to heat and cold and related risks.

Kennecott Uranium Company requests that licensees be permitted to evaluate normal construction related risks associated with any proposed excavation of residual radioactivity and that should these risks exceed the risks posed by the residual contamination itself, the licensee not be required to excavate the material.

Unfortunately the Commission also states in the Preamble:

Two contributing factors to the accumulation of unidentified subsurface contamination is reluctance among some licensees to spend funds during operations to perform surveys and document spills and leaks that may affect site characterization, and to implement procedures for waste minimization.

Kennecott Uranium Company would like to clearly point out that it has been entirely proactive in identifying subsurface contamination at the Sweetwater Uranium Project. Kennecott Uranium Company has without any requirements from the Commission undertaken a major effort to characterize subsurface contamination at the Sweetwater Uranium Project caused by a previous operator's use of a Commission approved Catchment Basin design. Upon discovery of this subsurface contamination, Kennecott Uranium Company promptly reported it to the Commission, initiated further costly site characterization efforts, recovered perched contaminated fluids and submitted to the Commission a detailed plan to excavate the contaminated soils and address an associated groundwater plume which is documented in the following submittals:

- *Request of Amendment to License conditions 11.3 - Groundwater Corrective Action Program and 11.5 - Mill Standby Environmental Monitoring Program. – May 12, 2004 ADAMS Accession Number: ML041450434*

- *Response to Comments License Amendment Request for the Proposed Change in the Groundwater Corrective Action Program, Environmental Monitoring Program and Reclamation Plan. – July 22, 2004*

- *Response to Request for Additional Information – December 15, 2004*

- *Response to Comments Regarding Natural Uranium and Thorium-230 Remediation in Subsurface Soils – January 18, 2005 ADAMS Accession Number: ML-050350266*

Upon approval of the plan as a license amendment, following preparation of an Environmental Assessment (ENVIRONMENTAL ASSESSMENT FOR AMENDMENT OF SOURCE MATERIAL LICENSE SUA-1350 FOR THE CATCHMENT BASIN RECLAMATION – ADAMS Accession Number: ML-051220301), which is a public record document, Kennecott Uranium Company excavated the contaminated subsurface soils that were not beneath building or other slabs and placed the materials for disposal in the mill tailings impoundment. Over 233,000 cubic yards of material was so excavated. Kennecott Uranium Company has substantial/exhaustive experience in characterizing and remediation of residual subsurface radioactivity. This remediation effort will be discussed in detail later in this document.

SRM–SECY–03–0069 (as quoted in the Preamble) authorized this proposed rulemaking. It states:

Licensees should not be required to submit the equivalent of a full scale MARSSIM [Multi-Agency Radiation Survey and Site Investigation Manual] survey every year."

Kennecott Uranium Company agrees with this statement for reasons described further in the text.

The preamble states:

The NRC recognizes that ground-water monitoring may be a surrogate for subsurface monitoring at some sites, that soil sampling may be appropriate at other sites, and that there are sites with no subsurface residual radioactivity where the existing monitoring method is appropriate.

Kennecott Uranium Company agrees with the above statement and would like to add that soil sampling can be conducted when drilling boreholes for monitoring wells so that subsurface soil sampling can be conducted concurrently with the completion of monitor wells. This was done at the Sweetwater Uranium Project

The Preamble continues by stating:

Also, the NRC recognizes that an area within the footprint of a building, during licensed operations, may not be a suitable area for subsurface residual radioactivity surveys if the process of sampling would have an adverse impact on facility operations. The decision to perform subsurface residual radioactivity sampling in a particular area should be balanced against the potential to jeopardize the safe operation of the facility.

Kennecott Uranium Company agrees with this statement and would also like to add that excavation of residual radioactivity can also have an adverse impact on a facility and may pose risks to it. Kennecott Uranium Company requests that the Commission allow the license to consider risks to the facility and the structures on site in any assessment of the need to excavate residual radioactivity.

The following are Kennecott Uranium Company's comments on specific elements of this proposed rule:

Background

The definition of *Residual Radioactivity* states in part, *...but excludes background radiation.*

The use of the term *Residual Radioactivity* creates major problems for all source material recovery licensees (conventional uranium mills, in-situ recovery operations and operations that recovery source material as a byproduct). Uranium, thorium and their decay products are ubiquitous in nature. *SECY-03-0069 - RESULTS OF THE LICENSE TERMINATION RULE ANALYSIS* states:

Source material (uranium and thorium) is found ubiquitously in nature.

The following table describes uranium concentrations in soils:

Uranium Content in Parts per Million (PPM) of Various Sedimentary Rock Types		
Rock Type	**Average Uranium Concentration**	**Range of Uranium Concentration**
Fine grained clastics		
Common shales	3.7	1 - 13
North American gray and green shales	3.2	1.2 - 12
Mancos shale (western U.S.A.)	3.7	0.9 - 12
Black shales		3 - 1250
Coarse grained clastics		
Sandstones		0.45 - 3.2
Orthoquartzites	0.45	0.2 - 0.6
Carbonates		
Carbonate rocks	2.2	0.1 - 9
Russian carbonates	2.1	
North American carbonates	2.2	0.65 - 8.8
California limestones	1.3	0.3 - 4.9
Florida limestones	2	0.5 - 6
Other sedimentary rocks		
Marine phosphorites		50 - 300
Evaporites		0.01 - 0.43
Bentonites	5.0	1 - 21
Bauxites	8.0	3 - 27

Source: *Hydrothermal Uranium Deposits* - Robert A Rich, Heinrich D. Holland and Ulrich Petersen Elsevier Scientific Publishing Company New York 1977

Attached please find additional background soil data applicable to Wyoming in the following appendices:

- Data from *Geology of the Lost Creek Schroeckingerite Deposits Sweetwater County, Wyoming - Geological Survey Bulletin 1087-J*
  Appendix 3 – Trench Sample Data – Sections 2-7 Lost Creek Area, Wyoming
  Appendix 4 - Trench Sample Data – Sections 8 - 13 Lost Creek Area, Wyoming
  Appendix 5 - Trench Sample Data – Section 1 Lost Creek Area, Wyoming
  This paper provides near surface trench sampling data for the Lost Creek Area in Sections 1 to 13, Townships 25 and 26 North, Ranges 94 and 95 West in Sweetwater County, Wyoming. This sampling was performed by the United States Geological Survey (USGS) and provides detailed information on the extent of concentrations of naturally occurring radionuclides in soils. All of these samples were collected within fifteen (15) feet of the surface which is at depths that residual radioactive material could be found in an area in which a uranium recovery facility could be constructed.

- Data previously submitted to the Commission in *Request for Amendment to Final Design VI – Part 2 Mill Decommissioning Addendum to the Existing impoundment Reclamation Plan – ADAMS Accession Number: ML041450434* regarding pre-operational near surface background radionuclide activities in and around the Sweetwater Uranium Project.
  Appendix 6 – Sweetwater Uranium Project – Pre-operational Soil Sampling Data

- Data generously provided by UMETCO Minerals Corporation concerning background radionuclide concentrations near its Gas Hills Site. They have previously submitted this data to the Commission.
  Appendix 7 – UMETCO Gas Hills Site – Non-random Background Soil Radiometric Data

- Data from soil samples collected at or near the bottom of a large excavation at the Sweetwater Uranium Project, created to remove soils contaminated by spilled diesel fuel. Appendix 11 contains a map of the excavation showing the locations of the samples discussed in Appendix 10. Appendices 8 and 9 contain background soil sample data from the excavation wall and from bulk samples collected in the course of installing a monitor well in the excavation bottom. This data has been previously submitted to the commission in the Sweetwater Uranium Project's 2007 Corrective Action Program (CAP) Review.
  Appendix 8 – South Pit Wall Sampling Results
  Appendix 9 – Bulk Sampling Results
  Appendix 10 – Excavation Soil Backgrounds
  Appendix 11 – Map of Spilled Fuel Excavation Soil Sample Locations
  The spilled fuel excavation was used to obtain radiological background samples since it was excavated solely to remove soils contaminated with spilled fuel and provided a convenient window for the collection of subsurface soil samples for radiological test.

Natural uranium concentrations vary widely in nature. Uranium recovery operations are sited at or very near deposits of uranium generally in the subsurface, which may also outcrop at the surface. This fact makes the distinction of subsurface soils containing naturally occurring uranium from soils contaminated by processing activities very difficult. Naturally occurring uranium concentrations around a uranium recovery site can be quite high. The table below shows the results of two (2) samples collected by Kennecott Uranium Company from its Catchment Basin excavation (the excavation created to remove subsurface contamination caused by the activities of a previous licensee):

Location	**Sample Type**	**Natural Uranium**	**Natural Uranium**	**Thorium-230**	**Thorium-230 - Uncertainty**	**Radium-226 Final**	
						Result	**Uncertainty**
		(milligrams per kilogram)	(picocuries per gram)	(picocuries per gram)	(picocuries per gram)	(picocuries per gram)	(picocuries per gram)
K Minus 3	Black Material	2550.00	1726.35	393.0	17.0	396	9
K Minus 3	Sand	2350.00	1590.95	708.0	29.0	326	6.4

Initially, Kennecott Uranium Company believed that this material was contamination. However, it was examined by Gareth D. Mitchell, a consulting geologist. The results of his examination are included in Appendix 1. He concluded as follows:

These observations demonstrate that the organic matter contained in sample #C07051289-001A were derived from terrestrial plants with secondary woody tissues that have gone through at least the initial stage of coalification. Depending upon stratigraphy and sample location in the field, the type and condition of organic matter and mineralization observed suggests that it is naturally occurring.

Thus in spite of the fact that the samples contained uranium, thorium-230 and radium-226, contaminants associated with source material processing and were collected in et vicinity of known subsurface contamination, the organics and associated radionuclides were in fact natural associated with accumulations of uranium associated with plant matter undergoing coalification. The only reason that the licensee was able to determine that the radionuclides were natural in origin was that the area was excavated and the material was exposed in an excavation wall that allowed for the collection of a sample of sufficient quality to allow for detailed petrographic analysis. Identification of the material as woody tissues undergoing coalification would probably have been impossible if the material was sampled by pneumatic drilling and the material brought to the surface as drill cuttings. The attached report in Appendix 1 was previously submitted to the Commission as an attachment to an e-mail as part of correspondence related to the excavation and is a matter of public record.

All of the above presented data including data presented in Appendices 1 and 3 to 11 shows the extreme variability of natural background radionuclide concentrations, how elevated they can be in nature and how difficult they can be to distinguish from residual radioactivity in areas in which source material processing has occurred. In order to accurately identify areas of residual radioactivity, source material licensees must have a reliable means of distinguishing it from natural background materials at their sites in the subsurface.

The issue of uncertainties in evaluation background is discussed in former Commissioner Gail LePlanque's speech *In Search of ... Background* which is attached in Appendix 2.

Most uranium recovery licensees, when they collected pre-operational soil background did so to comply with one or more of the following documents:

- **Regulatory Guide 4.14 – Radiological Effluent and Environmental Monitoring at Uranium Mills**

which states regarding pre-operational soil sampling:

1.1.4 Soil and Sediment Samples

Prior to initiation of mill construction (and if possible prior to mining), one set of soil samples should be collected as follows:

a. *Surface soil samples (to a depth of five centimeters) should be collected using a consistent technique at 300-meter intervals in each of eight compass directions out to a distance of 1500 meters from the center of the milling area. The center is defined as the point midway between the proposed mill and the tailings area.*
b. *Surface soil samples should be collected at each of the locations chosen for air particulate samples*
c. *Subsurface samples (to a depth of 1 meter) should be collected at the center of et milling area and at a distance of 750 meters in each of the four compass directions*

Soil sampling should be repeated for each location disturbed by site excavation, leveling or contouring.

This level of required soil sampling is in no way adequate to establish background for the remediation of buried residual radioactivity. The maximum recommended sampling depth in the above document is one (1) meter.

- **10 CFR part 40 Appendix A Criterion 6**

which states in part:

(6) The design requirements in this criterion for longevity and control of radon releases apply to any portion of a licensed and/or disposal site unless such portion contains a concentration of radium in land, averaged over areas of 100 square meters, which, as a result of byproduct material, does not exceed the background level by more than: (i) 5 picocuries per gram (pCi/g) of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over the first 15

centimeters (cm) below the surface, and (ii) 15 pCi/g of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over 15-cm thick layers more than 15 cm below the surface.

Byproduct material containing concentrations of radionuclides other than radium in soil, and surface activity on remaining structures, must not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of radium contaminated soil to the above standard (benchmark dose), and must be at levels which are as low as is reasonably achievable. If more than one residual radionuclide is present in the same 100-square-meter area, the sum of the ratios for each radionuclide of concentration present to the concentration limit will not exceed "1" (unity). A calculation of the potential peak annual TEDE within 1000 years to the average member of the critical group that would result from applying the radium standard (not including radon) on the site must be submitted for approval. The use of decommissioning plans with benchmark doses which exceed 100 mrem/yr, before application of ALARA, requires the approval of the Commission after consideration of the recommendation of the NRC staff. This requirement for dose criteria does not apply to sites that have decommissioning plans for soil and structures approved before June 11, 1999.

This requirement is again focused on surface contamination generally windblown tailings. Licensees who guide their background sampling to establish background to perform future remediation to comply with the above criterion would again only perform near surface sampling.

- **NUREG-1620 - Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites under Title II of the Uranium Mill Tailings Radiation Control Act of 1978**

This document states in part:

(2) Soil Background Radioactivity
Determine that the background level of Ra-226 (and U-nat, Th-230 and Th-232, as needed) in surface {15 cm [6 in.]} soil has been estimated using representative soil samples from nearby {within 3.2 km [2 mi] of site boundary} undisturbed areas that are not affected by site activities and are geologically and chemically similar to the contaminated areas. The number of samples will depend partly on the variability in background values, but at least 30 samples should be obtained at the typical site to determine the average value, standard deviation, and distribution. The arithmetic mean of the sample data is used in the cleanup criteria unless appropriate statistical analysis demonstrates a log normal distribution (three tests) of the data.

Several different background values may be required if contaminated areas have distinctly different soil types. For example, if a portion of the site has a natural uranium and/or radium mineralization zone in/near the surface, the cleanup criterion for that area would use a background (reference) U-238 or Ra-226 value from a similarly mineralized area. A geologic site map with the background values placed on the sample location can be used to help identify whether more than one background value should be considered.

If the plan indicates that in situ ore is in the clean-up area, it should be characterized by Ra-226/U-238 ratios, visual criteria, and/or other means.

This guidance provides instructions for establishing near surface (within one (1) foot of surface) background at sites prior to decommissioning but after processing on site has been conducted. This is required for many older source material processing sites since detailed background sampling was not required at these sites prior to operations. Again, this guidance only addresses near surface residual radioactivity.

- **NUREG-1569 - Standard Review Plan for In Situ Leach Uranium Extraction License Applications**

Section 2.9.3 of this document states in part:

(2) Soil sampling is conducted at both a 5-cm [2-inch] depth as described in Regulatory Guide 4.14, Section 1.1.4 (NRC, 1980) and 15 cm [6 in] for background decommissioning data.

This document merely directs the reader to *Regulatory Guide 4.14 – Radiological Effluent and Environmental Monitoring at Uranium Mills.*

None of the above documents addresses the collection of background data that would be useful in evaluating a site for deeply buried residual radioactivity or useful in remediation of such material. Thus uranium recovery licensees were never required to and for the most part do not possess background data that would allow them to adequately distinguish residual radioactivity from naturally occurring background radionuclides.

This is particularly a problem with source material recovery licensees since they deal with radionuclides that occur in nature. This is much less of a problem with licensees that either handle 11(e).1 byproduct material, transuranics, or special nuclear material all of which do not occur in nature and if found in nature other than the result of a licensees operations are present due to *global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee.* (10 CFR Part 20.1003 – Definitions – Background)

Background radionuclide concentrations at depth vary markedly from those at the surface especially in mineralized areas and because rainfall containing oxygen and carbon dioxide often leach uranium from surface soils and carry it deeper into the subsurface. The table in Appendix 6 provides the near surface background soil sampling data for the Sweetwater Uranium Project. In no case do any of these pre-operational samples approach the radionuclide concentrations found in the sample of material proven to be background during remediation by excavation of the Catchment Basin contamination.

Kennecott Uranium Company requests that should the Commission adopt this proposed rule, clear guidance on establishing background parameters for subsurface soils be established with the input of the uranium recovery industry. These parameters should include specific information on sampling frequencies and distributions. Clear, unambiguous instructions should also be provided for use at legacy sites that do not possess high quality background soil data, if any at all.

Applicability of MARSSIM [Multi-Agency Radiation Survey and Site Investigation Manual]

Kennecott Uranium Company believes that MARSSIM [Multi-Agency Radiation Survey and Site Investigation Manual] should not be applied to the investigation of contamination in the subsurface at source material recovery sites since it is unsuited to the characterization of contamination consisting of radionuclides already found in nature.

The characterization and remediation of anthropogenic radionuclides such as Cobalt-60, Cesium-137, any isotope of plutonium, other transuranics and similar radionuclides is a far different issue from remediating radionuclides that belong to the naturally occurring Uranium-238, Uranium-235 and Thorium-232 decay chains.

Definition of 11(e).2 Byproduct Material versus the Definition of Residual Radioactivity

Residual radioactivity is defined as follows:

''Residual radioactivity means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the licensee's control. This includes radioactivity from all licensed and unlicensed sources used by the licensee, but excludes background radiation. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.''

11(e).2 byproduct materials is defined as follows:

(2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute "byproduct material" within this definition;

The definition of byproduct material nowhere includes the term *radioactive*. In fact it is the understanding of Kennecott Uranium Company that material does not have to be radioactive in order for it to be 11(e).2 byproduct material. In the case of the Catchment Basin excavation to remove contaminated soils, all of the excavated materials were placed in the site's tailings impoundment as 11(e).2-byproduct material. Not all of the materials were radiologically contaminated. A substantial portion of the materials were contaminated by organics (kerosene, isodecyl alcohol and tertiary amine (Alamine 360) and did not contain readily discernible radioactive contamination. Because the definition of 11(e).2 byproduct material includes ... *tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content,* ... it includes wastes (hydrocarbon contaminated soils) from the Catchment Basin excavation, since they were contaminated as a result of processing activities.

There may be cases of subsurface contamination directly resulting *from ore processed primarily for its source material content* (11(e).2-byproduct material) that does not meet the definition of *residual radioactivity.*

In addition, the definition of *residual radioactivity* includes *radioactivity from all licensed and unlicensed sources used by the licensee.* Licensed materials with the exception of:

(3)(i) Any discrete source of radium-226 that is produced, extracted, or converted after extraction, before, on, or after August 8, 2005, for use for a commercial, medical, or research activity; or
(ii) Any material that—
(A) Has been made radioactive by use of a particle accelerator; and
(B) Is produced, extracted, or converted after extraction, before, on, or after August 8, 2005, for use for a commercial, medical, or research activity; and
(4) Any discrete source of naturally occurring radioactive material, other than source material, that—
(i) The Commission, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, the Secretary of Homeland Security, and the head of any other appropriate Federal agency, determines would pose a threat similar to the threat posed by a discrete source of radium-226 to the public health and safety or the common defense and security; and
(ii) Before, on, or after August 8, 2005, is extracted or converted after extraction for use in a commercial, medical, or research activity. (10 CFR Part 20.1003 – Definitions)

are comprised of materials that are part of the nuclear fuel cycle. *Unlicensed sources* as mentioned in the definition of *residual radioactivity* could include materials not part of the nuclear fuel cycle such as Technologically Enhanced radioactive Material (TENORM). Tailings impoundments at licensed source material processing facilities are designed to accommodate 11(e).2-byproduct material and the Department of Energy (DOE) is only legally obligated to accept impoundments containing only 11(e).2-byproduct material absent any agreement from the Department to do otherwise. If a source material recovery licensee/conventional mil with an 11(e).2 byproduct material/tailings impoundment must excavate *residual radioactivity* as part of a remedial action the licensee may be unable to place all of it in their 11(e).2 byproduct material/tailings impoundment if the *residual radioactivity* includes material from *unlicensed sources* that could potentially be Technologically Enhanced Radioactive Material (TENORM).

This situation also impacts in-situ recovery licensees. In-situ recovery licensees drill numerous recovery wells in their wellfields. When doing the drilling, a mud pit is excavated to hold the drilling mud and drill cuttings as the well is drilled. In the course of drilling the well, cuttings from the ore zone containing uranium and its decay products are brought to the surface and settle in the mud pit. Since ***residual radioactivity*** *means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the licensee's control does* it also include uranium and its decay products in drill cuttings that have settled in mud pits? These cuttings are not *discrete surface wastes resulting from uranium solution extraction processes* but rather diffuse Naturally Occurring Radioactive Material (NORM). Kennecott Uranium Company believes that drill cuttings should not be included in the definition of *residual radioactivity.*

The definition of residual radioactivity includes the term *resulting from activities under the licensee's control.* Does this limit the area of responsibility of the licensee for residual radioactivity to the licensee's *controlled area* as defined in 10 CFR Part 20.1003 Definitions which states:

Controlled area *means an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.*

The definition of residual radioactivity is also ambiguous in that it includes:

radioactivity from all licensed and unlicensed sources used by the licensee

If the licensee is operating a licensed conventional uranium mill, they may also have a uranium mine operating in the vicinity. Unrefined and unprocessed ore is exempt from Commission regulation as per 10 CFR Part 40.13 Unimportant quantities of source material, which states:

(b) Any person is exempt from the regulations in this part and from the requirements for a license set forth in section 62 of the act to the extent that such person receives, possesses, uses, or transfers unrefined and unprocessed ore containing source material; provided, that, except as authorized in a specific license, such person shall not refine or process such ore.

This exemption is clear and unambiguous. However, the licensee as part of the mining operation may have to treat its mine discharge water with barium chloride in order to remove radium prior to discharge. This process would generate radium laden barium sulfate settlement pond sludges. If these settling ponds were within the licensees controlled area (not within the restricted area) they are clearly *under the licensee's control* and the sludges may constitute an *unlicensed source* of radiation. However they are clearly not 11(e).2 byproduct material since they are mining and not processing related, and could not be placed in a uranium mill tailings impoundment, unless a license amendment is obtained as per SECY-99-0012 – Use of Uranium Mill Tailings Impoundments for the Disposal of Waste Other than 11(e).2 Byproduct Material and Reviews of Applications to Process Material other than Natural Ore and its associated Staff Requirements Memorandum (SRM).

The definition of *residual radioactivity* should be clarified to state:

''Residual radioactivity means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from Atomic Energy Act (AEA) licensed activities under the licensee's control. This includes radioactivity from all Atomic Energy Act (AEA) licensed materials and unlicensed sources exempted from licensing under the Atomic Energy Act (AEA) including those materials added to the definition of byproduct material by the Commission effective November 30, 2007 used by the licensee, but excludes background radiation. It also includes Atomic Energy Act (AEA) radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.''

Soil Protection Standards

The Commission establishes Groundwater Protection Standards (GPS's) for conventional uranium recovery sites (mills) and their associated tailings impoundments. At first these standards were established by averaging the concentrations of various parameters for a number of samples taken over time from a single upgradient well. This subsequently was changed and in the case of the Sweetwater uranium Project established background values for various parameters based on a value of average of sample results plus two (2) standard deviations for samples (approximately 1029 samples) from a number of wells in et area around the facility. Please see the following two (2) docketed documents:

Addendum to the Revised Environmental Report – Background Ground Water Quality and Detection Standards – Submitted January 1996

Review of Request to Amend Groundwater Protection Standards and Responses to comments on the Sweetwater Environmental Report – May 28, 1998

If the Commission will now require evaluation of subsurface contamination and eventual remediation of it, Kennecott Uranium Company requests that a site specific soil protection standard for a facility be allowed, based on an average of a representative number of subsurface soil samples plus two (2) standard deviations. This would adequately account for the variability of the natural background concentrations of radionuclides in subsurface soils and be consistent with established practice for groundwater. The addition of two (2) standard deviations, now allowed for groundwater, should provide an adequate range to encompass background radionuclide concentrations provided that the background-sampling program is sufficiently comprehensive. In addition, differing soil protection standards for differing depths could be established based on pre-operational borehole sampling since natural uranium concentrations can vary markedly above, at or below the water table.

Characterization of Subsurface Contamination

Kennecott Uranium Company recognizes that the characterization of subsurface is difficult, having characterized subsurface soil contamination related to its Catchment Basin. A number of issues will have to be addressed in guidance with substantial industry input, including:

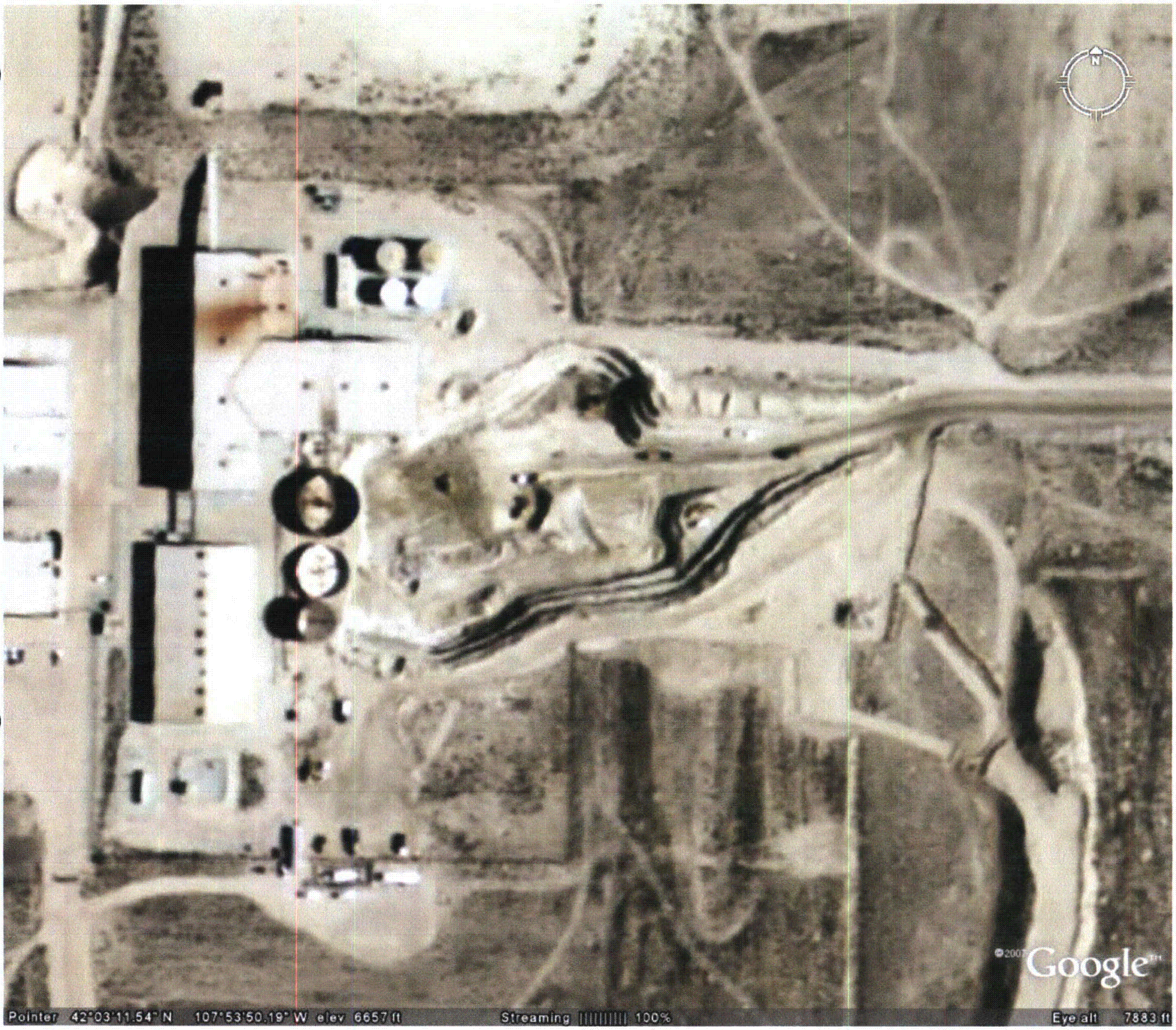
- Borehole, test pit or test trench density required to adequately characterize residual radioactivity
  - Kennecott Uranium Company drilled the area around the Catchment Basin on roughly fifty (50) foot centers with composite samples collected every five (5) vertical in each borehole to define an area containing 120, 000 cubic yards of material requiring excavation. Please see *Request of Amendment to License conditions 11.3 - Groundwater Corrective Action Program and 11.5 - Mill Standby Environmental Monitoring Program. – May 12, 2004 ADAMS Accession Number: ML041450434.* Upon completion of the planned excavation additional contamination was visible in the planned excavation's North wall.

- Removal of this material not found during the drilling program added approximately 113, 268 cubic yards to the excavation.

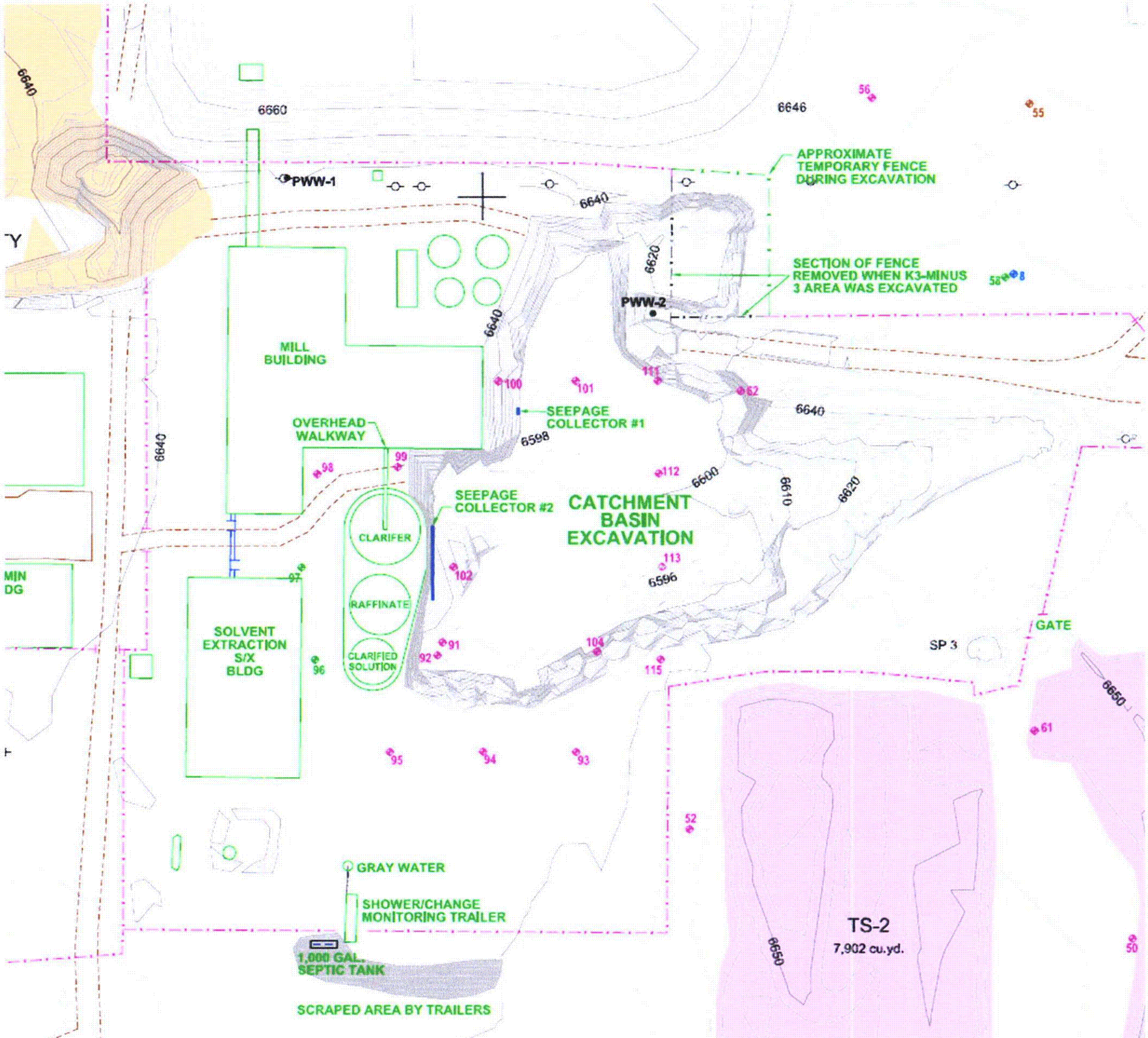
It is difficult accurately characterize the horizontal and vertical extent of residual radioactivity. Clear procedures must be developed to perform an adequate characterization/survey. This may well have to be site specific since the stratigraphy beneath the Sweetwater Uranium Project includes numerous thin highly discontinuous clay beds separated horizontally and vertically by permeable sand. Liquid contaminants percolated down to the first clay horizon, flowed along it until its end then flowed off its edge until the fluids hit another deeper clay layer. This contamination became distributed in the underlying formation often with layers of contaminated sand underlain by clean sand underlain by additional contaminated sand. This is clearly evident the cross sections in the above reference submittal. The distribution of residual radioactivity can become quite complex and is often governed by site specific factors.

Potential Extent and Magnitude of Subsurface Contamination

Subsurface contamination at a conventional uranium recovery facility can be extensive. The image below from Google Earth (August 2006) shows the extent of the excavation required to remove contaminated soils related to the Sweetwater Uranium Project's Catchment Basin. At the time of this image the excavation had not reached its full extent.



Below is a map of the excavation at its full extent.



It can be matched to the image above readily.

The panoramas below show the excavation looking West on July 14, 2006:

and looking East on June 20, 2006:

Groundwater

The preamble to the proposed rule repeatedly discusses one aspect of residual radioactivity that being groundwater contamination with such statements as:

"...licensees must be able to demonstrate their knowledge of residual radioactivity in the subsurface, including soil and ground-water contamination, ..."

"Based on past NRC experience, significant concentrations or quantities of undetected and unmonitored contamination, caused primarily by subsurface migration or ground water, has been a major contributor to a site becoming a legacy site and a potential radiological hazard "

Survey requirements may include ground-water monitoring if reasonable under the site specific conditions.

Kennecott Uranium Company wishes to make clear that ground water monitoring and protection requirements for both conventional and in-situ uranium recovery facilities are comprehensive. In the case of conventional mills their requirements are codified in 10 CFR Part 40 Appendix A and 40 CFR 192.32. In the case of in-situ uranium recovery facilities, groundwater protection and monitoring requirements are described in detail in *NUREG-1569*
Standard Review Plan for In Situ Leach Uranium Extraction License Applications Final Report.
Given the comprehensive nature of groundwater protection and monitoring requirements governing uranium recovery facilities, Kennecott Uranium Company requests that no further groundwater protection and/or monitoring requirements be added to already existing regulations governing the uranium recovery industry.

Options for Handling Residual Radioactivity

The Commission should develop guidance with clear options with industry input for licensees to address large volumes of residual radioactivity for the following reasons:

- Offsite disposal of large volumes of residual radioactivity is difficult and costly due to:
  - The paucity of disposal sites willing to accept such materials
  - The high costs of placing these materials at these sites

- Industrial safety/risk issues created by any large excavation efforts need to be evaluated relative to the risks created by the residual radioactivity.
- Excavating these materials includes difficulties in obtaining suitable personnel and equipment to perform the work.
- Excavation and transportation of these materials often present safety related risks greater than the risks posed by the materials themselves. The costs per life-year saved for various radiation control measures tend to be very high. Please see *Five-Hundred Life Saving Interventions and Their Cost Effectiveness* (page 377) included in Appendix 12. In Kennecott Uranium Company's experience with a major residual radioactivity excavation at its site occupational exposure rates were inconsequential. The real risks associated with the remediation of subsurface contamination were the ones associated with any large excavation/open pit mining operation such as interactions with personnel and equipment, exposure of personnel to heat and cold and related risks. Kennecott Uranium Company requests that licensees be permitted to evaluate normal construction related risks associated with any proposed excavation of residual radioactivity and that should these risks exceed the risks posed by the residual contamination itself, the licensee not be required to excavate the material.
  - As stated above the radiological risks were very low. Please refer to Appendix 13 which contains the following exposure information:
    - High volume air sample data collected during excavation – Please add 2006 ALARA Report Catchment Basin Excavation High Volume Air Sampling Results
    - Personal Breathing Zone Sample Results - Please add 2006 ALARA Report Catchment Basin Breathing Zone Sample Results using Lower Limit of Detection (LLD) values
    - Dosimetry Data – Please add 2006 dosimetry data which is being entered for the Catchment Basin Excavation Completion Report
- The Commission should develop options to address residual radioactivity if licensees will be required to characterize and remediate it. These options should include:
  - Reclamation in Place
    - Upon completion of suitable long term modeling using ResRad or similar dose modeling programs that show that the residual radioactivity presents minimal risk to human health, safety or the environment the licensee should be allowed to leave it in place provided that:
      - The land beneath which the residual radioactivity is found is deeded to the Federal or a State government for long term care, maintenance and monitoring and suitable funds are deposited so that the income from them (at a reasonable rate of return) will be available to monitor and maintain the site in perpetuity.
      - Regulations could be structured to accomplish this end which would be similar to 10 CFR Part 40 Appendix A, which states:
        - *Criterion 10--A minimum charge of $250,000 (1978 dollars) to cover the costs of long-term surveillance must be paid by each mill operator to the general treasury of the United States or to an appropriate State agency prior to the termination of a uranium or thorium mill license.*

          If site surveillance or control requirements at a particular site are determined, on the basis of a site-specific evaluation, to be significantly greater than those specified in Criterion 12 (e.g., if fencing is determined to be necessary), variance in funding requirements may be specified by the Commission. In any case, the total charge to cover the costs of long-term surveillance must be such that, with an assumed 1 percent annual real interest rate, the collected funds will yield interest in an amount sufficient to cover the annual costs of site surveillance. The total charge will be adjusted annually prior to actual payment to recognize inflation. The inflation rate to be used is that indicated by the change in the Consumer Price Index published by the U.S. Department of Labor, Bureau of Labor Statistics.

        - *Criterion 11—*
          A. These criteria relating to ownership of tailings and their disposal sites become effective on November 8, 1981, and apply to all licenses terminated, issued, or renewed after that date.
          B. Any uranium or thorium milling license or tailings license must contain such terms and conditions as the Commission determines necessary to assure that prior to termination of

the license, the licensee will comply with ownership requirements of this criterion for sites used for tailings disposal.

C. Title to the byproduct material licensed under this Part and land, including any interests therein (other than land owned by the United States or by a State) which is used for the disposal of any such byproduct material, or is essential to ensure the long term stability of such disposal site, must be transferred to the United States or the State in which such land is located, at the option of such State. In view of the fact that physical isolation must be the primary means of long-term control, and Government land ownership is a desirable supplementary measure, ownership of certain severable subsurface interests (for example, mineral rights) may be determined to be unnecessary to protect the public health and safety and the environment. In any case, however, the applicant/operator must demonstrate a serious effort to obtain such subsurface rights, and must, in the event that certain rights cannot be obtained, provide notification in local public land records of the fact that the land is being used for the disposal of radioactive material and is subject to either an NRC general or specific license prohibiting the disruption and disturbance of the tailings. In some rare cases, such as may occur with deep burial where no ongoing site surveillance will be required, surface land ownership transfer requirements may be waived. For licenses issued before November 8, 1981, the Commission may take into account the status of the ownership of such land, and interests therein, and the ability of a licensee to transfer title and custody thereof to the United States or a State.

- *Criterion 12--The final disposition of tailings, residual radioactive material, or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation. As a minimum, annual site inspections must be conducted by the government agency responsible for long-term care of the disposal site to confirm its integrity and to determine the need, if any, for maintenance and/or monitoring. Results of the inspections for all the sites under the licensee's jurisdiction will be reported to the Commission annually within 90 days of the last site inspection in that calendar year. Any site where unusual damage or disruption is discovered during the inspection, however, will require a preliminary site inspection report to be submitted within 60 days. On the basis of a site specific evaluation, the Commission may require more frequent site inspections if necessary due to the features of a particular disposal site. In this case, a preliminary inspection report is required to be submitted within 60 days following each inspection.*

- An attempt to move toward the system used for the reclamation of uranium recovery sites in 10 CFR 40 Appendix A is clearly visible in this proposed rule since it proposes using techniques used in addressing surety issues in the uranium recovery industry such as standby trusts, and holding of funds deposited by the licensee for decommissioning under restricted release in trust funds, and application of a 1% real rate of return to funds held for the site.
- Kennecott Uranium Company believes that the system of long term ownership, care, maintenance and environmental monitoring in place now for 11(e).2 byproduct material sites could be broadly applied to other types of sites as well. A similar system for the long term care and maintenance of other types of sites that involves transfer of the property to the Federal Government for care and monitoring in perpetuity could be established. Such a system would bring the high levels of assurance of perpetual care associated with 11(e).2 byproduct material sites to other types of sites as well.

- Creation of Additional Disposal Capacity for Bulk Low Activity Radioactive Materials
  - Excavation of residual radioactivity will result in the generation of large quantities of low activity bulk material (soils and rubble contaminated with source, special nuclear and byproduct (11(e).1 and 11(e).2) material). Viable options to handle these materials must be developed.
  - The Commission should implement the suggestions provided by the National Mining Association (NMA) in ***The National Mining Association's and the Fuel Cycle Facilities Forum's White Paper on Direct Disposal of Non-11e.(2) Byproduct Materials in Uranium Mill Tailings Impoundments*** and in its
  - **1996 Strategic Assessment and Rebaselining Initiative (SARI)** in which expanding the use of uranium tailings impoundments to allow disposal of wastes generated during decommissioning of nuclear facilities, along with 11e.(2) byproduct material, was considered when the document stated:
    "Because several...sites [currently undergoing decommissioning] have large quantities of uranium and thorium contaminated waste with characteristics similar to those of mill tailings, it may be cost-effective

to dispose of decommissioning waste at existing mill tailings sites...This cost is substantially less than disposal costs at licensed low-level waste disposal sites..."

- *This issue has been previously addressed by Kennecott Uranium Company in its comments entitled:*
  - *Kennecott Uranium Company's Comments Regarding: Federal Register: July 7, 2006 Volume 71, Number 130 Pages 38675-38676 Request for Comments on the Nuclear Regulatory Commission's Low Level Radioactive Waste Program* – Submitted to the Nuclear Regulatory Commission (NRC) 2006 and;
  - *Kennecott Uranium Company - Comments on Approaches to an Integrated Framework for Management and Disposal of Low-Activity Radioactive Waste: Request for Comment Federal Register (FR) Vol. 68, No. 222 / Tuesday, November 18, 2003 / Proposed Rules pages 65120 to 65151* – Submitted to the Environmental Protection Agency 2004

Surety Issues

- Removal of the option of providing a line of credit for surety.
  - This surety method is not used in the uranium recovery industry and has not been used by licensees since 1988 which is stated in the preamble.
  - This change is acceptable since Kennecott Uranium Company uses an irrevocable letter of credit to meet its surety obligations.
- Require an upfront standby trust fund for the parent guarantee and self-guarantee options.
  - The preamble states," *A standby trust is necessary because the NRC cannot accept decommissioning funds directly. Under the ''miscellaneous receipts'' statute, 31 U.S.C. 3302(b), the NRC must turn over all payments received to the U.S. Treasury. Therefore, a standby trust is necessary to receive funds in the event the NRC requires the guarantor to put the funds into a segregated account."*
  - The use of a Standby Trust is already required for uranium recovery licensees and Kennecott Uranium Company believes that this system should be broadly applied in the interests of fairness and consistency
- Require a Trust Fund for Decommissioning Under Restricted Release
  - The preamble also states in this section," *A further change to 10 CFR 20.1403(c)(1) would be the addition of a requirement that the initial amount of the trust fund established for long-term care and maintenance be based on a 1 percent annual real rate of return on investment. A similar provision is currently contained in 10 CFR part 40, appendix A, Criterion 10, which provides that if a site-specific evaluation shows that a sum greater than the minimum amount specified in the rule is necessary for long-term surveillance following decontamination and decommissioning of a uranium mill site, the total amount to cover the cost of long-term surveillance must be that amount that would yield interest in an amount sufficient to cover the annual costs of site surveillance, assuming a 1 percent annual real rate of interest."*
  - Kennecott Uranium Company agrees with this approach. Once reclamation is complete at Title II uranium mill tailings sites, the licensee is required to transfer the land containing the 11(e)2 byproduct to the Federal Government/Department of Energy (DOE) or to the State Government (if the State agrees to accept it) along with funds (a minimum of $250,000. In 1978 dollars – more if required) to fund long term site monitoring and maintenance assuming a 1% real rate of return on the funds. Extending this type of regulation to other licensees is consistent and fair.

Kennecott Uranium Company appreciates the opportunity to comment on this proposed rule. Kennecott Uranium Company is preparing its Completion Report on the Catchment Basin excavation and will submit it (as required) to the Commission in the very near future. This document will contain substantial additional information about the remediation of the residual radioactivity associated with the Catchment Basin that the Commission may find useful in this rulemaking. If you have any questions please do not hesitate to contact me.

Sincerely yours,

Oscar A Paulson

Oscar Paulson
Facility Supervisor

cc: Katie Sweeney – National Mining Association (NMA)
John Lucas – Rio Tinto Energy America (RTEA)

Gareth D. Mitchell
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Email: n8h@psu.edu

June 13, 2007

Mr. Steve Dobos
Energy Laboratories, Inc.
2393 Salt Creek Hwy.
Casper, WY 82602

RE: **Petrographic Evaluation of Sample #C07051289-001A from P.O. # 1845**

Dear Mr. Dobos,

Work requested in your purchase order of 5-29-07 for sample #C07051289-001A to perform carbon identification using reflected-light optical microscopy has been completed and the final report is attached.

If there are any questions or concerns, please call or e-mail me directly.

Thank you.

Sincerely,

Gareth Mitchell

Enclosure: Report

Final Report

To: Mr. Steve Dobos
From: Gareth D. Mitchell
Date: June 13, 2007
Subject: **Petrographic Evaluation of Sample #C07051289-001A from P.O. # 1845**

Request

A sample identified as **#C07051289-001A** was received 6-7-07 for petrographic evaluation. The sample had been shipped in a cooler containing bags of ice and was still cold when received. Consequently, the specimen was placed under refrigeration until sample preparation was initiated. As established from our email conversation of 5-24-07, optical microscopy was to be employed to determine the nature of the organic matter found in the sample and specifically to determine if "any naturally-occurring organic matter" (such as lignin, kerogen, bitumen, etc. that might have precipitated uranium at this location) was present.

Procedures

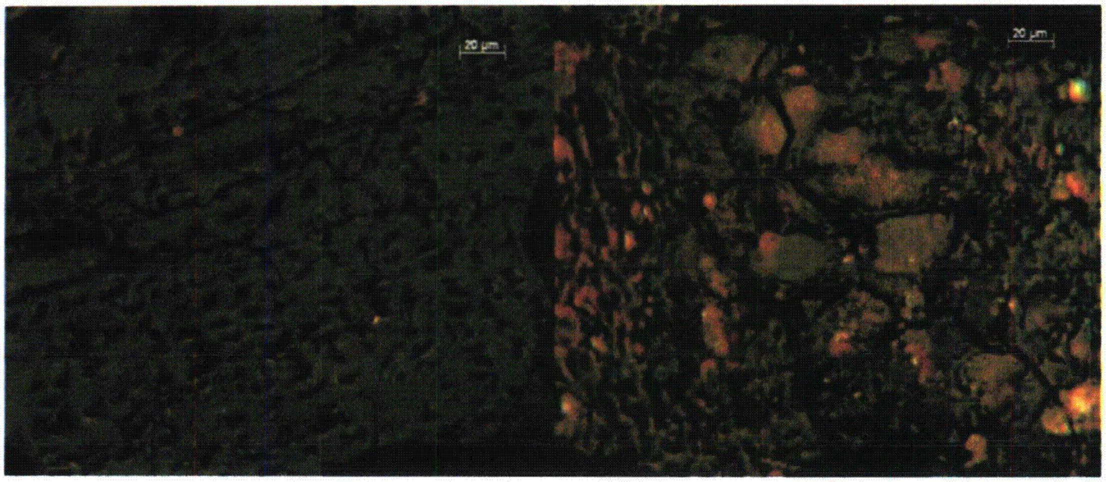
The sample was found to be composed of three fairly large angular particles (~10 g) and a coarse powder (~11 g). These components were separated and allowed to come to room temperature before they were inspected. The largest particle was soft, organic matter which had prominent bedding and considerable surface moisture, whereas the particulate matter ranged in particle size (0.5 – 3.0 mm), appeared to be a mixture of light and dark colored materials and was agglomerated with surface moisture. To prepare an optical mount suitable for reflected-light microscopy, the moisture content had to be reduced. The large particle was placed in a drying pan and a one-quarter split of the particulate sample retrieved by riffling was placed in second pan. Both samples were placed in a vacuum oven between 30-50°C for about 18 hrs with the result that the large particle had become swollen, desiccated and broken into smaller segments, while the particulate sample was composed of individual loose particles.

Remnants of the large particle were glued fast to the bottom of a 28 mm sample mold and embedded under vacuum with a cold-setting epoxy (EL01). The particulate sample (EL02) was vacuum impregnated in epoxy resin and placed in a centrifuge to establish a density/particle-size gradient. After hardening, the sample was cut longitudinally to expose the particle gradation and mounted 25 mm sample mold with additional epoxy. Both specimen surfaces were ground using 400 and 600 grit papers and polished using 0.3 and 0.05 micron alumina slurries on a high-nap cloth and silk, respectively. The sample was examined first in air using blue-light (436 nm) irradiation inspecting the 520 nm emission surface at 500X magnification and then using white light employing an oil immersion objective at 625X magnification using Zeiss research microscopes. In addition, a few reflectance readings were taken from the main organic component identified in EL01. A Leitz MPV2 reflectance photometer system at 625 X magnification in oil immersion and polarized white-light was used to collect maximum reflectance values from 11 different areas and the mean value is provided below. Mean reflectance values are an acceptable procedure for determination of organic maturity.

Results

The organic matter observed in both specimens (EL01 and EL02) separated from sample #C07051289-001A is basically humified woody tissue of very low maturity (mean maximum reflectance in oil of 0.18 % ±0.01) that contains fluorescent and presumably resinous material within open cell lumens and along some open fractures. A few fluorescent bodies appearing to be amorphous organic matter were the only other organic matter observed in either sample.

As seen in the photomicrographs below, the regular alignment of cell wall and filled or open lumens taken from EL01 are compared with a fragment of humified and gelified woody tissue found in specimen EL02. The large particle separated as EL01 was composed entirely



EL01 **EL02**

of woody tissue that had gone through the biochemical stage of coalifiaction in which the cell walls were gelified and converted to humic matter. The tissue observed in the EL01 photograph exhibits little detail within the remnant cell walls and most of the lumens were filled with amorphous humic material or a fluorescing resin (dark areas), suggesting that the tissue has gone beyond the peat stage. However, the very low mean reflectance suggests that it may not have reached the rank of lignite in terms of coal maturity.

The photograph of the dominant organic matter in specimen EL02 shows many rounded bodies which in brown coal terminology are referred to as gelinite. As the name implies the humic matter from which they were derived were once gelatinous and have since formed into these amorphous bodies surrounded by the remnants of cell walls. In addition to organic matter, specimen EL02 contained mostly angular fragments of minerals and rocks composed of quartz, other silicates and carbonate. Furthermore, some of the organic material had been infilled and was in the early stage of being replaced by silica.

These observations demonstrate that the organic matter contained in sample #C07051289-001A were derived from terrestrial plants with secondary woody tissues that have gone through at least the initial stage of coalification. Depending upon stratigraphy and sample location in the field, the type and condition of organic matter and mineralization observed suggests that it is naturally occurring.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
Office of Public Affairs
Washington, D.C. 20555

No. S-28-94
Tel. 301-415-8200

Remarks by Dr. E. Gail de Planque
Commissioner, U.S. Nuclear Regulatory Commission
before the
NRC Workshop on Site Characterization for Decommissioning
Rockville, Maryland
November 29, 1994

In Search of . . . Background

It is a pleasure to be here this morning at the NRC Workshop on Site Characterization for Decommissioning. I'm so pleased to see so many in attendance because I think that the issue of decommissioning is one of the most significant issues on the Commission's plate, one that will have long lasting and far reaching impacts.

Introduction

As you know, the NRC is undergoing a lengthy process aimed at formulating radiological criteria for the decommissioning of NRC-licensed facilities. During that process, extensive discussions have focused on four possible approaches to this task: (1) establishing an annual risk or dose limit for an individual; (2) establishing an annual risk or dose goal; (3) requiring use of the best available technology; or (4) requiring return of the site to background radioactivity. While many commenters preferred a risk-based or dose-based standard, many others favored the "return-to-background" approach.

The proposed rule attempts to accommodate both groups by establishing a dose limit for release of the site of 15 millirem per year Total Effective Dose Equivalent (TEDE) for residual radioactivity distinguishable from background with further reductions As Low As Reasonably Achievable, or ALARA.

First, an aside. To make life easier, I will usually use the quantity total effective dose equivalent expressed in units of mrem. But for brevity's sake, I will use the term "dose" when speaking of total effective dose equivalent.

The objective expressed in the proposed rule is to cleanup up to dose levels that are indistinguishable from background. Return to background!

Sounds good, doesn't it? On the surface, this seems like a relatively easy, common-sense approach: for example, survey a nearby spot unaffected by a nuclear facility, use that radiation level as a baseline, clean up the contaminated site to that level, and . . . voila! The site is decommissioned, the method indisputable, the job completed.

But, as we all know, the devil is in the details. And in this case, the devil could produce a series of torments for those involved in returning a site to background.

I'd like to discuss some of the details with you this morning, particularly the details that are relevant to determining what background is and how it is measured. But I'd also like to place this discussion of the details within the broader context of a regulatory decision-making process.

Risk-Based Decision-Making

The decision-making process I'm referring to is "risk-based" decision-making, a process gaining popularity both in the Clinton Administration and in Congress, and widely advocated by the most recent Supreme Court member, Justice Stephen Breyer. Let me say at the outset that as far as I know this particular mode of making decisions was not followed in any rigorous way in formulating the proposed rule. Nevertheless, for reasons which I hope will be clear later in this talk, it may offer a useful framework for working out the details of a decommissioning program.

Risk-based decision-making allows for the assumption that the resources available for limiting risks are not inexhaustible and seeks to ensure that the resources which are available to society as a whole will be put to the best overall use considering risk, cost and benefit. It can be divided into three basic components as illustrated by the following Sydney Harris cartoons: (1) risk assessment, (2) selection of an acceptable level of risk, and (3) risk management. In the context of decommissioning, risk assessment is an evaluation of the hazard associated with residual radioactivity remaining at a site released for unrestricted or restricted use. Selection of an acceptable risk level involves weighing the benefits of lowering risk to a certain level against the costs and may involve comparing the risk at issue with other similar risks confronting society. Risk management consists of a regulatory process designed to keep the risk below the level found to be acceptable.

Risk Assessment

As the NRC begins to formulate a regulatory program to manage the risk associated with sites cleaned up to levels of radiation contamination that are indistinguishable from background, it might be useful to revisit Step 1 of the risk-based decision-making process: risk assessment. Perhaps this can most easily be done by reviewing the levels of radiation to which humans are typically exposed and the health consequences of those levels.

Broadly speaking, the average American's annual radiation dose is attributable to two sources: naturally occurring radiation which, in the U.S., produces about 82% of the dose, and anthropogenic radiation which produces the remaining 18%. Humans are bathed in a sea of naturally-occurring radiation which has been present since the formation of the earth. About 56% of the average annual dose is from radon and its decay products. Another 11% is from other internal sources, mainly from inhalation and ingestion of food and water which contain naturally occurring radioactive elements. The remainder is from external sources, about 7.5% from cosmic rays and about 7.5% from terrestrial gamma ray sources such as uranium, potassium, and thorium, that are present naturally in soil and rocks.

Just to complete the picture, let's look at the anthropogenic sources. About 11% of the average annual dose comes from medical x-rays, about 4% from nuclear medicine, and about 3% from consumer products such as smoke detectors. The small remainder is from fallout from weapons testing, and occupational exposures at various nuclear facilities.

The proposed rule defines "background radiation" as:

> radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents like Chernobyl which contribute to background radiation and are not under the control of the licensee.

Although naturally-occurring radiation and fallout from atmospheric weapons testing and the Chernobyl accident are present everywhere, each of these components of what I'll refer to as background, and the corresponding dose delivered, is by no means constant. Background levels fluctuate significantly due to various physical phenomena that differ from place to place and change with time at any given place. For example, over the long-term, cosmic radiation varies by about 10% over the 11 year solar cycle. Seasonal cycles produce changes in soil moisture, rainfall, snow cover, and evapotranspiration that cause variations in the dose from terrestrial gamma radiation, fallout and radon. Many sporadic geophysical phenomena, volcanic eruptions or earthquakes for example, can also introduce radioactivity into the environment.

Temporal variations can also occur over the short term. Rain, for example, will wash out radon and other radionuclides from the air causing an immediate rapid increase in dose that typically decreases exponentially after the rain stops. Doses from radon typically exhibit a diurnal cycle due to local climate conditions.

Radiation varies spatially. The dose from cosmic radiation is a function of both latitude and altitude. The population of the city of Denver, at an altitude of a mile receives an annual cosmic ray dose that is a factor of 2 higher than the U.S. average. Terrestrial gamma radiation, including fallout, varies from place to place because of differing amounts of uranium, potassium and thorium in the earth's surface material and can easily differ by a factor of 10 across the country. Granite, for example, contains higher than average uranium concentrations and monazite sands can have particularly high concentrations of thorium. Furthermore, humans sometimes alter soil content with fertilizer which contains varying amounts of potassium-40. Spatial variations occur locally as well; the well-known Reading Prong in New Jersey provides an interesting regional example. The average annual dose from gamma radiation is approximately 50 mrem but if one resides closer to the rock formations along the prong, the annual dose can be much greater. About sixty miles away at the New Jersey shore, the gamma radiation dose levels fall to less than 10% of the average measured over the Prong.

Even in the immediate environment of a typical facility site (this happens to be Shoreham, Long Island), significant fluctuations occur (Figure 1). For this site with an annual average terrestrial gamma dose of about 35 mrem, when measured simultaneously, levels varied by more than 50% over a distance of only a mile within the site boundary, and the areas within a 4- or 5-mile radius of the site exhibited variations with even greater extremes.

This site in rural New Jersey, used as a background monitoring station, is only 50' by 200' (Figure 2). And even within such a small area, simultaneously measured terrestrial gamma radiation dose levels, which average about 125 mrem per year, differ by as much as 30% from spot to spot. That translates into differences of close to 40 mrem per year.

Other local variations occur due to the types of houses and buildings in which people live and work. Persons living in a wood frame house usually receive lower doses than persons living in an all brick house because, even though brick is a better shield of outdoor radiation, it has higher concentrations of naturally occurring radioactivity than wood. Persons working in granite and marble buildings may receive higher doses due to the radioactivity in the stone. Even moving from a rural to an urban setting may increase an individual's annual dose, due to the level of radioactivity present in concrete. The dose from cosmic rays can be measurably higher on the top floor of a high rise than on the ground floor. Measurements in a 12 story building in Manhattan indicated a cosmic ray dose on the ground floor one third that on the 12th floor, due principally to the shielding effect provided by many stories of concrete from the building in question as well as adjacent structures. In addition, a person's annual dose from radon can vary dramatically, by a factor of 10 or more, depending upon where they are and the adequacy of ventilation.

To further complicate matters, these temporal and spatial variations can be interdependent. For example, determining the average annual dose received from terrestrial gamma radiation cannot be done simply by measuring differences in soil concentration, since it is also affected by weather conditions. Moreover, usage must be considered and can result in what is often referred to as technologically enhanced natural background radiation. Finally, the actual dose to particular humans is heavily dependent upon the specific external and internal pathways of exposure.

Obviously then, there is no single number that represents the annual dose to U.S. citizens from background. But for perspective, it is useful to know that the average annual background dose for the U.S. population is about 300 mrem with about 200 mrem from radon, about 40 mrem from other internal sources, about 25 mrem from cosmic rays and about 25 mrem from terrestrial gamma rays. The average annual dose from fallout is less than 1 mrem.

However, because of the many factors that cause both spatial and temporal variations, the annual U.S. dose from background can easily range from 100 mrem for people who live in well-ventilated wooden houses on sandy soil at sea level to about 1000 mrem for people living in the Denver area, a factor of 10 (Figure 3). At the Shoreham site, annual doses from terrestrial gamma radiation differed with location alone by as much as 25 mrem per year. At the small New Jersey site, the equivalent spot to spot difference was as high as 40 mrem per year. It is in the context of these variations that the selection of 15 mrem over background as the acceptable annual dose for residual radiation from a decommissioned site must be viewed. For additional perspective, consider that we rarely choose our residences or domestic habits based on exposure to background radiation, yet the choice to live in a brick rather than a wood-frame house can increase one's annual dose by 45 or 50 mrem. A gas stove can deliver about 15 mrem per year to the lungs due to naturally occurring radioactive elements in the gas and a single flight across the U.S. yields about 4 mrem. A Denver resident can receive double the cosmic ray dose, triple the terrestrial dose, quadruple the radon dose, and a higher intake of radionuclides in drinking water compared to persons living in a coastal region--and if the house is not well ventilated the total dose could be still higher!

Selection of an Acceptable Level of Risk

To place the risk from exposure to background radiation in context, let's look at some general risks to the population. About 33% of the general population in the United States die of heart disease and about 23% die of cancer. Non-cancerous lung disease (7.7%), strokes (6.7%) and accidents (4.3%) also figure strongly as major causes of death (Figure 4). Comparing these causes of death, all of which carry a risk of greater than 1%, with the elective or accidental risks faced by selected groups or by the general population illustrates the complexity of adding societal choice to risk-based decision-making in terms of selection of an acceptable level of risk (Figure 5). Smoking one pack of cigarettes daily will result in death from a related cause for about 28% of smokers and a motorcyclist has about an 11% lifetime chance of dying in a motorcycle accident. By comparison, the average American's risk of dying in an air accident is several orders of magnitude lower, about 0.02%.

As I said earlier, the annual dose from natural background in the U.S. ranges from 100 to 1,000 mrem with an average of about 300 mrem. When relating these annual doses to risk, the risk assessment models developed by the International Commission of Radiological Protection (or ICRP) are usually applied. The ICRP performs risk assessments for both deterministic and stochastic effects of exposure to radiation based on research reports of radiation effects on tissues and animals, as well as on human epidemiology studies and modeling. For the purposes of radiation protection, the ICRP *assumes* a linear non-threshold dose-effect model and basically extrapolates to estimate the probability of harm resulting from low doses and dose rates where there is little, if any, human health effects data.

Using ICRP's method of risk assessment, the average annual 300 mrem dose from background produces a lifetime risk of fatal cancer of slightly less than 1 in 100, or approximately 0.82%. The corresponding lifetime fatal cancer risk for 100 and 1000 mrem are approximately 0.27% and 2.7%, respectively (Figure 6).

So how would an additional increment of 15 mrem change the public's risk from natural background? Looked at in isolation, 15 mrem per year over a 70-year lifetime would result in a risk of about 0.04% yet another decade lower on this log scale. When added to the risks associated with low, average, and high annual doses from background it is barely distinguishable (Figure 7). Indeed 15 mrem represents 5% of the average annual dose and is lost within the range of background which spans a factor of 10.

It is perhaps useful to note that for members of the public, the NCRP recommends an annual limit of 100 mrem for continuous exposure and an annual limit of 500 mrem for infrequent exposures due to all anthropogenic sources and recommends that ALARA be practiced below that. They further recommend that where there are multiple sources, no single source or set of sources under one control should result in an individual being exposed to more than 25 mrem annually.

What does one conclude from all of this? The limit of 15 mrem, including 4 mrem from drinking water which in itself is material for a lengthy lecture which I won't attempt to address here, carries a risk that is a small increment over the risk from background itself. Given that the risk is small and masked by the variation in the risk over the range of background doses, one must ask what all this should imply for the third or final component of risk-based decision-making, risk management.

Risk Management

The major questions for risk management are: (1) What is it that will be measured or used to represent "background" at a particular decommissioning site? (2) What will be measured to determine compliance with the 15 mrem limit? and (3) What margins of error or what uncertainties will be considered acceptable in determining compliance?

The difficulties involved in answering these questions become apparent when a site's decommissioning efforts are broken down into a series of steps and the complications that can exist with each step are examined. The overall process consists of, first, an analysis of the activities that have been performed at the site to be decommissioned; second, an assessment or survey to establish what represents background and a survey of the site to determine the degree of cleanup required; third, cleanup; fourth, a resurvey of the site; and, finally, release of the decontaminated site.

Each of these activities can be further broken down into sub-steps. For example, the person performing an analysis of the activity at the site must ask a series of questions: (1) Did the licensed activities involve single or multiple radionuclides? (2) With respect to each radionuclide, does it also exist in background or is it only produced as a result of licensed activities at the site? (3) For each radionuclide, are there single or multiple pathways that may result in exposure to humans?

Surveying also has multiple sub-steps. Survey methods and the required number of surveys of each type must be determined to establish the background level or levels. The corresponding number of site surveys that will be necessary to establish the level of residual radioactivity on site with reasonable confidence must be determined and the background surveys and initial site surveys must then be performed.

The site is now ready for cleanup. Based on the analysis and survey results, the appropriate methods must be chosen and cleanup performed with periodic re-surveying to determine the level of progress until the release criteria are met and the site is ready for release.

Let's consider a few examples of how this process actually works. First, consider a simple example in which the residual radioactivity involves a single, non-naturally occurring nuclide. For simplicity's sake, postulate that the radionuclide has only one pathway of exposure. This will result in a single set of surveys, presumably a single method of decontamination, and a straightforward path toward releasing the site.

For a second example, let's consider a slightly more complicated scenario, involving multiple naturally occurring nuclides, at least one of which is known to result in human exposure via several pathways. This analysis is still relatively simple, but the surveys will be somewhat more complex. In this situation background will have to be established in a manner that accounts for variability, and that will differentiate quantitatively between background radiation and that produced by site activities. The clean-up may also be somewhat more complex due to the multiple nuclides and pathways of exposure.

The third scenario, unfortunately, may be the most realistic picture for most licensees, including reactor facilities. In this case, the analysis may involve a whole spectrum of radionuclides, some, but not all, of which occur in background. It may also involve a variety of interrelated pathways of human exposure. As a result, establishing background becomes much more complicated, even for a site with a detailed pre-operational survey. Multiple elements of spatial and temporal variation will complicate this scenario further, requiring a higher number of surveys and sometimes multiple methods to achieve the necessary degree of confidence. The decontamination of such a site, of course, will be correspondingly more difficult, involving multiple clean-up methods and, quite possibly, repeated attempts, with re-surveys performed as necessary until the criterion of 15 mrem above background has been met and the site is ready for unrestricted release.

How does this affect cost, certainly an element in risk-based decision-making? Survey costs alone, not even considering cleanup costs, will vary based on the complexity of the situation considering the number of surveys taken and the quality of those surveys in terms of the degree of confidence required, or level of uncertainty considered acceptable.

Consider the cost per sample of various radiation measurements likely to be used in any major decommissioning effort (Figure 8).[1] Assessing the potential radiation dose to humans for a multi-nuclide site could require a complete pathway analysis, including measurements of external gamma dose; air, soil and vegetation samples; and samples of surface water, drinking water, and precipitation. Obviously, to attempt to sample and measure every cubic meter of the relevant environment would be both impractical and prohibitively expensive. Instead, a sampling strategy must be developed combining radiation survey readings over large areas with selective sampling and analysis at representative locations, using the results of past measurement programs as appropriate.

Even with an efficient sampling strategy, however, the cost of performing surveys just to establish background can escalate sharply depending on the degree of uncertainty that is acceptable, which will directly influence both the survey methods employed and the number of surveys taken. In general, measuring smaller doses means increasing costs as more sophisticated techniques are employed.

Similarly the costs of site surveys and decontamination increase based on the background criteria employed and the level of sensitivity and confidence desired. For some radionuclides, the detection limits of standard laboratory instruments can be reached, causing the survey costs to rise dramatically as sophisticated research techniques become necessary. For naturally occurring radionuclides or those present in residual levels from weapons fallout, it may be virtually impossible to distinguish the contribution of site activities given the spatial and temporal variations in background discussed earlier.

Just as an example, consider the cost of measuring cesium-137 in soil (Figure 9).[2] At dose increments of about 30 mrem per year or higher, the cost is about $50 per sample. The cost roughly quadruples when trying to measure at levels of 10 mrem per year or less--based on the need for more sensitive laboratory methods--and increases dramatically again, to about $500 per sample, when measuring at a level of 0.3 mrem per year, which requires sophisticated research techniques. Because cesium-137 is present in residual radioactivity from weapons fallout, the typical levels and degree of variability make the cost of measuring this radionuclide at dose increments of 0.1 mrem per year more or less indeterminate.

What all this reveals is that every assessment of dose due to either natural or anthropogenic radiation will entail some degree of uncertainty. Whether that uncertainty stems from spatial or temporal variations, the limitations of the measurement technique, or the ability of the analyst to interpret data, it is still uncertainty, and it can never be entirely eliminated. Now let's review how the compliance process might work. First, background (χ_o) must be

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[1]NUREG-1496, Vol 2, "Generic Environmental Impact Statement in Support of Rulemaking on radiological Arteria for Decommissioning of NRC-Licensed Nuclear Facilities," Appendices, p. A-44, August, 1994.

[2]NUREG-1496, Vol 2, "Generic Environmental Impact Statement in Support of Rulemaking on radiological Arteria for Decommissioning of NRC-Licensed Nuclear Facilities," Appendices, p. A-53, August, 1994.

determined. But, unless it is zero, this is clearly not well-defined and carries an uncertainty (σ_o). To determine if cleanup is sufficient, the site must be surveyed to determine what remains (x_1) which may or may not include natural background as discussed earlier. This, too, of course, carries an uncertainty (σ_1). Compliance requires that what remains after cleanup not contribute more than 15 mrem above background.

In addition, the proposed rule requires that further reductions be made As Low As Reasonably Achievable. Defining ALARA, in this framework, might be much more problematic than when working with higher, more readily measurable doses. Can ALARA be assigned a cost-per-dose-increment value, as is done for occupational exposures? Is it simply a matter of vague principle? And how will it take into consideration other risks, such as those associated with the decommissioning activities themselves? These are the questions of the risk management phase of risk-based decision-making.

Now let us return to the framework of risk-based decision-making which is premised on balancing risk, cost, and benefit. To implement the 15 mrem criterion, as well as ALARA, in this context, one needs to ask at least two fundamental questions:

1) How should both background and residual radioactivity be defined or measured in practical terms, and what degree of uncertainty will be considered acceptable? Recall from the examples of our earlier discussion that if one takes into account spatial or temporal variations of background, not to mention measurement uncertainties, the sigma may easily be of the same order as, or even multiples of, the 15 mrem criterion.

2) The second question follows naturally from the first: given that the risk associated with a 15 mrem residual dose adds very little to the risk of exposure to background and indeed is buried in the noise of the natural variations of that background, then how much money and effort should be spent not only to clean up to this level, but to assure compliance?

Conclusion

These are among the questions that we, as regulators, licensees, and members of the public must consider as we proceed toward final decommissioning rulemaking. And remember, I've only touched the surface. For example, we haven't even discussed the proposed 4 mrem criterion for the water pathway and the associated risk management scheme necessary to assure compliance. These are challenges of risk-based decision-making as we all go in search of background.

In this endeavor, I would urge that we be ever mindful of our goal as captured in the NRC's mission, that is, "to help assure that the use of nuclear materials is carried out in such a way that public health and safety, the common defense and security and environment are protected," and that we be mindful of the principles of good regulation, namely, independence, openness, efficiency, clarity, and reliability. This is our challenge as we strive to protect the citizens of our nation and fulfill our responsibilities as stewards of our planet. I, for one, welcome the challenge, daunting as it may seem, and I look forward to the contributions and participation of all parties as we proceed toward what I hope will be rational and responsible final rulemaking.

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RELATIVE TERRESTRIAL GAMMA RADIATION LEVELS (MAY 1974)

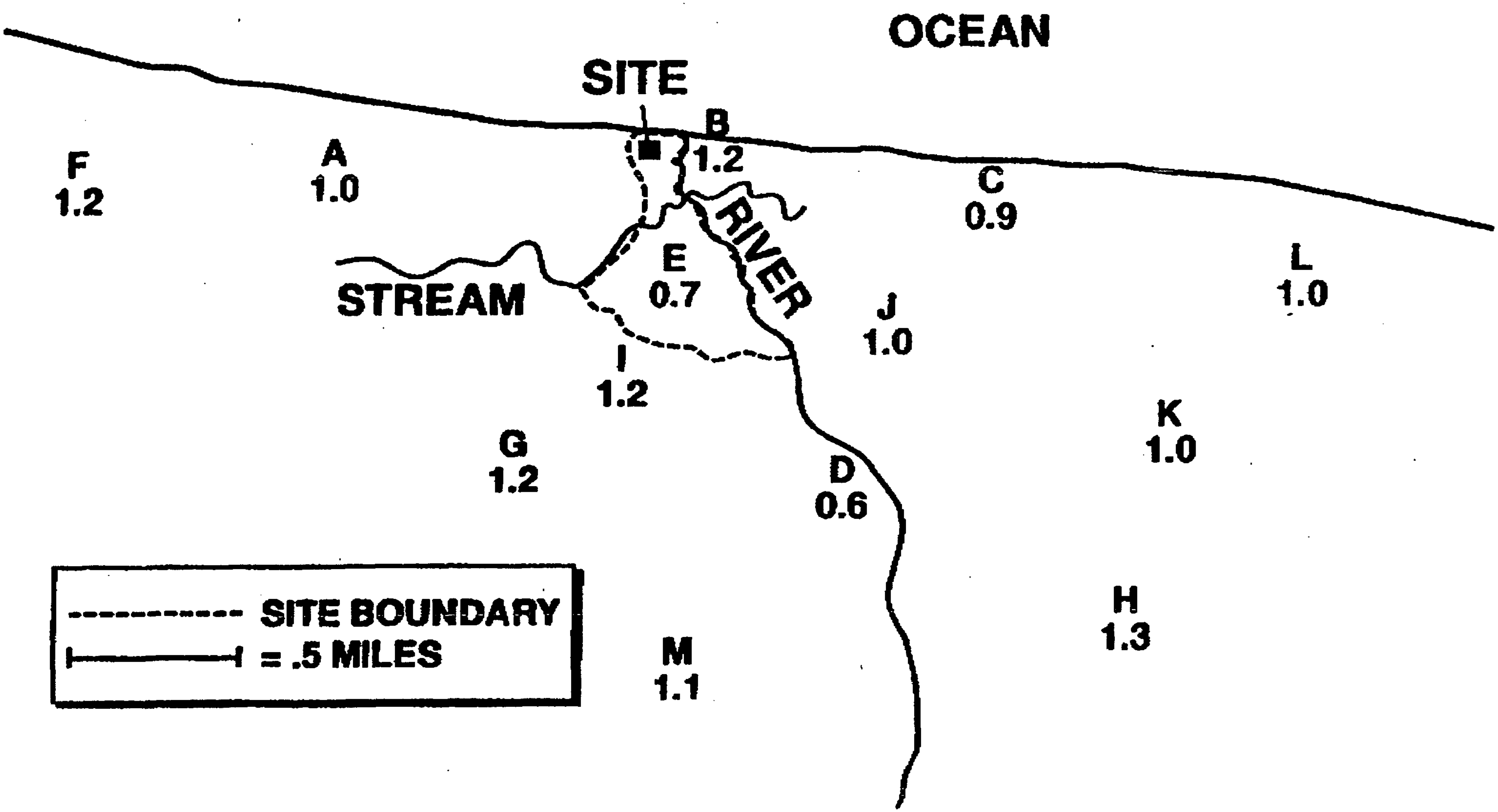


FIGURE 1

RELATIVE TERRESTRIAL GAMMA RADIATION LEVELS (SEPTEMBER 1974)

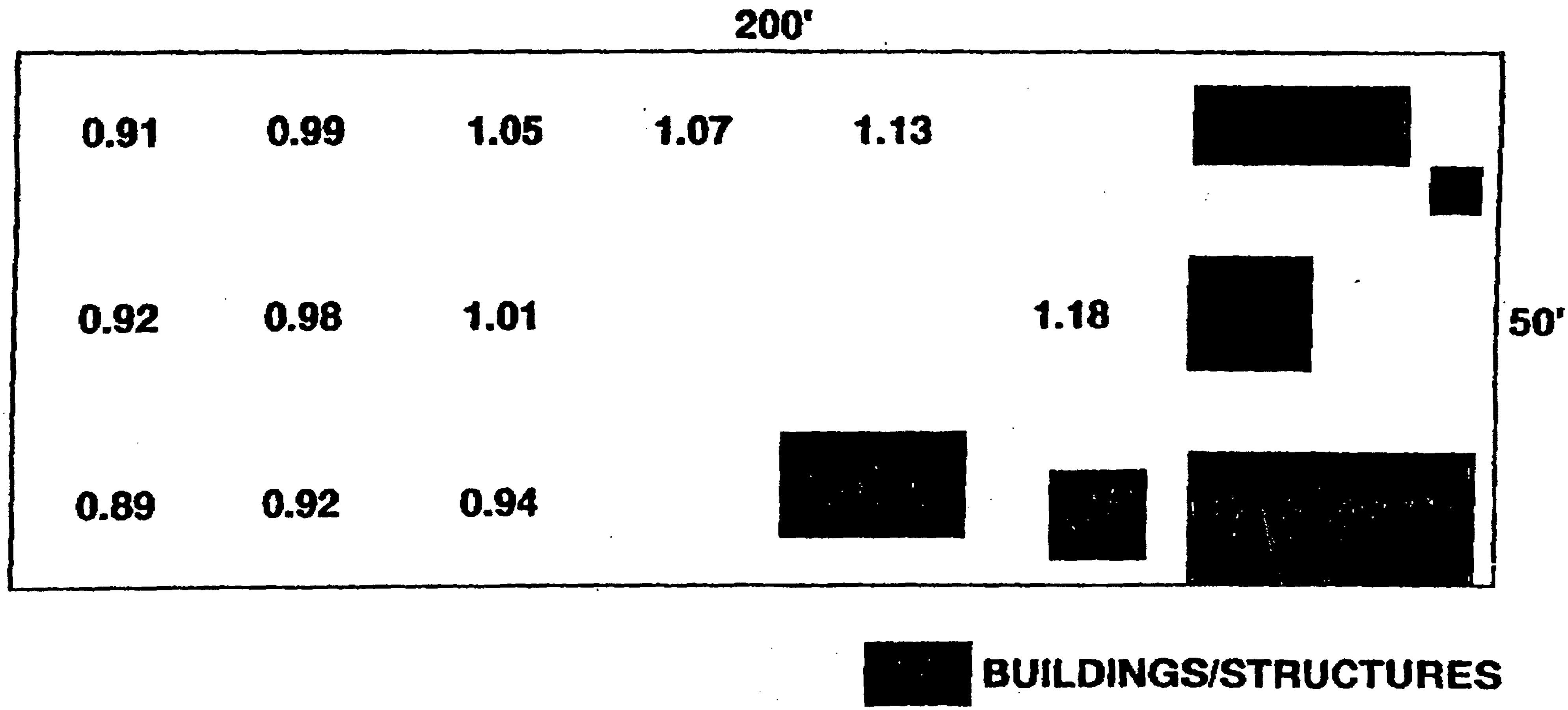


FIGURE 2

RANGE OF ANNUAL RADIATION DOSE: NATURAL SOURCES (MREM)

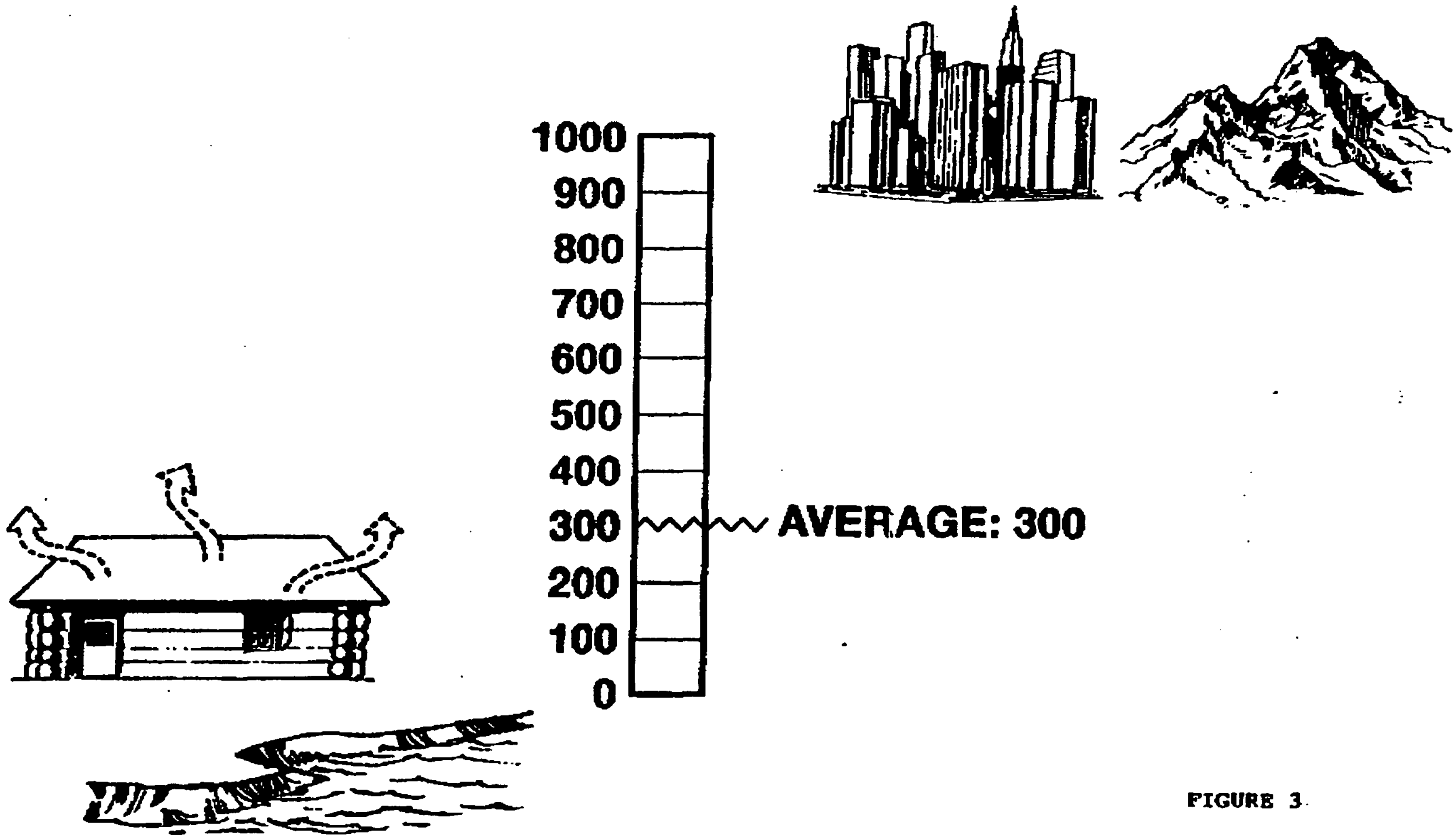


FIGURE 3

LIFETIME MORTALITY RISKS
(PERCENT OF GENERAL POPULATION)

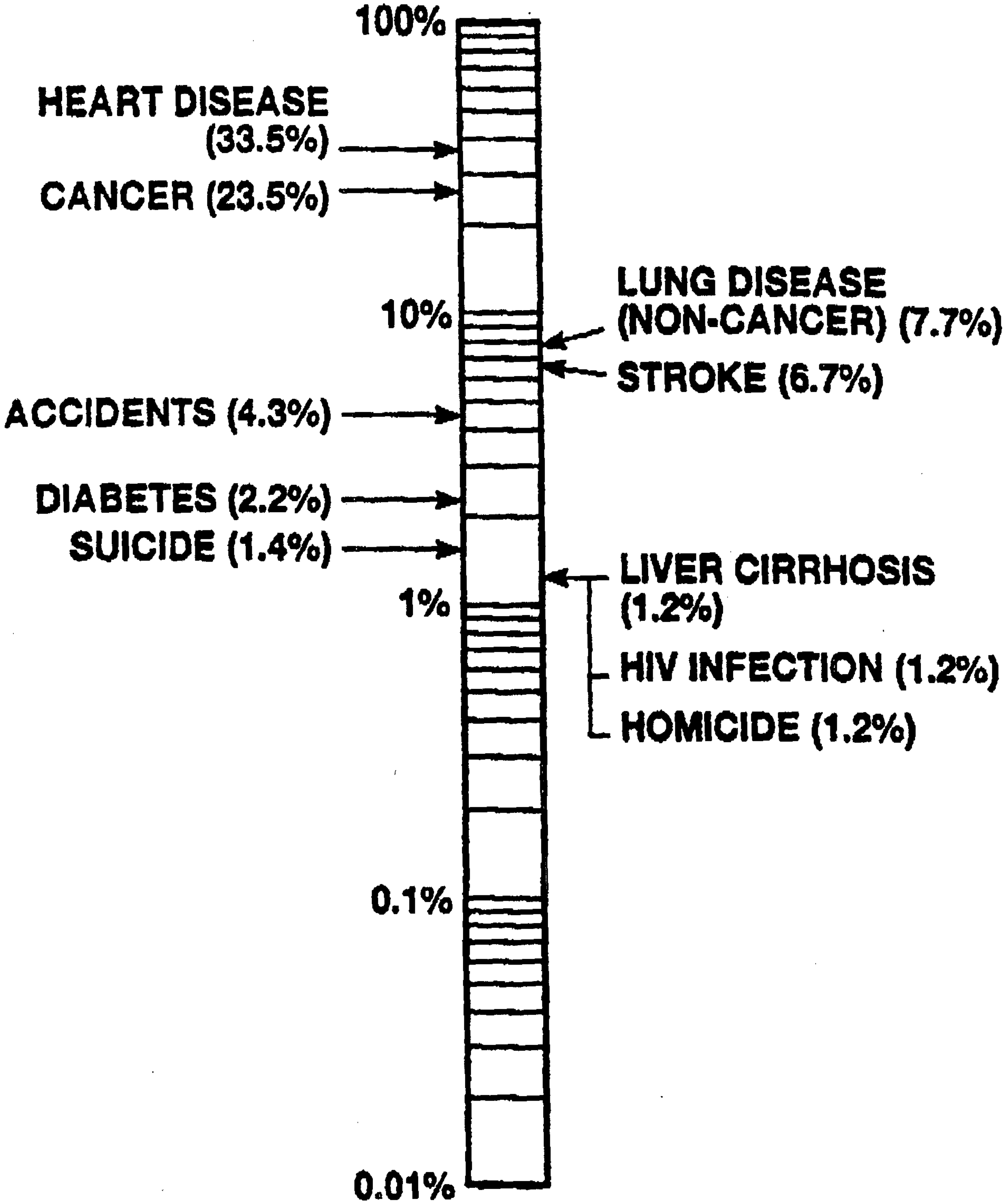
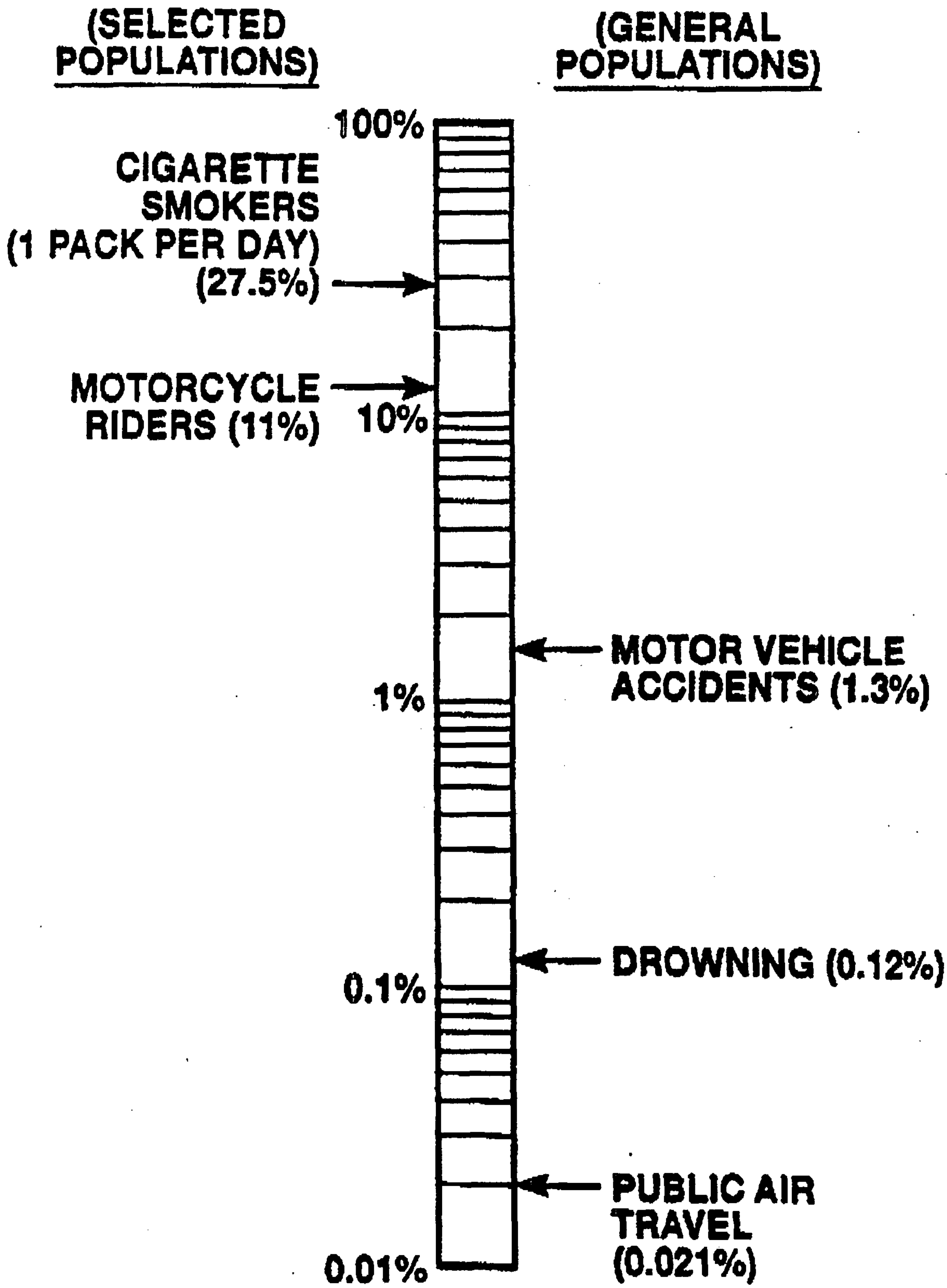
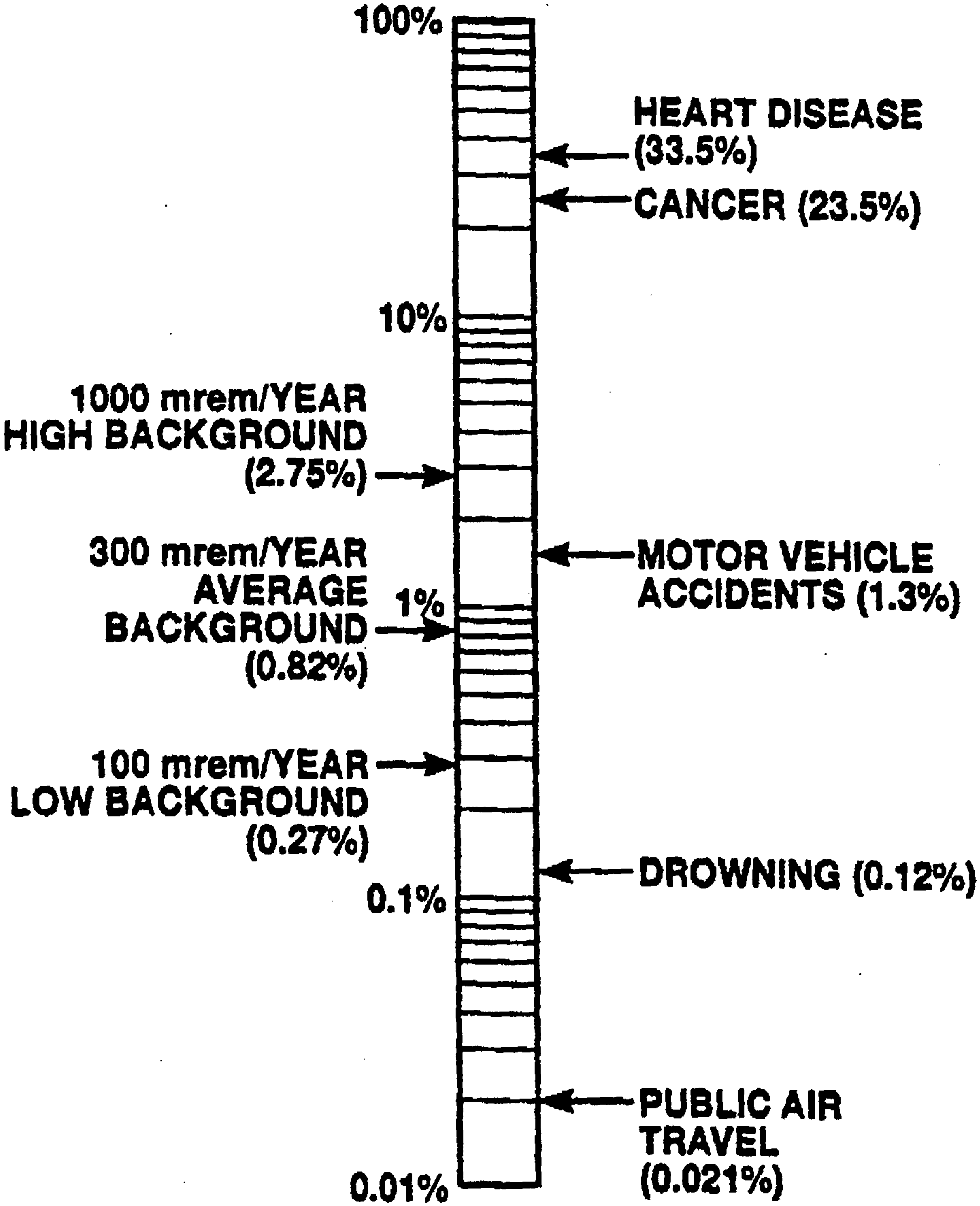


FIGURE 4

LIFETIME MORTALITY RISKS
(PERCENT)



LIFETIME MORTALITY RISKS
(PERCENT)



LIFETIME MORTALITY RISKS
(PERCENT)

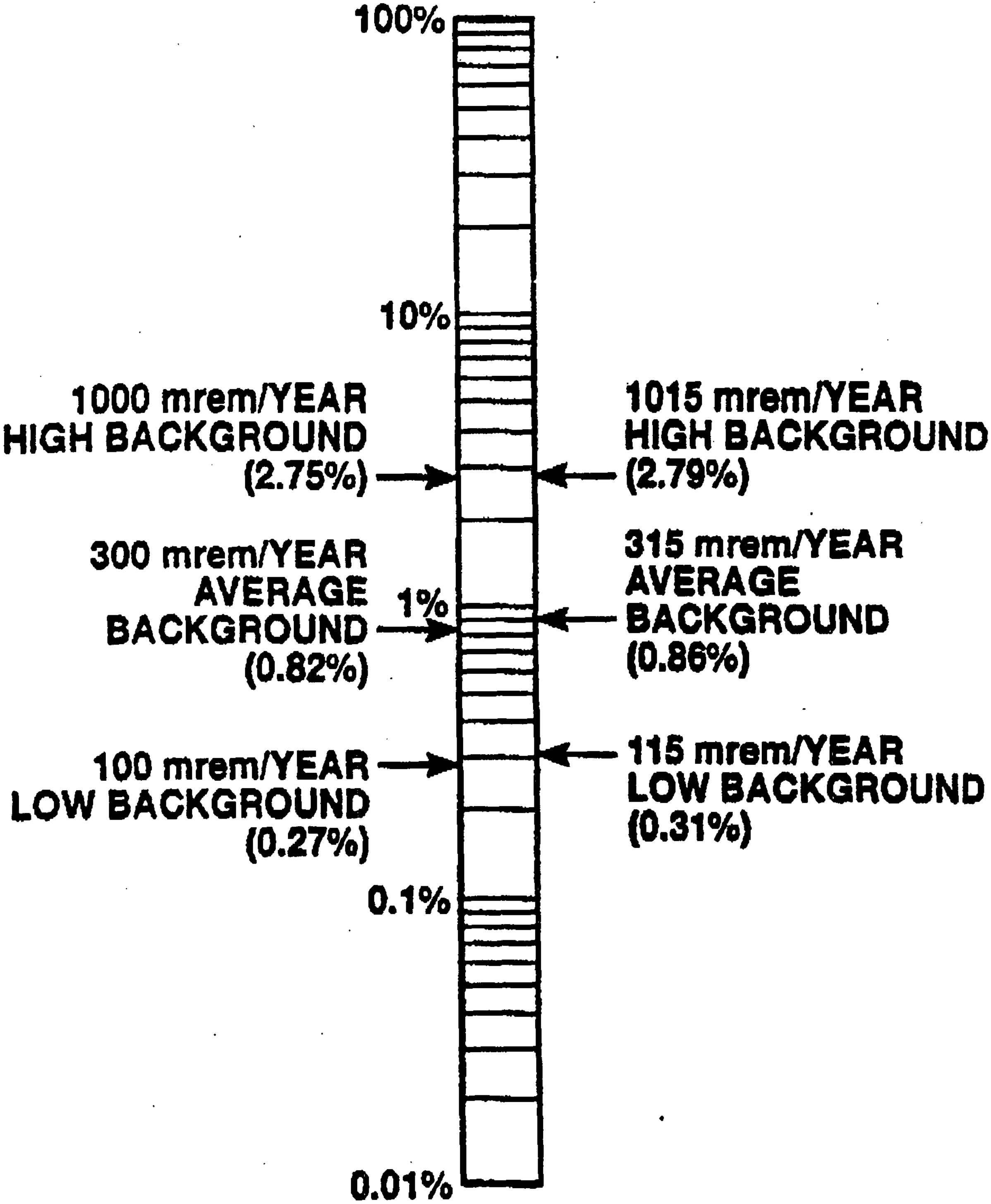


FIGURE 7

ESTIMATED COSTS OF RADIATION MEASUREMENTS

METHOD	COST PER SAMPLE
ALPHA SPECTROMETRY	$300-1000
BETA ANALYSIS	$50-750
EXTERNAL GAMMA EXPOSURE SURVEY	$50
EXTERNAL GAMMA TLD MEASUREMENT	$20
GAMMA SPECTROMETRY	$100-300
RADON MEASUREMENT	$10-20
SOIL SAMPLE COLLECTION	$100-200
SOIL SAMPLE PROCESSING	$100-400
THERMAL IONIZATION MASS SPECTROMETRY	$1000

FIGURE 8

ESTIMATED COST PER MEASUREMENT OF CESIUM-137 IN SOIL

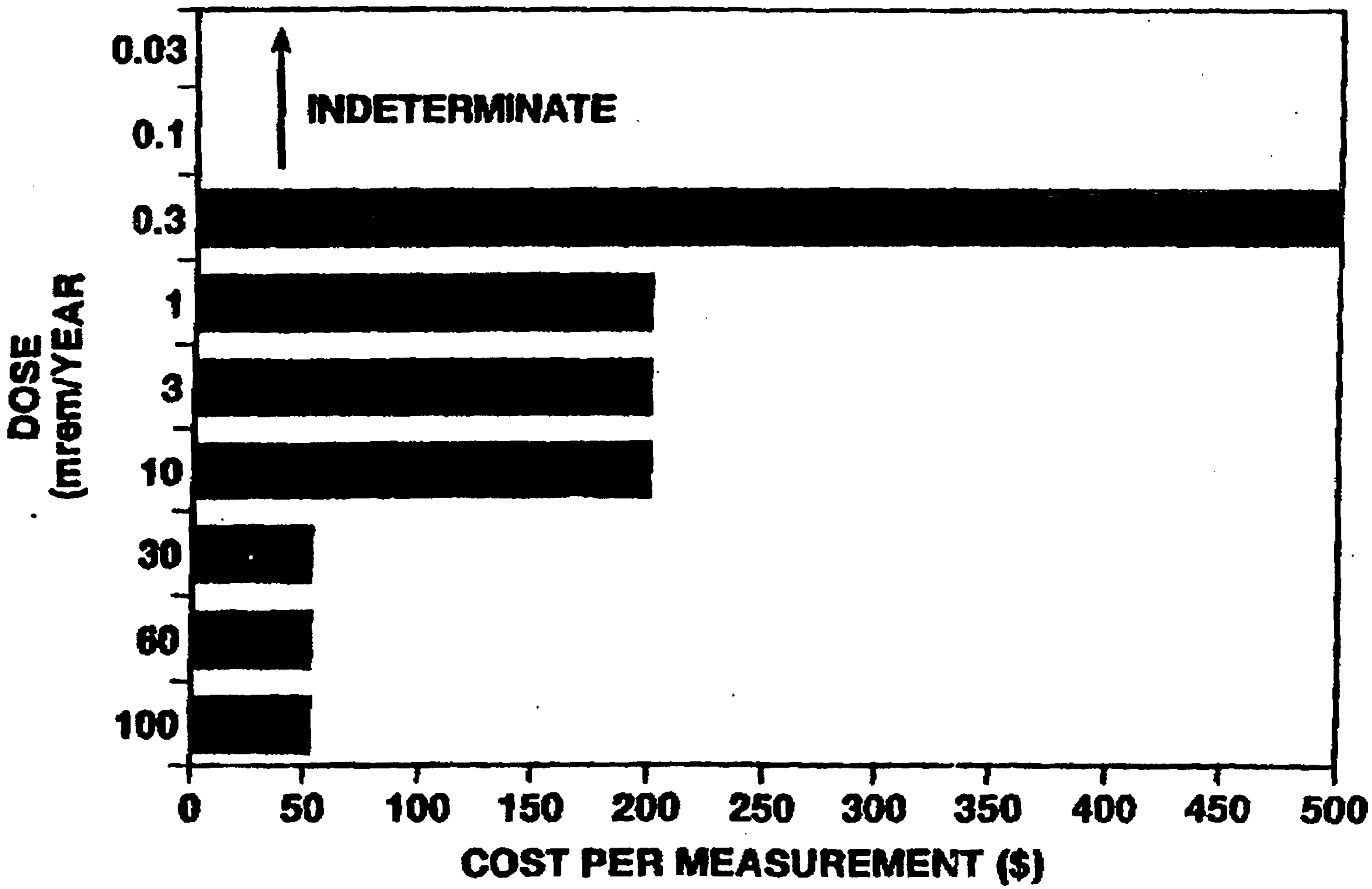


FIGURE 9

KENNECOTT URANIUM COMPANY
LOST CREEK TRENCH SAMPLING
Sections 2-7

Source: **Geology of the Lost Creek Schroeckingerite Deposits Sweetwater County, Wyoming**
Geological Survey Bulletin 1087-J

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
DS-52-237	1.9		0.004	0.004	13.5	13.5	0.004	27.1
DS-52-238	4.9		0.005	0.005	16.9	16.9	0.004	27.1
DS-52-239	4.8		0.007	0.007	23.6	23.6	0.012	81.2
DS-52-242	1.2		0.008	0.008	27.0	27.0	0.015	101.6
DS-52-248	0.6		0.021	0.021	70.9	70.9	0.048	325.0
DS-52-249	4.4		0.027	0.027	91.1	91.1	0.06	406.2
DS-52-250	3		0.014	0.014	47.3	47.3	0.024	162.5
DS-52-251	0.8		0.008	0.008	27.0	27.0	0.012	81.2
DS-52-256	1.3		0.008	0.008	27.0	27.0	0.012	81.2
DS-52-257	5.7		0.012	0.012	40.5	40.5	0.018	121.9
DS-52-258	2.6		0.01	0.010	33.8	33.8	0.019	128.6
DS-52-259	2		0.014	0.014	47.3	47.3	0.015	101.6
DS-52-262	0.7		0.021	0.021	70.9	70.9	0.035	237.0
DS-52-263	2.9		0.025	0.025	84.4	84.4	0.049	331.7
DS-52-264	5.5		0.027	0.027	91.1	91.1	0.053	358.8
DS-52-265	3.2		0.015	0.015	50.6	50.6	0.029	196.3
DS-52-265A	4.1		0.029	0.029	97.9	97.9	0.06	406.2
DS-52-266	6.9		0.017	0.017	57.4	57.4	0.034	230.2
DS-52-267	0.4		0.007	0.007	23.6	23.6	0.015	101.6
DS-52-275	6.4		0.039	0.039	131.6	131.6	0.08	541.6
DS-52-207	1.2		0.013	0.013	43.9	43.9	0.021	142.2
DS-52-213	0.8		0.047	0.047	158.7	158.7	0.087	589.0
DS-52-214	3		0.014	0.014	47.3	47.3	0.022	148.9
DS-52-216	1.3		0.012	0.012	40.5	40.5	0.022	148.9
DS-52-218	5.6		0.016	0.016	54.0	54.0	0.035	237.0
DS-52-220	4.9		0.019	0.019	64.1	64.1	0.038	257.3
DS-52-222	3.3		0.012	0.012	40.5	40.5	0.024	162.5
DS-52-227	0.7		0.029	0.029	97.9	97.9	0.065	440.1
DS-52-228	1.3		0.037	0.037	124.9	124.9	0.072	487.4
DS-52-230	1.5		0.016	0.016	54.0	54.0	0.03	203.1
DS-51-199	1.2		0.008	0.008	27.0	27.0	0.013	88.0
DS-52-200	0.3		0.007	0.007	23.6	23.6	0.008	54.2
DS-52-204	1.2		0.012	0.012	40.5	40.5	0.022	148.9
DS-52-224	4		0.016	0.016	54.0	54.0	0.031	209.9
DS-52-233	1.2		0.01	0.010	33.8	33.8	0.012	81.2
DS-52-236	4		0.01	0.010	33.8	33.8	0.016	108.3
DS-52-184	3.5		0.023	0.023	77.6	77.6	0.041	277.6
DS-52-186	1.5		0.011	0.011	37.1	37.1	0.015	101.6
DS-52-190	2		0.02	0.020	67.5	67.5	0.043	291.1
DS-52-193	1		0.011	0.011	37.1	37.1	0.013	88.0
DS-52-194	0.2		0.03	0.030	101.3	101.3	0.062	419.7
DS-52-197	0.5		0.024	0.024	81.0	81.0	0.051	345.3
DS-52-149	4.3		0.015	0.015	50.6	50.6	0.015	101.6
DS-52-150	6.8		0.023	0.023	77.6	77.6	0.037	250.5
DS-52-152	0.3		0.009	0.009	30.4	30.4	0.01	67.7
DS-52-153	7.3		0.013	0.013	43.9	43.9	0.019	128.6
DS-52-155	1.4		0.004	0.004	13.5	13.5	0.004	27.1
DS-52-158	4.1		0.011	0.011	37.1	37.1	0.016	108.3
DS-52-141	20		0.011	0.011	37.1	37.1	0.013	88.0
DS-52-143	1.6		0.01	0.010	33.8	33.8	0.007	47.4
DS-52-145	1.7		0.005	0.005	16.9	16.9	0.003	20.3
DS-52-146	0.2		0.008	0.008	27.0	27.0	0.007	47.4
DS-52-99	2.8		0.034	0.034	114.8	114.8	0.055	372.4
DS-52-100	1.2		0.028	0.028	94.5	94.5	0.05	338.5
DS-52-101	4.5		0.03	0.030	101.3	101.3	0.053	358.8
DS-52-102	0.6		0.018	0.018	60.8	60.8	0.022	148.9
DS-52-103	3.7		0.026	0.026	87.8	87.8	0.036	243.7
DS-52-104	0.2		0.044	0.044	148.5	148.5	0.072	487.4
DS-52-107	7.6		0.037	0.037	124.9	124.9	0.066	446.8
DS-52-109	1		3.024	3.002	10207.9	10207.9	0.037	250.5
DS-52-110	0.6		0.035	0.035	118.1	118.1	0.055	372.4
DS-52-113	2		0.042	0.042	141.8	141.8	0.051	345.3
DS-52-24	0.5		0.024	0.024	81.0	81.0	0.035	237.0

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY	RADIUM-226 ACTIVITY	PERCENT URANIUM	NATURAL URANIUM ACTIVITY
					(picoCuries per gram)	(picoCuries per gram)		(picoCuries per gram)
DS-52-25	1.4		0.032	0.032	108.0	108.0	0.048	325.0
DS-52-27	9.8		0.019	0.019	64.1	64.1	0.026	176.0
DS-52-28	2.8		0.06	0.060	202.5	202.5	0.11	744.7
DS-52-31	4.8		0.025	0.025	84.4	84.4	0.041	277.6
DS-52-32	2		0.05	0.050	168.8	168.8	0.079	534.8
DS-52-33	1.5		0.044	0.044	148.5	148.5	0.071	480.7
DS-52-34	8.7		0.026	0.026	87.8	87.8	0.041	277.6
DS-52-35	4.1		0.014	0.014	47.3	47.3	0.015	101.6
DS-52-45	2		0.024	0.024	81.0	81.0	0.05	338.5
DS-52-46	26.8		0.049	0.049	165.4	165.4	0.097	656.7
DS-52-47	11.8		0.041	0.041	138.4	138.4	0.075	507.8
DS-52-59	5.9		0.028	0.028	94.5	94.5	0.038	257.3
DS-52-60	12.8		0.018	0.018	60.8	60.8	0.023	155.7
DS-52-61	10.7		0.02	0.020	67.5	67.5	0.029	196.3
DS-52-62	12.2		0.034	0.034	114.8	114.8	0.055	372.4
DS-52-63	16		0.06	0.060	202.5	202.5	0.12	812.4
DS-52-64	4		0.013	0.013	43.9	43.9	0.015	101.6
DS-52-65	9.3		0.058	0.058	195.8	195.8	0.11	744.7
DS-52-66	8.8		0.049	0.049	165.4	165.4	0.078	528.1
DS-52-67	0.7		0.016	0.016	54.0	54.0	0.026	176.0
DS-52-79	0.5		0.024	0.024	81.0	81.0	0.031	209.9
DS-52-80	65		0.017	0.017	57.4	57.4	0.021	142.2
DS-52-81	7.5		0.016	0.016	54.0	54.0	0.023	155.7
DS-52-82	7.4		0.032	0.032	108.0	108.0	0.057	385.9
DS-52-53	5.4		0.02	0.020	67.5	67.5	0.031	209.9
DS-52-84	1.3		0.031	0.031	104.6	104.6	0.047	318.2
DS-52-58	4.4		0.021	0.021	70.9	70.9	0.027	182.8
DS-52-86	8.2		0.028	0.028	94.5	94.5	0.037	250.5
DS-52-87	3.1		0.031	0.031	104.6	104.6	0.043	291.1
DS-52-88	1.6		0.049	0.049	165.4	165.4	0.07	473.9
DS-52-2	1.5		0.035	0.035	118.1	118.1	0.079	534.8
DS-52-4	0.3		0.018	0.018	60.8	60.8	0.033	223.4
DS-52-5	0.2		0.011	0.011	37.1	37.1	0.018	121.9
DS-52-22	1.1		0.033	0.033	111.4	111.4	0.045	304.7
DS-52-7	2.2		0.017	0.017	57.4	57.4	0.03	203.1
DS-52-8	3		0.019	0.019	64.1	64.1	0.031	209.9
DS-52-10	6		0.025	0.025	84.4	84.4	0.041	277.6
DS-52-12	0.3		0.022	0.022	74.3	74.3	0.026	176.0
DS-52-13	9.5		0.037	0.037	124.9	124.9	0.063	426.5
DS-52-14	2.4		0.022	0.022	74.3	74.3	0.035	237.0
DS-52-15	2		0.022	0.022	74.3	74.3	0.032	216.6
DS-52-20	0.5		0.096	0.095	324.1	324.1	0.15	1015.5
LRP-28	6.7		0.011	0.011	37.1	37.1	0.017	115.1
LRP-31	5.8		0.008	0.008	27.0	27.0	0.008	54.2
LRP-10	4.5		0.01	0.010	33.8	33.8	0.017	115.1
LRP-7	0.6		0.004	0.004	13.5	13.5	0.002	13.5
LRP-12	2.1		0.017	0.017	57.4	57.4	0.029	196.3
LRP-H-14		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-13	2.5		0.013	0.013	43.9	43.9	0.019	128.6
LRP-14	3		0.012	0.012	40.5	40.5	0.014	94.8
LRP-15	6.4		0.017	0.017	57.4	57.4	0.026	176.0
LRP-16	2.3		0.015	0.015	50.6	50.6	0.019	128.6
LRP-18	1.6		0.01	0.010	33.8	33.8	0.014	94.8
LRP-19	0.7		0.007	0.007	23.6	23.6	0.005	33.9
LRP-20	0.8		0.02	0.020	67.5	67.5	0.029	196.3
LRP-24	1.7		0.019	0.019	64.1	64.1	0.037	250.5
DS-H-407		10	0.007	0.007	23.6	23.6	0.006	40.6
DS-H-406		10	0.006	0.006	20.3	20.3	0.007	47.4
DS-H-405		10	0.002	0.002	6.8	6.8	0.001	6.8
DS-H-404		10	0.005	0.005	16.9	16.9	0.003	20.3
DS-H-260		10	0.005	0.005	16.9	16.9	0.004	27.1
DS-H-259		10	0.004	0.004	13.5	13.5	0.004	27.1
DS-H-258		10	0.005	0.005	16.9	16.9	0.002	13.5
DS-H-257		10	0.004	0.004	13.5	13.5	0.003	20.3
DS-H-256		10	0.005	0.005	16.9	16.9	0.003	20.3
DS-H-255		10	0.003	0.003	10.1	10.1	0.002	13.5
DS-H-254		10	0.005	0.005	16.9	16.9	0.003	20.3
DS-51-261	7.4		0.017	0.017	57.4	57.4	0.035	237.0
DS-51-259	2.4		0.01	0.010	33.8	33.8	0.013	88.0
DS-H-251		10	0.003	0.003	10.1	10.1	0.002	13.5

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY	RADIUM-226 ACTIVITY	PERCENT URANIUM	NATURAL URANIUM ACTIVITY
					(picoCuries per gram)	(picoCuries per gram)		(picoCuries per gram)
DS-H-250		10	0.004	0.004	13.5	13.5	0.002	13.5
DS-H-249		10	0.003	0.003	10.1	10.1	0.003	20.3
DS-H-248		10	0.005	0.005	16.9	16.9	0.003	20.3
DS-H-247		10	0.004	0.004	13.5	13.5	0.001	6.8
DS-H-246		10	0.005	0.005	16.9	16.9	0.003	20.3
DS-H-245		10	0.004	0.004	13.5	13.5	0.004	27.1
DS-H-244		10	0.004	0.004	13.5	13.5	0.002	13.5
DS-H-243		10	0.004	0.004	13.5	13.5	0.002	13.5
DS-H-242		10	0.005	0.005	16.9	16.9	0.005	33.9
DS-51244B	0.4		0.004	0.004	13.5	13.5	0.004	27.1
DS-H-241		10	0.004	0.004	13.5	13.5	0.003	20.3
DS-H-240		10	0.004	0.004	13.5	13.5	0.002	13.5
DS-52-161	6.2		0.014	0.014	47.3	47.3	0.02	135.4
DS-52-160	10.3		0.016	0.016	54.0	54.0	0.035	237.0
DS-52-159	4.7		0.019	0.019	64.1	64.1	0.033	223.4
DS-51-266	2		0.006	0.006	20.3	20.3	0.009	60.9
DS-51-264	3.6		0.028	0.028	94.5	94.5	0.05	338.5
DS-51-263	3.1		0.007	0.007	23.6	23.6	0.008	54.2
DS-51-262	1.1		0.008	0.008	27.0	27.0	0.01	67.7
DS-H-253		10	0.003	0.003	10.1	10.1	0.002	13.5
DS-H-252		10	0.003	0.003	10.1	10.1	0.002	13.5
DS-51-258	5.8	Sample missing		0.000	0.0	0.0		0.0
DS-51-252	2.5		0.003	0.003	10.1	10.1	0.003	20.3
DS-51-251	8.8		0.004	0.004	13.5	13.5	0.003	20.3
DS-51-250	8.7		0.004	0.004	13.5	13.5	0.003	20.3
DS-51-246	9		0.007	0.007	23.6	23.6	0.008	54.2
DS-51-245	10		0.017	0.017	57.4	57.4	0.025	169.3
	6.1	Not Sampled		0.000	0.0	0.0		0.0
DS-51-244A	0.6		0.045	0.045	151.9	151.9	0.075	507.8
DS-51-243	1.6		0.005	0.005	16.9	16.9	0.004	27.1
DS-52-164	4.8		0.009	0.009	30.4	30.4	0.013	88.0
DS-52-163	5.1		0.016	0.016	54.0	54.0	0.024	162.5
DS-52-162	7.5		0.018	0.018	60.8	60.8	0.039	264.0
	0.4	Not Sampled		0.000	0.0	0.0		0.0
DS-51-265	6.9		0.021	0.021	70.9	70.9	0.038	257.3
DS-51-260	3.2		0.004	0.004	13.5	13.5	0.006	40.6
DS-51-256	8.4		0.008	0.008	27.0	27.0	0.01	67.7
DS-51-255	2.2		0.004	0.004	13.5	13.5	0.004	27.1
DS-51-254	4.6		0.005	0.005	16.9	16.9	0.008	54.2
DS-51-253	4.4		0.006	0.006	20.3	20.3	0.009	60.9
DS-51-249	8.2		0.008	0.008	27.0	27.0	0.009	60.9
DS-51-248	17.5		0.006	0.006	20.3	20.3	0.008	54.2
DS-51-247	15.5		0.01	0.010	33.8	33.8	0.015	101.6
DS-51-257	4.6		0.008	0.008	27.0	27.0	0.008	54.2
DS-H-431		10	0.003	0.003	10.1	10.1	<.001	
DS-H-428		7	0.009	0.009	30.4	30.4	0.024	162.5
DS-H-427		5	0.006	0.006	20.3	20.3	0.009	60.9
DS-H-426		10	0.003	0.003	10.1	10.1	0.002	13.5
DS-52-172	0.4		0.008	0.008	27.0	27.0	0.011	74.5
DS-H-411		10	0.005	0.005	16.9	16.9	0.002	13.5
DS-52-165	4.9		0.023	0.023	77.6	77.6	0.044	297.9
DS-H-409		10	0.003	0.003	10.1	10.1	0.001	6.8
DS-H-408		10	0.003	0.003	10.1	10.1	<.001	
DS-H-407	continued in E'-F'			0.000	0.0	0.0		0.0
DS-H-430		10	0.003	0.003	10.1	10.1	<.001	
DS-H-429		8	0.004	0.004	13.5	13.5	<.001	
DS-52-179	2.9		0.012	0.012	40.5	40.5	0.027	182.8
DS-52-178	5.6		0.015	0.015	50.6	50.6	0.037	250.5
DS-52-176	2.3		0.012	0.012	40.5	40.5	0.026	176.0
DS-52-175	0.5		0.009	0.009	30.4	30.4	0.021	142.2
DS-H-425		10	0.003	0.003	10.1	10.1	0.001	6.8
DS-H-424		10	0.002	0.002	6.8	6.8	0.001	6.8
DS-H-422		10	0.002	0.002	6.8	6.8	<.001	
DS-H-421		5	0.004	0.004	13.5	13.5	0.004	27.1
DS-H-420		5	0.004	0.004	13.5	13.5	0.005	33.9
DS-H-419		10	0.004	0.004	13.5	13.5	0.004	27.1
DS-H-418		10	0.003	0.003	10.1	10.1	0.001	6.8
DS-H-417		10	0.002	0.002	6.8	6.8	0.001	6.8
DS-H-416		10	0.005	0.005	16.9	16.9	0.004	27.1
DS-H-415		10	0.004	0.004	13.5	13.5	0.003	20.3

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY	RADIUM-226 ACTIVITY	PERCENT URANIUM	NATURAL URANIUM ACTIVITY
					(picoCuries per gram)	(picoCuries per gram)		(picoCuries per gram)
DS-H-414		10	0.002	0.002	6.8	6.8	0.001	6.8
DS-H-413		10	0.004	0.004	13.5	13.5	0.001	6.8
DS-H-412		10	0.004	0.004	13.5	13.5	0.002	13.5
DS-52-167	7.6		0.012	0.012	40.5	40.5	0.021	142.2
DS-52-166	6		0.009	0.009	30.4	30.4	0.014	94.8
DS-H-410		10	0.003	0.003	10.1	10.1	0.001	6.8
DS-52-182	3.3		0.014	0.014	47.3	47.3	0.031	209.9
DS-52-181	3.7		0.014	0.014	47.3	47.3	0.03	203.1
DS-52-180	7.4		0.015	0.015	50.6	50.6	0.041	277.6
DS-52-177	2.9		0.015	0.015	50.6	50.6	0.033	223.4
DS-52-174	0.8		0.008	0.008	27.0	27.0	0.017	115.1
DS-52-173	0.9		0.006	0.006	20.3	20.3	0.007	47.4
DS-52-171	5.4		0.022	0.022	74.3	74.3	0.046	311.4
DS-52-170	4		0.01	0.010	33.8	33.8	0.018	121.9
DS-52-169	6		0.011	0.011	37.1	37.1	0.015	101.6
DS-52-168	6.4		0.016	0.016	54.0	54.0	0.022	148.9
	0.7	Not Sampled		0.000	0.0	0.0		0.0
LRP-74	2		0.01	0.010	33.8	33.8	0.017	115.1
LRP-73	8.5		0.006	0.006	20.3	20.3	0.009	60.9
LRP-72	1.8		0.014	0.014	47.3	47.3	0.022	148.9
	0.08	Not Sampled		0.000	0.0	0.0		0.0
LRP-64	6		0.017	0.017	57.4	57.4	0.026	176.0
LRP-63	7.8		0.013	0.013	43.9	43.9	0.014	94.8
LRP-H-106		13.5	0.009	0.009	30.4	30.4	0.011	74.5
LRP-H-105		9	0.002	0.002	6.8	6.8	0	0.0
LRP-39	1		0.014	0.014	47.3	47.3	0.02	135.4
LRP-68	3.4		0.012	0.012	40.5	40.5	0.02	135.4
LRP-78	1.5		0.018	0.018	60.8	60.8	0.028	189.6
LRP-H-67		5	0.005	0.005	16.9	16.9	0.007	47.4
LRP-H-108		14	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-66		13	0.007	0.007	23.6	23.6	0.008	54.2
LRP-70	3		0.017	0.017	57.4	57.4	0.018	121.9
LRP-H-65		4	0.005	0.005	16.9	16.9	0.005	33.9
LRP-69	2.7		0.012	0.012	40.5	40.5	0.015	101.6
LRP-H-64		8	0.003	0.003	10.1	10.1	0.002	13.5
LRP-H-63		10	0.004	0.004	13.5	13.5	0.005	33.9
LRP-67	0.4		0.039	0.039	131.6	131.6	0.061	413.0
LRP-H-62		10	0.004	0.004	13.5	13.5	0.004	27.1
LRP-65	2		0.03	0.030	101.3	101.3	0.064	433.3
LRP-H-61		6	0.005	0.005	16.9	16.9	0.006	40.6
LRP-60		10	0.005	0.005	16.9	16.9	0.003	20.3
LRP-59		10	0.003	0.003	10.1	10.1	0.003	20.3
LRP-H-107		10	0.005	0.005	16.9	16.9	0.004	27.1
LRP-H-58		9	0.005	0.005	16.9	16.9	0.004	27.1
LRP-H-57		10	0.004	0.004	13.5	13.5	0.004	27.1
LRP-H-56		10	0.004	0.004	13.5	13.5	0.006	40.6
LRP-62	2.2		0.022	0.022	74.3	74.3	0.036	243.7
LRP-60	2		0.025	0.025	84.4	84.4	0.043	291.1
LRP-H-55		4	0.005	0.005	16.9	16.9	0.008	54.2
LRP-58	4.4		0.008	0.008	27.0	27.0	0.009	60.9
LRP-57	11.5		0.012	0.012	40.5	40.5	0.018	121.9
LRP-H-54		10	0.004	0.004	13.5	13.5	0.002	13.5
LRP-55	3.7		0.008	0.008	27.0	27.0	0.007	47.4
LRP-53		7	0.005	0.005	16.9	16.9	0.012	81.2
LRP-49	4.7		0.007	0.007	23.6	23.6	0.008	54.2
LRP-48	10.1		0.014	0.014	47.3	47.3	0.017	115.1
LRP-47	14.6		0.01	0.010	33.8	33.8	0.015	101.6
LRP-H-52		10	0.005	0.005	16.9	16.9	0.001	6.8
LRP-H-51		10	0.003	0.003	10.1	10.1	0.001	6.8
LRP-H-50		6	0.004	0.004	13.5	13.5	0.002	13.5
LRP-46	2.9		0.01	0.010	33.8	33.8	0.013	88.0
LRP-45	8.4		0.016	0.016	54.0	54.0	0.019	128.6
LRP-H-49		4	0.003	0.003	10.1	10.1	0.001	6.8
LRP-H-48		10	0.003	0.003	10.1	10.1	0.002	13.5
LRP-41	3.9		0.016	0.016	54.0	54.0	0.02	135.4
LRP-40	6.3		0.012	0.012	40.5	40.5	0.017	115.1
H-47		13	0.003	0.003	10.1	10.1	0.001	6.8
LRP-H-46		10	0.003	0.003	10.1	10.1	0.002	13.5
LRP-H-45		11.5	0.004	0.004	13.5	13.5	0.004	27.1
LRP-37	2.1		0.018	0.018	60.8	60.8	0.027	182.8

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
LRP-36	10.6		0.015	0.015	50.6	50.6	0.024	162.5
LRP-H-44		10	0.004	0.004	13.5	13.5	0.004	27.1
LRP-H-43		10	0.004	0.004	13.5	13.5	0.003	20.3
LRP-H-42		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-41		10	0.004	0.004	13.5	13.5	0.004	27.1
LRP-H-40		10	0.005	0.005	16.9	16.9	0.004	27.1
LRP-32	7.3		0.008	0.008	27.0	27.0	0.011	74.5
LRP-H-39		10	0.004	0.004	13.5	13.5	0.004	27.1
LRP-H-38		10	0.004	0.004	13.5	13.5	0.003	20.3
LRP-77	4.2		0.012	0.012	40.5	40.5	0.019	128.6
LRP-76	2.6		0.007	0.007	23.6	23.6	0.011	74.5
LRP-75	4.8		0.015	0.015	50.6	50.6	0.03	203.1
LRP-71	7.2		0.021	0.021	70.9	70.9	0.034	230.2
LRP-66	3.8		0.033	0.033	111.4	111.4	0.06	406.2
LRP-61	3.3		0.026	0.026	87.8	87.8	0.041	277.6
LRP-59	0.5		0.017	0.017	57.4	57.4	0.023	155.7
LRP-56	2.9		0.018	0.018	60.8	60.8	0.028	189.6
LRP-53	3.6		0.007	0.007	23.6	23.6	0.007	47.4
LRP-52	9.7		0.012	0.012	40.5	40.5	0.016	108.3
LRP-51	13.7		0.012	0.012	40.5	40.5	0.017	115.1
LRP-50	9		0.013	0.013	43.9	43.9	0.012	81.2
LRP-44	7.2		0.017	0.017	57.4	57.4	0.027	182.8
LRP-43	9.2		0.013	0.013	43.9	43.9	0.021	142.2
LRP-42	6.1		0.01	0.010	33.8	33.8	0.012	81.2
LRP-38	9.4		0.014	0.014	47.3	47.3	0.021	142.2
LRP-35	9.4		0.025	0.025	84.4	84.4	0.051	345.3
LRP-34	4		0.012	0.012	40.5	40.5	0.019	128.6
LRP-33	5.5		0.009	0.009	30.4	30.4	0.012	81.2
LRP-168	2.6		0.007	0.007	23.6	23.6	0.008	54.2
LRP-H-104		5.5	0.004	0.004	13.5	13.5	0.002	13.5
LRP-162	1.2		0.037	0.037	124.9	124.9	0.078	528.1
LRP-161	2.8		0.014	0.014	47.3	47.3	0.022	148.9
	0.6	Not Sampled		0.000	0.0	0.0		0.0
LRP-H-127		6	0.003	0.003	10.1	10.1	0	0.0
LRP-H-126		10	0.003	0.003	10.1	10.1	0	0.0
LRP-H-125		10.5	0.003	0.003	10.1	10.1	0	0.0
LRP-H-124		10	0.007	0.007	23.6	23.6	0.009	60.9
LRP-H-123		10	0.006	0.006	20.3	20.3	0.004	27.1
LRP-H-122		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-121		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-120		10	0.004	0.004	13.5	13.5	0	0.0
LRP-H-119		10	0.004	0.004	13.5	13.5	0	0.0
LRP-H-118		10	0.004	0.004	13.5	13.5	0	0.0
LRP-H-117		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-116		10	0.008	0.008	27.0	27.0	0.008	54.2
LRP-112	9.2		0.022	0.022	74.3	74.3	0.04	270.8
LRP-111	9.6		0.021	0.021	70.9	70.9	0.039	264.0
LRP-H-114		7	0.004	0.004	13.5	13.5	0	0.0
LRP-H-113		5	0.005	0.005	16.9	16.9	0.003	20.3
LRP-H-112		10	0.005	0.005	16.9	16.9	0.004	27.1
LRP-H-111		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-110		10	0.005	0.005	16.9	16.9	0.007	47.4
LRP-85	4.6		0.016	0.016	54.0	54.0	0.027	182.8
LRP-81	2.8		0.021	0.021	70.9	70.9	0.038	257.3
LRP-79	1.7		0.045	0.045	151.9	151.9	0.085	575.5
LRP-H-103		20	0.005	0.005	16.9	16.9	0.003	20.3
LRP-H-102		10	0.003	0.003	10.1	10.1	0.002	13.5
LRP-167	0.4		0.006	0.006	20.3	20.3	0.006	40.6
LRP-H-101		10	0.003	0.003	10.1	10.1	0.001	6.8
LRP-H-100		10	0.003	0.003	10.1	10.1	0.001	6.8
LRP-H-99		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-98		10.5	0.004	0.004	13.5	13.5	0.001	6.8
LRP-H-97		11.5	0.006	0.006	20.3	20.3	0.002	13.5
LRP-H-96		10	0.006	0.006	20.3	20.3	0.003	20.3
LRP-H-95		10	0.005	0.005	16.9	16.9	0.003	20.3
LRP-H-94		10	0.009	0.009	30.4	30.4	0.011	74.5
LP-H-128		7	0.006	0.006	20.3	20.3	0.008	54.2
LRP-H-93		7	0.005	0.005	16.9	16.9	0.002	13.5
LRP-H-92		10	0.004	0.004	13.5	13.5	0.002	13.5
LRP-H-91		10	0.003	0.003	10.1	10.1	0.001	6.8

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
LRP-H-90		10	0.003	0.003	10.1	10.1	<.001	
LRP-H-89		9.5	0.004	0.004	13.5	13.5	0.002	13.5
LRP-H-88		10	0.004	0.004	13.5	13.5	0.001	6.8
LRP-156	1.6		0.014	0.014	47.3	47.3	0.024	162.5
LRP-155	12.3		0.008	0.008	27.0	27.0	0.012	81.2
LRP-154	12.6		0.009	0.009	30.4	30.4	0.012	81.2
LRP-H-87		12.5	0.003	0.003	10.1	10.1	0.001	6.8
LRP-H-86		10	0.004	0.004	13.5	13.5	<.001	
LRP-149	9.4		0.013	0.013	43.9	43.9	0.026	176.0
LRP-148	7.8		0.01	0.010	33.8	33.8	0.019	128.6
LRP-147	9.5		0.009	0.009	30.4	30.4	0.011	74.5
LRP-146	11.2		0.007	0.007	23.6	23.6	0.009	60.9
LRP-145	12.3		0.007	0.007	23.6	23.6	0.008	54.2
LRP-144	4.2		0.007	0.007	23.6	23.6	0.006	40.6
LRP-143	7.5		0.012	0.012	40.5	40.5	0.021	142.2
LRP-142	3.6	Sample Missing		0.000	0.0	0.0		0.0
LRP-135	3.4		0.011	0.011	37.1	37.1	0.02	135.4
LRP-134	7.3		0.015	0.015	50.6	50.6	0.025	169.3
LRP-133	8.9		0.017	0.017	57.4	57.4	0.031	209.9
LRP-132	6		0.011	0.011	37.1	37.1	0.022	148.9
LRP-H-85		4	0.001	0.001	3.4	3.4	0.001	6.8
LRP-126	8		0.011	0.011	37.1	37.1	0.019	128.6
LRP-125	6.4		0.013	0.013	43.9	43.9	0.022	148.9
LRP-124	8.7		0.007	0.007	23.6	23.6	0.01	67.7
LRP-H-84		2	0.004	0.004	13.5	13.5	0.003	20.3
LRP-H-83		10	0.003	0.003	10.1	10.1	0.001	6.8
LRP-123	1.4		0.013	0.013	43.9	43.9	0.024	162.5
LRP-H-82		4	0.004	0.004	13.5	13.5	0.001	6.8
LRP-122	1		0.012	0.012	40.5	40.5	0.009	60.9
LRP-121	3.2		0.027	0.027	91.1	91.1	0.045	304.7
LRP-H-81		1.5	0.004	0.004	13.5	13.5	0.001	6.8
LRP-113	7.1		0.025	0.025	84.4	84.4	0.04	270.8
LRP-H-80		11	0.005	0.005	16.9	16.9	0.007	47.4
LRP-H-79		10	0.004	0.004	13.5	13.5	0.002	13.5
LRP-H-78		10	0.003	0.003	10.1	10.1	0.001	6.8
LRP-106	1.3		0.018	0.018	60.8	60.8	0.031	209.9
LRP-105	11.7		0.019	0.019	64.1	64.1	0.028	189.6
LRP-H-77		6	0.004	0.004	13.5	13.5	<.001	
LRP-H-76		10	0.006	0.006	20.3	20.3	0.006	40.6
LRP-101	4.6		0.01	0.010	33.8	33.8	0.016	108.3
LRP-100	8		0.009	0.009	30.4	30.4	0.011	74.5
LRP-H-75	2.2	Sample Missing		0.000	0.0	0.0		0.0
LRP-94	3.7		0.009	0.009	30.4	30.4	0.011	74.5
LRP-93	6.8		0.012	0.012	40.5	40.5	0.014	94.8
LRP-92	4.8		0.009	0.009	30.4	30.4	0.009	60.9
LRP-H-74		2	0.004	0.004	13.5	13.5	0.004	27.1
LRP-88	1.8		0.012	0.012	40.5	40.5	0.018	121.9
LRP-87	7.4		0.035	0.035	118.1	118.1	0.067	453.6
LRP-H-73		5	0.007	0.007	23.6	23.6	0.006	40.6
LRP-H-72		10	0.006	0.006	20.3	20.3	0.008	54.2
LRP-86	4.1		0.018	0.018	60.8	60.8	0.025	169.3
LRP-H-109		11	0.006	0.006	20.3	20.3	0.005	33.9
LRP-H-71		11	0.008	0.008	27.0	27.0	0.007	47.4
LRP-H-70		10	0.006	0.006	20.3	20.3	0.008	54.2
LRP-H-69		10	0.005	0.005	16.9	16.9	0.002	13.5
LRP-H-68		10	0.005	0.005	16.9	16.9	0.005	33.9
LRP-169	3.3		0.007	0.007	23.6	23.6	0.008	54.2
LRP-165	5.3		0.006	0.006	20.3	20.3	0.008	54.2
LRP-164	9.9		0.006	0.006	20.3	20.3	0.008	54.2
LRP-163	2.6		0.009	0.009	30.4	30.4	0.011	74.5
LRP-160	1.2		0.005	0.005	16.9	16.9	0.002	13.5
LRP-159	10.1		0.017	0.017	57.4	57.4	0.024	162.5
LRP-158	11.7		0.008	0.008	27.0	27.0	0.01	67.7
LRP-157	9.7		0.008	0.008	27.0	27.0	0.009	60.9
LRP-153	6		0.016	0.016	54.0	54.0	0.028	189.6
LRP-152	7.7		0.012	0.012	40.5	40.5	0.02	135.4
LRP-151	4.7		0.009	0.009	30.4	30.4	0.013	88.0
LRP-150	7.4		0.01	0.010	33.8	33.8	0.011	74.5
LRP-141	5.8		0.009	0.009	30.4	30.4	0.015	101.6
LRP-140	10.3		0.01	0.010	33.8	33.8	0.013	88.0

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
LRP-139	7.6		0.007	0.007	23.6	23.6	0.011	74.5
LRP-138	8.4		0.009	0.009	30.4	30.4	0.013	88.0
LRP-137	7.4		0.012	0.012	40.5	40.5	0.021	142.2
LRP-136	5.8		0.009	0.009	30.4	30.4	0.02	135.4
LRP-131	7.4		0.01	0.010	33.8	33.8	0.017	115.1
LRP-130	6.8		0.009	0.009	30.4	30.4	0.016	108.3
LRP-129	10.2		0.011	0.011	37.1	37.1	0.017	115.1
LRP-128	7.7		0.008	0.008	27.0	27.0	0.011	74.5
LRP-127	7.6		0.005	0.005	16.9	16.9	0.006	40.6
LRP-120	2.5		0.027	0.027	91.1	91.1	0.047	318.2
LRP-119	4.6		0.013	0.013	43.9	43.9	0.019	128.6
LRP-118	6.5		0.018	0.018	60.8	60.8	0.012	81.2
LRP-117	4		0.011	0.011	37.1	37.1	0.023	155.7
LRP-116	2.7		0.031	0.031	104.6	104.6	0.053	358.8
LRP-115	13.4		0.02	0.020	67.5	67.5	0.035	237.0
LRP-114	8.5		0.015	0.015	50.6	50.6	0.025	169.3
LRP-110	2.4		0.003	0.003	10.1	10.1	0.005	33.9
LRP-109	3.7		0.006	0.006	20.3	20.3	0.008	54.2
	2	Not Sampled		0.000	0.0	0.0		0.0
LRP-108	10.9		0.01	0.010	33.8	33.8	0.012	81.2
LRP-107	6		0.017	0.017	57.4	57.4	0.023	155.7
LRP-103	1.4		0.005	0.005	16.9	16.9	0.004	27.1
LRP-102	3.9		0.006	0.006	20.3	20.3	0.008	54.2
LRP-99	2		0.007	0.007	23.6	23.6	0.008	54.2
LRP-98	2.4		0.008	0.008	27.0	27.0	0.012	81.2
LRP-97	8.6		0.007	0.007	23.6	23.6	0.009	60.9
LRP-96	7.4		0.009	0.009	30.4	30.4	0.014	94.8
LRP-95	8.1		0.011	0.011	37.1	37.1	0.014	94.8
LRP-91	5.2		0.009	0.009	30.4	30.4	0.009	60.9
LRP-90	5		0.023	0.023	77.6	77.6	0.037	250.5
LRP-89	0.7		0.017	0.017	57.4	57.4	0.027	182.8
LRP-84	4.4		0.021	0.021	70.9	70.9	0.031	209.9
LRP-83	10		0.017	0.017	57.4	57.4	0.025	169.3
LRP-82	6.5		0.023	0.023	77.6	77.6	0.037	250.5
LRP-80	6.3		0.006	0.006	20.3	20.3	0.008	54.2
Mean:			0.020	0.019	65.094	65.094	0.020	132.923
Median:			0.009	0.009	30.381	30.381	0.013	88.010
Standard Deviation:			0.144	0.142	481.791	481.791	0.021	144.308
Maximum:			3.024	3.002	10207.881	10207.881	0.150	1015.500
Minimum:			0.001	0.000	0.000	0.000	0.000	0.000
	Values computed by Kennecott Uranium Company from data in paper							
OAP:02/17/08								

KENNECOTT URANIUM COMPANY								
LOST CREEK TRENCH SAMPLING								
		Sections 8-13						
Source:	**Geology of the Lost Creek Schroeckingerite Deposits Sweetwater County, Wyoming**							
	Geological Survey Bulletin 1087-J							
SAMPLE #	**SAMPLE AREA**	**SAMPLE LENGTH**	**PERCENT EQUIVALENT URANIUM**	**PERCENT EQUIVALENT URANIUM-238**	**EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)**	**RADIUM-226 ACTIVITY (picoCuries per gram)**	**PERCENT URANIUM**	**NATURAL URANIUM ACTIVITY (picoCuries per gram)**
DS-52-294	3.9		0.008	0.008	27.0	27.0	0.008	54.2
DS-52-295	2.9		0.008	0.008	27.0	27.0	0.007	47.4
DS-52-297	1.7		0.005	0.005	16.9	16.9	0.002	13.5
DS-52-284	5		0.016	0.016	54.0	54.0	0.028	189.6
DS-52-285	5.6		0.014	0.014	47.3	47.3	0.024	162.5
DS-52-286	3.5		0.017	0.017	57.4	57.4	0.033	223.4
DS-52-287	0.06		0.006	0.006	20.3	20.3	0.006	40.6
DS-52-371	5		0.014	0.014	47.3	47.3	0.024	162.5
DS-52-372	3.5		0.014	0.014	47.3	47.3	0.018	121.9
DS-52-373	3.6		0.008	0.008	27.0	27.0	0.008	54.2
DS-52-374	3.4		0.009	0.009	30.4	30.4	0.011	74.5
DS-52-375	5.3		0.008	0.008	27.0	27.0	0.015	101.6
DS-52-376	4.5		0.009	0.009	30.4	30.4	0.009	60.9
DS-52-377	5.7		0.008	0.008	27.0	27.0	0.01	67.7
DS-52-378	4.2		0.013	0.013	43.9	43.9	0.02	135.4
DS-52-379	3.7		0.011	0.011	37.1	37.1	0.019	128.6
DS-52-380	4.7		0.011	0.011	37.1	37.1	0.015	101.6
DS-52-382	3.5		0.031	0.031	104.6	104.6	0.065	440.1
DS-52-390	5.8		0.015	0.015	50.6	50.6	0.026	176.0
DS-52-391	5		0.007	0.007	23.6	23.6	0.01	67.7
DS-52-392	6.5		0.005	0.005	16.9	16.9	0.007	47.4
DS-52-393	5.7		0.008	0.008	27.0	27.0	0.012	81.2
DS-52-394	3.9		0.005	0.005	16.9	16.9	0.005	33.9
DS-52-395	3		0.007	0.007	23.6	23.6	0.007	47.4
DS-52-397	5.6		0.004	0.004	13.5	13.5	0.003	20.3
DS-52-399	3.4		0.006	0.006	20.3	20.3	0.004	27.1
DS-52-299	5.6		0.004	0.004	13.5	13.5	0.003	20.3
DS-52-300	5.6		0.009	0.009	30.4	30.4	0.011	74.5
DS-52-301	6		0.005	0.005	16.9	16.9	0.005	33.9
DS-52-304	3.3		0.006	0.006	20.3	20.3	0.006	40.6
DS-52-305	4.9		0.012	0.012	40.5	40.5	0.015	101.6
DS-52-306	4.4		0.011	0.011	37.1	37.1	0.011	74.5
DS-52-307	3.6		0.021	0.021	70.9	70.9	0.032	216.6
DS-52-311	4.4		0.01	0.010	33.8	33.8	0.012	81.2
DS-52-314	2.6		0.006	0.006	20.3	20.3	0.007	47.4
DS-52-315	1.4		0.009	0.009	30.4	30.4	0.007	47.4
DS-52-317	3.2		0.012	0.012	40.5	40.5	0.014	94.8
DS-52-318	4.3		0.012	0.012	40.5	40.5	0.014	94.8
DS-52-320	2.6		0.008	0.008	27.0	27.0	0.008	54.2
DS-52-321	3.8		0.01	0.010	33.8	33.8	0.014	94.8
DS-52-322	4.5		0.009	0.009	30.4	30.4	0.013	88.0
DS-52-323	4.6		0.009	0.009	30.4	30.4	0.011	74.5
DS-52-324	5.1		0.007	0.007	23.6	23.6	0.007	47.4
DS-52-325	5		0.005	0.005	16.9	16.9	0.004	27.1
DS-52-332	1.5		0.005	0.005	16.9	16.9	0.005	33.9
DS-52-333	1.8		0.003	0.003	10.1	10.1	0.001	6.8
DS-52-340	0.7		0.007	0.007	23.6	23.6	0.009	60.9
DS-52-341	4.7		0.009	0.009	30.4	30.4	0.011	74.5
DS-52-342	5		0.011	0.011	37.1	37.1	0.014	94.8
DS-52-343	5.6		0.008	0.008	27.0	27.0	0.011	74.5
DS-52-344	5.1		0.007	0.007	23.6	23.6	0.008	54.2
DS-52-345	4.6		0.011	0.011	37.1	37.1	0.018	121.9
DS-52-346	5.5		0.011	0.011	37.1	37.1	0.017	115.1

SAMPLE #	SAMPLE AREA	SAMPLE LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
DS-52-347	5.8		0.015	0.015	50.6	50.6	0.022	148.9
DS-52-348	6.1		0.018	0.018	60.8	60.8	0.03	203.1
DS-52-349	6.8		0.015	0.015	50.6	50.6	0.025	169.3
DS-52-312	4.8		0.009	0.009	30.4	30.4	0.012	81.2
DS-52-313	4		0.009	0.009	30.4	30.4	0.016	108.3
DS-52-316	3.3		0.009	0.009	30.4	30.4	0.01	67.7
DS-52-319	2.6		0.01	0.010	33.8	33.8	0.01	67.7
DS-52-326	4.5		0.028	0.028	94.5	94.5	0.019	128.6
DS-52-327	0.8		0.004	0.004	13.5	13.5	0.002	13.5
DS-52-328	3.8		0.004	0.004	13.5	13.5	0.005	33.9
DS-52--329	3.3		0.008	0.008	27.0	27.0	0.011	74.5
DS-52-330	3.5		0.005	0.005	16.9	16.9	0.005	33.9
DS-52-331	2.6		0.005	0.005	16.9	16.9	0.006	40.6
DS-52-352	2.7		0.005	0.005	16.9	16.9	0.004	27.1
DS-52-302	6		0.007	0.007	23.6	23.6	0.007	47.4
DS-52-303	4.9		0.005	0.005	16.9	16.9	0.005	33.9
DS-52-308	3.1		0.008	0.008	27.0	27.0	0.007	47.4
DS-52-309	4.7		0.011	0.011	37.1	37.1	0.013	88.0
DS-52-310	3.9		0.019	0.019	64.1	64.1	0.029	196.3
DS-52-334	3.2		0.005	0.005	16.9	16.9	0.02	135.4
DS-52-335	3		0.004	0.004	13.5	13.5	0.001	6.8
DS-52-336	0.9		0.004	0.004	13.5	13.5	0.002	13.5
DS-52-337	6		0.012	0.012	40.5	40.5	0.017	115.1
DS-52-338	6.1		0.012	0.012	40.5	40.5	0.018	121.9
DS-52-339	6.2		0.012	0.012	40.5	40.5	0.018	121.9
DS-52-350	5.3		0.011	0.011	37.1	37.1	0.018	121.9
DS-52-351	4.8		0.01	0.010	33.8	33.8	0.016	108.3
DS-52-353	3.1		0.01	0.010	33.8	33.8	0.012	81.2
DS-52-354	5.2		0.009	0.009	30.4	30.4	0.012	81.2
DS-52-355	5.7		0.014	0.014	47.3	47.3	0.02	135.4
DS-52-356	6.2		0.01	0.010	33.8	33.8	0.013	88.0
DS-52-357	5.7		0.015	0.015	50.6	50.6	0.024	162.5
DS-52-278	1		0.007	0.007	23.6	23.6	0.009	60.9
DS-52-281	3.1		0.021	0.021	70.9	70.9	0.034	230.2
DS-52-282	2.4		0.006	0.006	20.3	20.3	0.007	47.4
DS-52-283	4.7		0.012	0.012	40.5	40.5	0.021	142.2
DS-52-408	4.3		0.017	0.017	57.4	57.4	0.031	209.9
DS-52-409	3.8		0.017	0.017	57.4	57.4	0.033	223.4
DS-52-410	4		0.018	0.018	60.8	60.8	0.035	237.0
DS-52-411	3.2		0.016	0.016	54.0	54.0	0.035	237.0
DS-52-414	0.9		0.009	0.009	30.4	30.4	0.014	94.8
DS-52-415	2.7		0.008	0.008	27.0	27.0	0.014	94.8
DS-52-418	1.6		0.011	0.011	37.1	37.1	0.023	155.7
DFS-52-403	1.3		0.028	0.028	94.5	94.5	0.051	345.3
Mean:			0.010	0.010	34.661	34.661	0.015	99.107
Median:			0.009	0.009	30.381	30.381	0.012	81.240
Standard Deviation:			0.005	0.005	17.905	17.905	0.011	72.634
Maximum:			0.031	0.031	104.644	104.644	0.065	440.050
Minimum:			0.003	0.003	10.127	10.127	0.001	6.770
(shaded)	Values computed by Kennecott Uranium Company from data in paper							
OAP:02/17/08								

KENNECOTT URANIUM COMPANY								
LOST CREEK TRENCH SAMPLING								
	Section 1							
Source:	**Geology of the Lost Creek Schroeckingerite Deposits Sweetwater County, Wyoming**							
	Geological Survey Bulletin 1087-J							
SAMPLE #	**AREA**	**LENGTH**	**PERCENT EQUIVALENT URANIUM**	**PERCENT EQUIVALENT URANIUM-238**	**EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)**	**RADIUM-226 ACTIVITY (picoCuries per gram)**	**PERCENT URANIUM**	**NATURAL URANIUM ACTIVITY (picoCuries per gram)**
DS-H-185		1.3	0.005	0.005	16.9	16.9	0.004	27.1
DS-51-179		0.7	0.006	0.006	20.3	20.3	0.002	13.5
DS-H-187		3.8	0.006	0.006	20.3	20.3	0.007	47.4
DS-H-188		1.9	0.005	0.005	16.9	16.9	0.005	33.9
DS-H-189		4.3	0.01	0.010	33.8	33.8	0.011	74.5
DS-H-190		0.7	0.005	0.005	16.9	16.9	0.006	40.6
DS-H-192		2.7	0.013	0.013	43.9	43.9	0.015	101.6
DS-51-191		0.3	0.008	0.008	27.0	27.0	0.009	60.9
DS-51-192		0.4	0.013	0.013	43.9	43.9	0.018	121.9
DS-51-193		0.7	0.013	0.013	43.9	43.9	0.02	135.4
DS-51-194		0.4	0.03	0.030	101.3	101.3	0.052	352.0
DS-H-198		0.6	0.009	0.009	30.4	30.4	0.01	67.7
DS-H-200		0.4	0.008	0.008	27.0	27.0	0.007	47.4
DS-H-205		3.7	0.007	0.007	23.6	23.6	0.008	54.2
DS-H-207		1	0.008	0.008	27.0	27.0	0.01	67.7
DS-H-208		6.1	0.011	0.011	37.1	37.1	0.015	101.6
DS-H-213		2.5	0.016	0.016	54.0	54.0	0.02	135.4
DS-51-178		0.7	0.003	0.003	10.1	10.1	0.001	6.8
DS-51-180		0.09	0.011	0.011	37.1	37.1	0.01	67.7
DS-51-181		1	0.011	0.011	37.1	37.1	0.011	74.5
DS-51-182		1.4	0.007	0.007	23.6	23.6	0.005	33.9
DS-51-183		1.2	0.006	0.006	20.3	20.3	0.004	27.1
DS-51-184		0.9	0.013	0.013	43.9	43.9	0.013	88.0
DS-51-185		1.2	0.008	0.008	27.0	27.0	0.006	40.6
DS-51-186		1.4	0.005	0.005	16.9	16.9	0.003	20.3
DS-51-187		0.7	0.005	0.005	16.9	16.9	0.003	20.3
DS-51-188		1.4	0.01	0.010	33.8	33.8	0.011	74.5
DS-51-189		1.2	0.01	0.010	33.8	33.8	0.012	81.2
DS-51-190		1.1	0.13	0.129	438.8	438.8	0.018	121.9
DS-51-195		0.3	0.011	0.011	37.1	37.1	0.016	108.3
DS-51-196		0.4	0.007	0.007	23.6	23.6	0.006	40.6
DS-51-197		0.7	0.006	0.006	20.3	20.3	0.006	40.6
DS-51-198		0.8	0.018	0.018	60.8	60.8	0.033	223.4
DS-51-199		0.4	0.007	0.007	23.6	23.6	0.008	54.2
DS-51-200		0.6	0.012	0.012	40.5	40.5	0.018	121.9
DS-51-201		1.1	0.018	0.018	60.8	60.8	0.033	223.4
DS-51-202		2.1	0.008	0.008	27.0	27.0	0.011	74.5
DS-51-203		1.3	0.011	0.011	37.1	37.1	0.015	101.6
DS-51-204		0.9	0.01	0.010	33.8	33.8	0.014	94.8
DS-51-205		1.1	0.016	0.016	54.0	54.0	0.032	216.6
DS-51-206		1.4	0.039	0.039	131.6	131.6	0.096	649.9
DS-51-78		0.5	0.005	0.005	16.9	16.9	0.004	27.1
DS-H-98		5.9	0.031	0.031	104.6	104.6	0.051	345.3
DS-51-81		1	0.016	0.016	54.0	54.0	0.022	148.9
DS-51-84		0.6	0.007	0.007	23.6	23.6	0.004	27.1
DS-H-100		0.9	0.017	0.017	57.4	57.4	0.023	155.7
DS-H-101		2.9	0.004	0.004	13.5	13.5	0.004	27.1
DS-H-102		1.4	0.022	0.022	74.3	74.3	0.039	264.0
DS-51-88		0.6	0.012	0.012	40.5	40.5	0.013	88.0
DS-51-90		0.5	0.014	0.014	47.3	47.3	0.021	142.2
DS-H-104		4	0.029	0.029	97.9	97.9	0.044	297.9
DS-51-96		1.3	0.022	0.022	74.3	74.3	0.039	264.0
DS-H-106		4.4	0.021	0.021	70.9	70.9	0.032	216.6
DS-H-111		2.4	0.026	0.026	87.8	87.8	0.035	237.0
DS-H-112		3.1	0.014	0.014	47.3	47.3	0.014	94.8
DS-H-114		1.3	0.014	0.014	47.3	47.3	0.021	142.2
DS-52-138		2.2	0.01	0.010	33.8	33.8	0.011	74.5
DS-H-122		6	0.027	0.027	91.1	91.1	0.043	291.1

SAMPLE #	AREA	LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
DS-H-149		1.3	0.19	0.189	641.4	641.4	0.035	237.0
DS-51-151		0.8	0.019	0.019	64.1	64.1	0.032	216.6
DS-H-150		3.2	0.048	0.048	162.0	162.0	0.09	609.3
DS-51-153		0.7	0.023	0.023	77.6	77.6	0.032	216.6
DS-51-156		1	0.022	0.022	74.3	74.3	0.049	331.7
DS-H-151		1.9	0.008	0.008	27.0	27.0	0.009	60.9
DS-H-156		0.8	0.011	0.011	37.1	37.1	0.011	74.5
DS-51-158		0.4	0.008	0.008	27.0	27.0	0.007	47.4
DS-H-157		4.3	0.031	0.031	104.6	104.6	0.051	345.3
DS-H-158		1.2	0.011	0.011	37.1	37.1	0.007	47.4
DS-H-164		0.9	0.01	0.010	33.8	33.8	0.014	94.8
DS-H-165		1.3	0.013	0.013	43.9	43.9	0.019	128.6
DS-51-173		0.7	0.008	0.008	27.0	27.0	0.002	13.5
DS-H-166		1.1	0.008	0.008	27.0	27.0	0.007	47.4
DS-51-174		0.8	0.013	0.013	43.9	43.9	0.012	81.2
DS-H-168		1	0.01	0.010	33.8	33.8	0.008	54.2
DS-H-169		0.9	0.009	0.009	30.4	30.4	0.006	40.6
DS-H-170		0.4	0.019	0.019	64.1	64.1	0.021	142.2
DS-H-172		1	0.012	0.012	40.5	40.5	0.012	81.2
DS-51-79		0.3	0.005	0.005	16.9	16.9	0.005	33.9
DS-51-80		0.6	0.017	0.017	57.4	57.4	0.018	121.9
DS-51-82		2.1	0.054	0.054	182.3	182.3	0.096	649.9
DS-51-83		1.4	0.013	0.013	43.9	43.9	0.022	148.9
DS-51-85		0.5	0.016	0.016	54.0	54.0	0.03	203.1
DS-51-86		0.9	0.012	0.012	40.5	40.5	0.016	108.3
DS-51-87		0.6	0.027	0.027	91.1	91.1	0.027	182.8
DS-51-89		1.2	0.004	0.004	13.5	13.5	0.002	13.5
DS-51-91		0.5	0.043	0.043	145.2	145.2	0.083	561.9
DS-51-92		1.4	0.041	0.041	138.4	138.4	0.043	291.1
DS-51-93		1.5	0.03	0.030	101.3	101.3	0.055	372.4
DS-51-94		1.5	0.031	0.031	104.6	104.6	0.05	338.5
DS-51-95		1.7	0.02	0.020	67.5	67.5	0.03	203.1
DS-H-105		3.5	0.005	0.005	16.9	16.9	0.007	47.4
DS-51-97		1.3	0.015	0.015	50.6	50.6	0.026	176.0
DS-51-98		1.3	0.013	0.013	43.9	43.9	0.023	155.7
DS-51-99		0.4	0.009	0.009	30.4	30.4	0.01	67.7
DS-51-100		0.5	0.012	0.012	40.5	40.5	0.02	135.4
DS-51-101		1	0.015	0.015	50.6	50.6	0.019	128.6
DS-51-102		0.8	0.016	0.016	54.0	54.0	0.023	155.7
DS-51-103		0.7	0.007	0.007	23.6	23.6	0.008	54.2
DS-51-104		0.6	0.015	0.015	50.6	50.6	0.018	121.9
DS-51-105		0.5	0.012	0.012	40.5	40.5	0.016	108.3
DS-51-105		0.5	0.012	0.012	40.5	40.5	0.016	108.3
DS-51-106		0.7	0.006	0.006	20.3	20.3	0.006	40.6
DS-51-107		1.3	0.018	0.018	60.8	60.8	0.033	223.4
DS-51-108		1.8	0.018	0.018	60.8	60.8	0.028	189.6
DS-51-109		2.8	0.021	0.021	70.9	70.9	0.032	216.6
DS-51-110		1.5	0.022	0.022	74.3	74.3	0.038	257.3
DS-51-111		1.5	0.034	0.034	114.8	114.8	0.06	406.2
DS-51-112		1	0.039	0.039	131.6	131.6	0.082	555.1
DS-51-152		0.5	0.068	0.068	229.5	229.5	0.07	473.9
DS-51-154		1.4	0.1	0.099	337.6	337.6	0.2	1354.0
DS-51-155		0.7	0.091	0.090	307.2	307.2	0.26	1760.2
DS-51-157		1	0.011	0.011	37.1	37.1	0.017	115.1
DS-51-159		1.2	0.035	0.035	118.1	118.1	0.055	372.4
DS-51-160		1	0.02	0.020	67.5	67.5	0.023	155.7
DS-51-161		1.1	0.019	0.019	64.1	64.1	0.023	155.7
DS-51-162		1	0.011	0.011	37.1	37.1	0.0004	2.7
DS-51-282		0.9	0.008	0.008	27.0	27.0	0.004	27.1
DS-51-172		1.2	0.014	0.014	47.3	47.3	0.018	121.9
DS-51-175.		0.6	0.012	0.012	40.5	40.5	0.011	74.5
DS-51-177		0.8	0.011	0.011	37.1	37.1	0.008	54.2
DS-H-65		2.5	0.009	0.009	30.4	30.4	0.014	94.8
DS-H-66		3.9	0.007	0.007	23.6	23.6	0.012	81.2

SAMPLE #	AREA	LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
DS-H-67		3.9	0.016	0.016	54.0	54.0	0.03	203.1
DS-H-68		3.2	0.003	0.003	10.1	10.1	0.001	6.8
DS-H-69		3.3	0.014	0.014	47.3	47.3	0.024	162.5
DS-H-72		10	0.013	0.013	43.9	43.9	0.027	182.8
DS-H-73		4.4	0.014	0.014	47.3	47.3	0.025	169.3
DS-H-77		1.5	0.008	0.008	27.0	27.0	0.014	94.8
DS-H-78		7.9	0.009	0.009	30.4	30.4	0.016	108.3
DS-H-79		3.5	0.016	0.016	54.0	54.0	0.02	135.4
DS-H-80		9.3	0.004	0.004	13.5	13.5	0.003	20.3
DS-51-42A		0.6	0.004	0.004	13.5	13.5	0.003	20.3
DS-H-81		10.1	0.011	0.011	37.1	37.1	0.017	115.1
DS-H-82		0.6	0.004	0.004	13.5	13.5	0.005	33.9
DS-H-83		6.2	0.013	0.013	43.9	43.9	0.021	142.2
DS-H-84		1.3	0.005	0.005	16.9	16.9	0.005	33.9
DS-H-85		2.1	0.009	0.009	30.4	30.4	0.001	6.8
DS-H-86		2.5	0.008	0.008	27.0	27.0	0.004	27.1
DS-H-87		3.3	0.038	0.038	128.3	128.3	0.071	480.7
DS-H-89		0.7	0.008	0.008	27.0	27.0	0.005	33.9
DS-H-94		10	0.018	0.018	60.8	60.8	0.026	176.0
DS-H-95		1.3	0.006	0.006	20.3	20.3	0.006	40.6
DS-H-96		3.7	0.005	0.005	16.9	16.9	0.004	27.1
DS-H-97		3	0.019	0.019	64.1	64.1	0.039	264.0
DS-51-6		0.8	0.01	0.010	33.8	33.8	0.019	128.6
DS-51-7		0.5	0.009	0.009	30.4	30.4	0.016	108.3
DS-51-8		0.9	0.009	0.009	30.4	30.4	0.019	128.6
DS-51-9		1.9	0.011	0.011	37.1	37.1	0.018	121.9
DS-51-10		0.7	0.02	0.020	67.5	67.5	0.031	209.9
DS-51-11		1	0.006	0.006	20.3	20.3	0.012	81.2
DS-51-12		1.3	0.028	0.028	94.5	94.5	0.057	385.9
DS-51-13		1	0.01	0.010	33.8	33.8	0.015	101.6
DS-51-14		1.7	0.019	0.019	64.1	64.1	0.034	230.2
DS-51-15		0.7	0.017	0.017	57.4	57.4	0.034	230.2
DS-51-16		1	0.009	0.009	30.4	30.4	0.014	94.8
DS-51-17		1	0.012	0.012	40.5	40.5	0.026	176.0
DS-51-18		0.6	0.012	0.012	40.5	40.5	0.02	135.4
DS-51-36		0.4	0.032	0.032	108.0	108.0	0.052	352.0
DS-51-37		0.4	0.01	0.010	33.8	33.8	0.012	81.2
DS-51-38		0.5	0.012	0.012	40.5	40.5	0.013	88.0
DS-51-39		0.4	0.004	0.004	13.5	13.5	0.003	20.3
DS-51-40		0.6	0.006	0.006	20.3	20.3	0.008	54.2
DS-51-41		2.3	0.011	0.011	37.1	37.1	0.022	148.9
DS-51-42B		0.9	0.027	0.027	91.1	91.1	0.04	270.8
DS-51-43		1.4	0.007	0.007	23.6	23.6	0.008	54.2
DS-51-44		1.2	0.019	0.019	64.1	64.1	0.039	264.0
DS-51-45		1	0.007	0.007	23.6	23.6	0.012	81.2
DS-51-46		1	0.01	0.010	33.8	33.8	0.018	121.9
DS-51-47		0.6	0.018	0.018	60.8	60.8	0.037	250.5
DS-51-48		1	0.027	0.027	91.1	91.1	0.035	237.0
DS-51-49		1	0.033	0.033	111.4	111.4	0.063	426.5
DS-51-50		0.8	0.077	0.076	259.9	259.9	0.007	47.4
DS-51-51		3.5	0.008	0.008	27.0	27.0	0.013	88.0
DS-51-52		1.3	0.025	0.025	84.4	84.4	0.041	277.6
DS-51-53		20	0.028	0.028	94.5	94.5	0.051	345.3
DS-51-54		0.8	0.026	0.026	87.8	87.8	0.047	318.2
DS-51-55		0.8	0.021	0.021	70.9	70.9	0.035	237.0
DS-51-56		1.2	0.009	0.009	30.4	30.4	0.012	81.2
DS-51-77		1.1	0.023	0.023	77.6	77.6	0.048	325.0
DS-52-114	0.8		0.014	0.014	47.3	47.3	0.016	108.3
DS-52-115	12.9		0.013	0.013	43.9	43.9	0.017	115.1
DS-52-116	8.7		0.01	0.010	33.8	33.8	0.01	67.7
DS-52-117	7.7		0.005	0.005	16.9	16.9	0.006	40.6
DS-52-118	5		0.012	0.012	40.5	40.5	0.015	101.6
DS-52-119	3.8		0.014	0.014	47.3	47.3	0.018	121.9
DS-52-120	8		0.013	0.013	43.9	43.9	0.014	94.8

SAMPLE #	AREA	LENGTH	PERCENT EQUIVALENT URANIUM	PERCENT EQUIVALENT URANIUM-238	EQUIVALENT URANIUM-238 ACTIVITY (picoCuries per gram)	RADIUM-226 ACTIVITY (picoCuries per gram)	PERCENT URANIUM	NATURAL URANIUM ACTIVITY (picoCuries per gram)
DS-52-121	10.7		0.011	0.011	37.1	37.1	0.01	67.7
DS-52-122	1.2		0.006	0.006	20.3	20.3	0.001	6.8
DS-52-123	637		0.009	0.009	30.4	30.4	0.009	60.9
DS-52-124	10.3		0.012	0.012	40.5	40.5	0.013	88.0
DS-52-125	6		0.013	0.013	43.9	43.9	0.02	135.4
DS-52-126	6.2		0.022	0.022	74.3	74.3	0.033	223.4
DS-52-127	6.8		0.013	0.013	43.9	43.9	0.016	108.3
DS-52-131	6		0.015	0.015	50.6	50.6	0.015	101.6
DS-52-129	5.9		0.011	0.011	37.1	37.1	0.012	81.2
DS-52-130	9		0.023	0.023	77.6	77.6	0.045	304.7
DS-52-131	6		0.015	0.015	50.6	50.6	0.015	101.6
DS-52-132	5.3		0.004	0.004	13.5	13.5	0.005	33.9
DS-52-133	4.8		0.008	0.008	27.0	27.0	0.013	88.0
DS-52-134	7.5		0.013	0.013	43.9	43.9	0.024	162.5
DS-52-135	6.5		0.021	0.021	70.9	70.9	0.033	223.4
DS-52-136	5.5		0.013	0.013	43.9	43.9	0.024	162.5
DS-51-19		0.5	0.008	0.008	27.0	27.0	0.009	60.9
DS-51-20		1.2	0.014	0.014	47.3	47.3	0.021	142.2
DS-51-21		0.8	0.009	0.009	30.4	30.4	0.014	94.8
DS-51-22		0.7	0.014	0.014	47.3	47.3	0.019	128.6
DS-51-23		1	0.01	0.010	33.8	33.8	0.014	94.8
DS-51-24		0.7	0.015	0.015	50.6	50.6	0.019	128.6
DS-51-25		1.3	0.013	0.013	43.9	43.9	0.024	162.5
DS-51-26		0.9	0.002	0.002	6.8	6.8	0.002	13.5
DS-51-27		0.5	0.004	0.004	13.5	13.5	0.003	20.3
DS-51-28		1.2	0.008	0.008	27.0	27.0	0.009	60.9
DS-51-29		1.3	0.033	0.033	111.4	111.4	0.062	419.7
DS-51-30		0.3	0.017	0.017	57.4	57.4	0.025	169.3
DS-51-31		1	0.024	0.024	81.0	81.0	0.04	270.8
DS-51-32		0.5	0.01	0.010	33.8	33.8	0.015	101.6
DS-51-33		0.7	0.011	0.011	37.1	37.1	0.02	135.4
DS-51-34		0.4	0.009	0.009	30.4	30.4	0.013	88.0
DS-51-35		0.8	0.01	0.010	33.8	33.8	0.019	128.6
DS-51-57		0.6	0.016	0.016	54.0	54.0	0.021	142.2
DS-51-58	0.06	Sample missing		0.000	0.0	0.0		0.0
DS-51-59		0.5	0.03	0.030	101.3	101.3	0.052	352.0
DS-51-60		2	0.021	0.021	70.9	70.9	0.024	162.5
DS-51-61		1.6	0.017	0.017	57.4	57.4	0.028	189.6
DS-51-62		1.5	0.003	0.003	10.1	10.1	0.002	13.5
DS-51-63		1.5	0.009	0.009	30.4	30.4	0.012	81.2
DS-51-64		1	0.011	0.011	37.1	37.1	0.012	81.2
DS-51-65		2	0.013	0.013	43.9	43.9	0.022	148.9
DS-51-66		1.4	0.016	0.016	54.0	54.0	0.027	182.8
DS-51-67		1.3	0.01	0.010	33.8	33.8	0.014	94.8
DS-51-69		1.6	0.012	0.012	40.5	40.5	0.016	108.3
DS-51-69		3	0.008	0.008	27.0	27.0	0.011	74.5
DS-51-72		1.9	0.011	0.011	37.1	37.1	0.015	101.6
DS-51-73		1.3	0.026	0.026	87.8	87.8	0.042	284.3
DS-51-74		1.6	0.025	0.025	84.4	84.4	0.036	243.7
DS-51-75		1.7	0.02	0.020	67.5	67.5	0.028	189.6
DS-51-76		2.8	0.006	0.006	20.3	20.3	0.004	27.1
Mean:			0.017	0.017	56.2	56.2	0.023	156.6
Median:			0.012	0.012	40.5	40.5	0.016	108.3
Standard Deviation:			0.019	0.018	62.5	62.5	0.026	177.6
Maximum:			0.190	0.189	641.4	641.4	0.260	1760.2
Minimum:			0.002	0.000	0.0	0.0	0.000	0.0
(shaded)	Values computed by Kennecott Uranium Company from data in paper							
OAP:02/17/08								

Kennecott Uranium Company						
Sweetwater Uranium Project						
Pre-operational Background Soil Sampling Data						
Sample Location	Date	Ra-226	U-nat	U-nat	Comments	
		pCi/g	ug/g	pCi/g		
MA (A)	5/10/1979	0.08	0.41	0.28	Mill Area Survey	
MA (B)	5/10/1979	0.49	0.73	0.49		
M-1-B(A)	5/10/1979	0.23	0.19	0.13		
M-1-B (B)	5/10/1979	0.32	0.38	0.26		
M-2-B(A)	5/10/1979	0.3	0.35	0.24		
M-2-B(B)	5/10/1979	0.16	0.47	0.32		
M-3-B(A)	5/10/1979	0.06	0.13	0.09		
M-3-B(B)	5/10/1979	0.45	0.28	0.19		
M-4-B(A)	5/10/1979	0.12	0.2	0.14		
M-4-B(B)	5/10/1979	0.64	0.76	0.51		
1A	4/13/1978	3	12	8.12	Soil Station Sampling	
1B	4/13/1978	4.2	9.4	6.36	#1 same location as Air 3	
2A	4/13/1978	4.2	14	9.48		
2B	4/13/1978	3.6	12	8.12	#2 same location as SVS 1	
3A	4/13/1978	1	1.3	0.88		
3B	4/13/1978	0.19	1.8	1.22	#3 same location as SVS 2	
4A	4/13/1978	1.7	3.1	2.10		
4B	4/13/1978	1.7	3.1	2.10	#4 same location as SVS 3	
5A	4/13/1978	0.55	3.5	2.37		
5B	4/13/1978	2.2	2.8	1.90	#5 same location as SVS 5	
6A	4/13/1978	1.8	4	2.71		
6B	4/13/1978	1.1	6.2	4.20		
7A	4/13/1978	1.8	2.2	1.49		
7B	4/13/1978	1.7	2.5	1.69		
#8	4/13/1978	2.8	2.6	1.76		
#9	4/13/1978	1.3	3.5	2.37		
T1-A	4/13/1978	0.13	0.46	0.31	T-series sampling	
T1-B	4/13/1978	0.28	0.55	0.37	Located SW of Mill	
T2-A	4/13/1978	0.55	0.53	0.36		
T2-B	6/16/1978	0.45	0.37	0.25		
T3-A	6/16/1978	0.2	0.51	0.35		
T3-B	8/29/1978	0.2	0.43	0.29		
T4-A	8/29/1978	0.05	0.57	0.39		
T4-B	8/29/1978	0.24	0.45	0.30		
T5-A	8/29/1978	0.34	0.36	0.24		
T5-B	8/28/1978	0.15	0.45	0.30		
A	9/27/1978	2	0.66	0.45	Center point of survey	
A-1	9/26/1978	3.32	0.88	0.60		
A-2	9/27/1978	4.48	0.73	0.49	Series located in T24N, R93W, Sections 10,	
A-3	9/27/1978	3.53	0.57	0.39	11,14,15,22 and 23	
1-C	9/26/1978	2.4				
1-E	9/27/1978	2.5			Radial survey (8 radials) from point A,	
1F-1	9/27/1978	2			located approx. 800' east of mill building	

1F-2	9/27/1978	1.6			(i.e. SE Mill)	
1F-3	9/27/1978	1.7				
1G	9/27/1978	1.5				
1-I	9/27/1978	1.4	0.32	0.22		
1K	9/27/1978	2.2				
2-C	9/27/1978	1.2				
2-E	9/27/1978	2.3				
2-G	9/27/1978	2.1				
2-I	9/27/1978	1.7	0.54	0.37		
2-K	9/27/1978	0.55				
3-C	9/27/1978	1.2				
3-E	9/27/1978	2	0.62	0.42		
3F-1	9/27/1978	1.8				
3F-2	9/27/1978	1				
3F-3	9/27/1978	0.29				
3-G	9/27/1978	0.93				
3-I	9/27/1978	4				
3-K	9/27/1978	1.6				
4-C	9/27/1978	4.6				
4-E	9/27/1978	0.78				
4-G	9/27/1978	1.7				
4-I	9/28/1978	1				
4-K	9/28/1978	0.62				
5-C	9/27/1978	2.3				
5-E	9/27/1978	0.97				
5F-1	9/27/1978	1.5	0.93	0.63		
5F-2	9/27/1978	1.4	1.1	0.74		
5F-3	9/27/1978	1.4	0.74	0.50		
5-G	9/26/1978	0.36				
5-I	9/26/1978	0.24				
5-K	9/28/1978	1.2				
6-C	9/28/1978	0.95	0.6	0.41		
6-E	9/28/1978	7.3				
6-G	9/26/1978	1.5				
6-I	9/26/1978	1.4				
6-K	9/28/1978	2.3				
7-C	9/26/1978	2.8				
7-E	9/29/1978	1.5				
7F-1	9/29/1978	1.4	0.6	0.41		
7F-2	9/29/1978	1.4	0.46	0.31		
7F-3	9/29/1978	1.8	0.37	0.25		
7-G	9/26/1978	0.51				
7-I	9/26/1978	0.87				
7-K	9/28/1978	1.8				
8-C	9/28/1978	1.86				
8-E	9/28/1978	2.07				
8-G	9/26/1978	1.7	0.38	0.26		
8-I	9/26/1978	0.99				
8-K	9/26/1978	1.03				
Air-1	8/28/1978	1.05	0.49	0.33	1978 Pre-Op Sampling	
Air-2	8/28/1978	0.3	0.47	0.32		
Air-3	8/28/1978	1.8	0.41	0.28		
Air-4	8/28/1978	3.7	0.59	0.40		
Air-5	8/28/1978	0.3	0.37	0.25		
PRO 1A	4/13/1978	3	12	8.12		
PRO 1B	4/13/1978	4.2	9.4	6.36		

PRO 6A	4/13/1978	1.8	4	2.71		
PRO 6A	10/20/1979		3.5	2.37		
PRO 6B	4/13/1978	1.1	6.2	4.20		
AIR 1	10/20/1979		1.8	1.22		
AIR 2	10/20/1979		1.8	1.22		
AIR 4	10/20/1979		2	1.35		
PRO 6	10/20/1979		3.5	2.37		
SVS 1A	10/16/1979	2	3.9	2.64	SVS Series Sampling	
SVS 1A	4/13/1978	4.2	14	9.48		Data Summary Sheet
SVS 1A	10/30/1980	1.6	3.4	2.30		Eberline Lab Data
SVS 1B	10/16/1979	2.1	4.6	3.11		Eberline
SVS 1B	4/13/1978	3.6	12	8.12		Summary Sheet
SVS 1B	10/30/1980	2	3	2.03		Eberline
SVS 2A	10/16/1979	0.63	1.1	0.74		Eberline
SVS 2A	10/16/1979	0.8		0.00		Hazen Lab Data
SVS 2A	4/13/1978	1	1.3	0.88		Summary Sheet
SVS 2A	10/29/1980	0.49	0.87	0.59		Eberline
SVS 2B	10/22/1979	0.74	1.9	1.29		Eberline
SVS 2B	4/13/1978	0.19	1.8	1.22		Summary Sheet
SVS 2B	10/30/1980	0.75	1.1	0.74		Eberline
SVS 3A	10/16/1979	1.4	2.3	1.56		Eberline
SVS 3A	10/16/1979	2		0.00		Hazen
SVS 3A	4/13/1978	1.7	2.1	1.42		Summary Sheet
SVS 3A	10/29/1980	1.2	2	1.35		Eberline
SVS 3B	10/16/1979	1.4	2	1.35		Eberline
SVS 3B	4/13/1978	1.7	3.1	2.10		Summary Sheet
SVS 3B	10/29/1980	1.5	2	1.35		Eberline
SVS 4A	10/20/1979	0.99	2.3	1.56		Eberline
SVS 4A	4/13/1978	1.8	2.2	1.49		Summary Sheet
SVS 4A	10/29/1980	0.41	1.4	0.95		Eberline
SVS 4B	10/20/1979	2.8	3	2.03		Eberline
SVS 4B	4/13/1978	1.7	2.51	1.70		Summary Sheet
SVS 4B	10/29/1980	0.78	1.9	1.29		Eberline
SVS 5A	10/20/1979	0.22	1.7	1.15		Eberline
SVS 5A	10/20/1979	1.2				Hazen
SVS 5A	4/13/1978	0.55	3.5	2.37		Summary Sheet
SVS 5A	10/29/1980	0.85	1.8	1.22		Eberline
SVS 5B	10/20/1979	0.78	1.8	1.22		Eberline
SVS 5B	4/13/1978	2.2	2.8	1.90		Summary Sheet
SVS 5B	10/29/1980	1.1	1.8	1.22		Eberline
SVS 6A	10/20/1979	0.59	2.6	1.76		Eberline
SVS 6A	10/30/1980	0.64	1.1	0.74		Eberline
SVS 6B	10/20/1979	0.71	2.7	1.83		Eberline
SVS 6B	10/30/1980	0.53	3.6	2.44		Eberline
SVS 7A	10/20/1979	0.52	1.3	0.88		Eberline
SVS 7A	10/30/1980	1.4	1.5	1.02		Eberline
SVS 7B	10/20/1979	0.36	1.3	0.88		Eberline
SVS 7B	10/30/1980	0.56	3.2	2.17		Eberline
SVS 8A	10/20/1979	0.57	1.3	0.88		Eberline
SVS 8A	10/30/1980	0.51	1.8	1.22		Eberline
SVS 8B	10/20/1979	0.94	1.8	1.22		Eberline
SVS 8B	10/30/1980	0.85	1.6	1.08		Eberline
MILL AREA AVERAGE		1.44	2.44	1.66		n = 146 (radium samples)
		1.16	3.00	2.03		
MILL AVG		0.29	0.39	0.26		n = 10

SOIL STATION SERIES AVG		2.05	5.25	3.55		n = 16
T-SERIES AVG		0.26	0.47	0.32		n = 10
1978 MILL RADIALS		1.80	0.63	0.43		n = 56
1978/79 PRO/Air		1.92	3.32	2.25		n = 9
SVS SERIES AVG		1.21	2.69	1.82		n = 45
PIT STOCKPILE AVG		1.00				n = 6
C-1 WASTE DUMP AVG		3.43				n = 18
Note:	**indicates a data population not used in the calculation of overall mean**					
Sample Loc	Date	Ra-226	U-nat		Comments	
		pCi/g	ug/g			

Kennecott Uranium Company
Soil Radiometric Data
UMETCO Gas Hills Site

Non-Random Background Soil Radiometric Data

SAMPLE I.D.#	U-Nat (pCi/g)	Ra226 pCi/g	Ra226 Prec. +/-	Th230 pCi/g	Th230 Pec. +/-	Pb210 pCi/g	Pb210 Prec. +/-
SS # 1; 0-6"	0.9	1.6	0.5	< 0.02		0.2	0.2
SS # 1; 6-12"	0.8	1.1	0.3	< 0.02		< 0.10	
SS # 2; 0-6"	0.07	1.3	0.2	2.3	0.7	0.3	0.3
SS # 2; 6-12"	0.06	1.3	0.2	< 0.02		0.5	0.4
SS # 3; Road Bed	37.4	119	0.2	177	5.8	89.3	3.2
SS # 4; 0-6"	0.05	1	1	< 0.02		0.3	0.3
SS # 4; 6-12"	0.6	1.1	0.3	< 0.02		0.3	0.3
SS # 5: 0-6"	1.1	1.4	0.3	< 0.02		< 0.10	
SS # 5; 6-12"	1.2	1.7	0.3	< 0.02		1.1	0.8
SS # 6; 0-6"	1.1	1.6	0.3	< 0.02		< 0.10	
SS # 6; 6-12"	1.4	1.6	0.3	< 0.02		< 0.10	
SS # 7; 0-6"	2.3	1.7	0.3	< 0.02		0.8	0.8
SS # 7; 6-12"	2.9	1.9	0.3	< 0.02		0.3	0.3
SS # 8; 0-6"	1.1	1.5	0.3	< 0.02		0.4	0.4
SS # 8; 6-12"	0.9	0.8	0.1	< 0.02		0.2	0.2
SS # 9; 0-6"	1.65	15.4	1	0.5	0.1	< 0.01	
SS # 9; 6-12"	0.66	7.7	0.8	0.4	0.1	< 0.01	
SS # 10; 0-6"	3.06	38.4	1.6	1.6	0.2	0.4	0.2
SS # 10; 6-12"	2.5	41	1.6	1.9	0.2	1.3	0.2
SS # 11; 0-6"	21.5	268	2.4	50.8	2.2	153	1.1
SS # 11; 6-12"	14.5	504	3.3	58.1	2.1	272	1.2
SS # 12; 0-6"	2.19	2.9	0.3	1	0.1	1.3	0.2
SS # 12; 6-12"	0.8	1.4	0.2	0.4	0.1	10.8	0.4
SS # 13; 0-6"	0.86	1.3	0.2	0.5	0.1	1.25	0.4
SS # 13; 6-12"	0.63	0.9	0.2	0.4	0.1	0.88	0.4
SS # 14; 0-6"	0.84	1	0.2	0.5	0.1	0.86	0.4
SS # 14; 6-12"	0.59	0.9	0.2	0.4	0.1	1.08	0.4
SS # 15; 0-6"	1.88	1.4	0.2	0.6	0.1	0.75	0.4
SS # 15; 6-12"	1.19	1.4	0.2	0.9	0.2	0.42	0.3
SS # 16; 0-6"	1.66	1.1	0.2	0.8	0.2	< 0.01	
SS # 16; 6-12"	2.16	0.9	0.2	0.8	0.2	1.18	0.4
SS # 17; 0-6"	1.23	1.5	0.2	1.7	0.2	1.17	0.4
SS # 17; 6-12"	1.19	1.3	0.2	0.9	0.2	< 0.01	
SS # 18; 0-6"	0.85	0.9	0.2	0.8	0.2	1.01	0.4
SS # 18; 6-12"	0.86	1.1	0.2	0.9	0.2	0.93	0.4
SS # 19; 0-6"	19.7	68.9	1.2	18	1.3	36	0.9
SS # 19; 6-12"	23.8	35.1	0.9	6.5	0.5	21.7	0.8
SS # 20; 0-6"	24.8	7.16	0.22	3.5	0.3	2.2	0.5
SS # 20; 6-12"	8.36	11.4	0.28	6.5	0.5	4.5	0.6
	0.02	0.02		0.02		0.1	
Mean:	4.85	29.58		12.99		19.56	
Median:	1.19	1.50		0.90		1.01	
Standard Deviation:	8.67	91.12		36.52		56.40	
Maximum:	37.40	504.00		177.00		272.00	
Minimum:	0.05	0.80		0.40		0.20	

Notes:
This data was collected by UMETCO Minerals Corporation
This data was provided by John Hamrick formerly of UMETCO Minerals Corporatrion now of Cotter Corporation
This data was collected from background soil sampling locations in the Gas Hills of Wyoming.
This data was collected by UMETCO Minerals Corporation to demonstrate the variability of natural background in the Gas Hills.

Kennecott Uranium Company
Sweetwater Uranium Project
Diesel Contaminated Soil Excavation
South Pit Wall Uranium Study

Depth Above Hole Bottom (feet)	Elevation (Feet above mean sea level)	Gamma Exposure (micro/R/hour)	Density (grams per cubic centimeter)	Moisture (Percent)	Chemical Uranium Concentration (milligrams per kilogram)	Chemical Uranium Concentration (Percent)	Chemical U3O8 Concentration (milligrams per kilogram)	Chemical U3O8 Concentration (Percent)	Radium-226 (picocuries per gram)	Gamma Equivalent Uranium Concentration (milligrams per kilogram)	Gamma Equivalent Uranium Concentration (Percent)	Notes	Sample Sequence Image
7.50	6556.2											Nail Set - Five (5) feet Above Water table	
7.00		156										Dry	
6.75			2.48	10.8	51.7	0.005	61.0	0.006	65	196	0.020	Dry	
6.50		222										Dry	
6.25			2.73	10.6	14	0.001	16.5	0.002	113	340	0.034	Dry	
6.00		351										Dry	
5.75			2.35	12.3	13.1	0.001	15.4	0.002	209	631	0.063	Dry	
5.50		422										Dry	
5.25			2.54	12.6	33.3	0.003	39.2	0.004	301	909	0.091	Dry	
5.00		464										Dry	
4.75			2.62	11.8	14.8	0.001	17.5	0.002	254	766	0.077	Dry	
4.50		524										Dry	
4.25			2.59	14.3	16.1	0.002	19.0	0.002	206	623	0.062	Dry	
4.00		548										Dry	
3.75			2.86	14.8	18.8	0.002	22.2	0.002	332	1000	0.100	Dry	
3.50		634										Dry	
3.25			2.44	16.3	26.3	0.003	31.0	0.003	224	676	0.068	Dry	
3.00		593										Dry	
2.75			2.69	18.5	39.7	0.004	46.9	0.005	379	1150	0.115	Dry	
												Top of Water	
2.50	6552.4	691										Table - Nail Set	
2.25			2.66	17.1	33	0.003	38.9	0.004	265	799	0.080	Wet	
2.00		751										Wet	
1.75			2.76	18.8	18.3	0.002	21.6	0.002	306	923	0.092	Wet	
1.50		655										Wet	
1.25			2.29	20.3	23.7	0.002	28.0	0.003	309	933	0.093	Wet	
1.00		448										Wet	
0.75			2.43	21.6	26.6	0.003	31.3	0.003	44.1	133	0.013	Wet	
0.50		351										Wet	
0.25			2.53	26.7	22	0.002	26.9	0.003	58.7	177	0.018	Wet	
0.00		340										Wet	
Average		477	2.56	16.2	25.1	0.003	29.6	0.003	219.0	661	0.066		
Median		464	2.57	15.6	22.9	0.002	27.0	0.003	239.0	721	0.072		
Maximum		751	2.76	26.7	51.7	0.005	61.0	0.006	379.0	1150	0.115		
Minimum		156	2.29	10.6	13.1	0.001	15.4	0.002	44.1	133	0.013		
Standard Deviation		173	0.14	4.7	11.1	0.001	13.1	0.001	109.4	331	0.033		

Coordinates

	Northing	Easting	Elevation
Nail at 7.5 Feet	149142.0	323018.63	6556.2
Nail at Water Table	149144.1	323019.84	6552.41

Kennecott Uranium Company
Sweetwater Uranium Project
Diesel Contaminated Soil Excavation
South Pit Wall Uranium Study

Bulk Sample Identification	Chemical Uranium Concentration as U (milligrams per kilogram)	Chemical Uranium Concentration as U (Percent)	Chemical Uranium Concentration as U3O8 (milligrams per kilogram)	Chemical Uranium Concentration as U3O8 (Percent)	Radium-226 (picocuries per gram)	Gamma Equivalent Uranium Concentration as U (milligrams per kilogram)	Gamma Equivalent Uranium Concentration as U (Percent)	Gamma Equivalent Uranium Concentration as U3O8 (milligrams per kilogram)	Gamma Equivalent Uranium Concentration as U3O8 (Percent)	Equilibrium ratio Chemical uranium divided by gamma equivalent uranium
Above Water Table - Barrel #1	23.9	0.002	28.2	0.003	225	679	0.068	800	0.080	0.04
Above Water Table - Barrel #2	35.2	0.004	41.4	0.004	277	838	0.084	988	0.099	0.04
At Water Table	24.7	0.002	29.1	0.003	226	681	0.068	803	0.080	0.04
Below Water Table	20	0.002	23.6	0.002	77.4	234	0.023	276	0.028	0.09

bulk_sampling_bottom.xls
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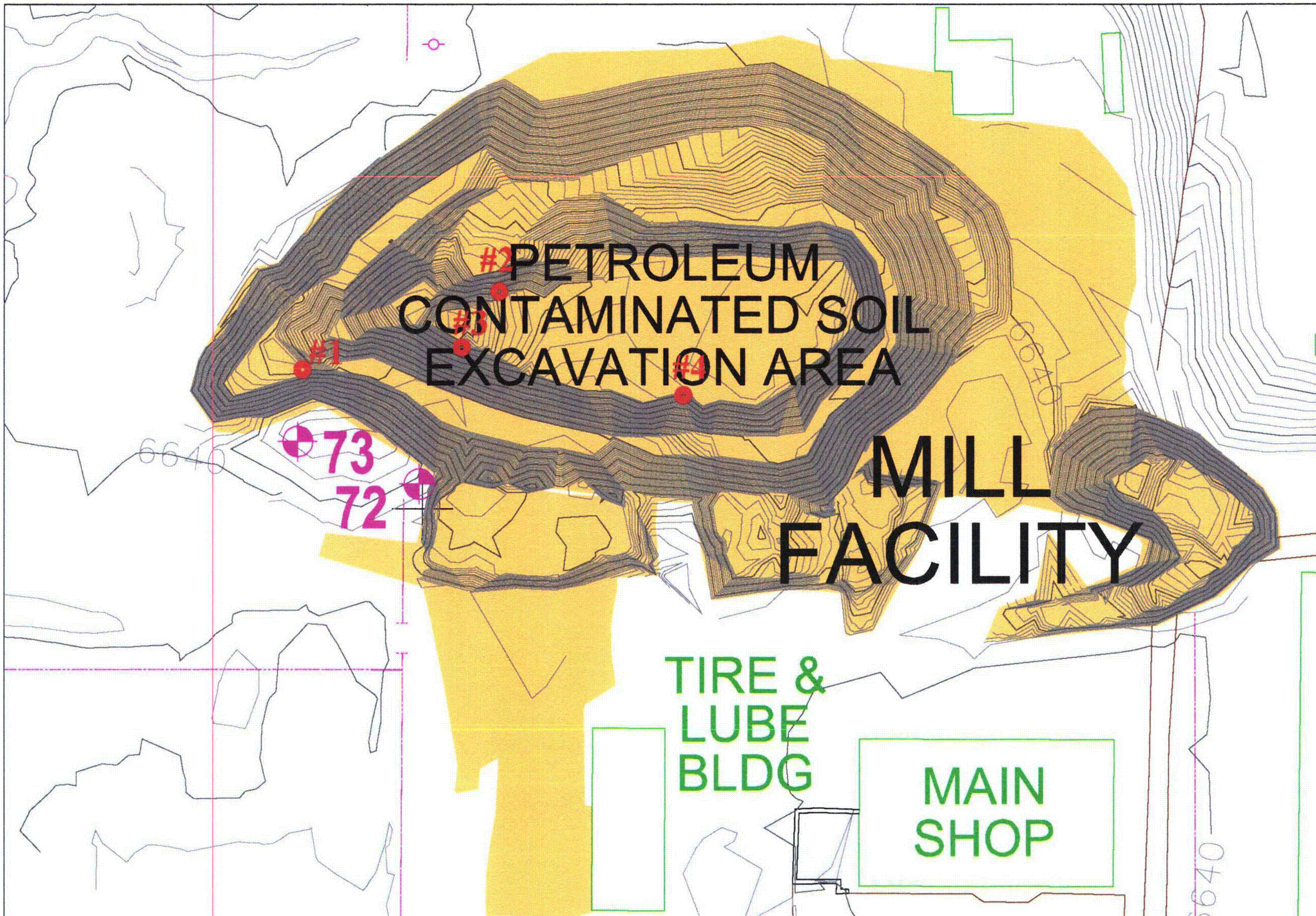
Kennecott Uranium Company
Sweetwater Uranium Project
Catchment Basin Excavation

Background Soil Samples
Diesel Contaminated Soil Excavation

Location	Sample Type	Diesel Range Organics (milligrams per kilogram)	Oil Range Hydrocarbons (milligrams per kilogram)	Total Extractable Hydrocarbons (milligrams per kilogram)	pH (Standard units)	Sulphate (milligrams per kilogram)	Natural Uranium (milligrams per kilogram)	Natural Uranium (picocuries per gram)	Uranium-238 (picocuries per gram)	Thorium-230 (picocuries per gram)	Th-230 - Uncertainty (picocuries per gram)	INITIAL Result (picocuries per gram)	INITIAL Uncertainty (picocuries per gram)	FINAL Result (picocuries per gram)	FINAL Uncertainty (picocuries per gram)	Equilibrium Uranium-238/ Thorium-230	Equilibrium Thorium-230/ Radium-226	Equilibrium Uranium-238/ Radium-226	Moisture (percent)
Southwest Corner Diesel Excavation - Bench #1	Soil	ND	ND	ND	8.93	63	43.3	29.31	14.62	6.4	1.2	12.7	1.4	18.3	1.4	2.28	0.35	0.80	4.5
Diesel Excavation North Wall West End Bottom Redox Area - #2	Soil	ND	ND	ND	8.45	94	17.5	11.85	5.91	5.9	1.3	4.4	1.1	4.6	1.1	1.00	1.28	1.28	3.1
Diesel Excavation South Wall at Bottom - #3	Soil	ND	ND	ND	8.1	321	9.85	6.67	3.32	1.7	0.7	16.5	1.8	20.2	109	1.96	0.08	0.16	11.8
Diesel Excavation South Wall at Bottom - #4	Soil	ND	ND	ND	8.56	81	16.4	11.10	5.54	0.7	0.5	5	1.3	6	1.3	7.91	0.12	0.92	7.4
Average:		0.0	0.0	0.0	8.51	140	21.8	14.73	7.35	3.7	0.9	9.7	1.4	12.3	28.2	3.29	0.46	0.79	6.7
Median:		0.0	0.0	0.0	8.51	88	17.0	11.48	5.72	3.8	1.0	8.9	1.4	12.2	1.4	2.12	0.23	0.86	6.0
Maximum:		0.0	0.0	0.0	8.93	321	43.3	29.31	14.62	6.4	1.3	16.5	1.8	20.2	109.0	7.91	1.28	1.28	11.8
Minimum:		0.0	0.0	0.0	8.10	63	9.9	6.67	3.32	0.7	0.5	4.4	1.1	4.6	1.1	1.00	0.08	0.16	3.1
STD DEV:		0.0	0.0	0.0	0.34	122	14.8	9.99	4.98	2.9	0.4	5.9	0.3	8.1	53.9	3.13	0.56	0.47	3.8

Background Radionuclide Sample Locations – West End Diesel Contaminated Soil Excavation



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Five-Hundred Life-Saving Interventions and Their Cost-Effectiveness

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We gathered information on the cost-effectiveness of life-saving interventions in the United States from publicly available economic analyses. "Life-saving interventions" were defined as any behavioral and/or technological strategy that reduces the probability of premature death among a specified target population. We defined cost-effectiveness as the net resource costs of an intervention per year of life saved. To improve the comparability of cost-effectiveness ratios arrived at with diverse methods, we established fixed definitional goals and revised published estimates, when necessary and feasible, to meet these goals. The 587 interventions identified ranged from those that save more resources than they cost, to those costing more than 10 billion dollars per year of life saved. Overall, the median intervention costs $42,000 per life-year saved. The median medical intervention costs $19,000/life-year; injury reduction $48,000/life-year; and toxin control $2,800,000/life-year. Cost/life-year ratios and bibliographic references for more than 500 life-saving interventions are provided.

KEY WORDS: Cost-effectiveness; economic evaluation; life-saving; resource allocation.

1. INTRODUCTION

Risk analysts have long been interested in strategies that can reduce mortality risks at reasonable cost to the public. Based on anecdotal and selective comparisons, analysts have noted that the cost-effectiveness of risk-reduction opportunities varies enormously, often over several orders of magnitude.[1-5] This kind of variation is unnerving because economic efficiency in promoting survival requires that the marginal benefit per dollar spent be equal across investments.

Despite continuing interest in cost-effectiveness, we could find no comprehensive and accessible data set on the estimated costs and effectiveness of risk management options. Such a dataset could provide useful comparative information for risk analysts as well as practical information for decision makers who must allocate scarce resources. To this end, we report cost-effectiveness ratios for more than 500 life-saving interventions across all sectors of American society.

2. METHODS

2.1. Literature Review

We performed a comprehensive search for publicly available economic analyses of life-saving interventions.

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"Life-saving interventions" were defined as any behavioral and/or technological strategy that reduces the probability of premature death among a specified target population. To identify analyses we used several on-line databases, examined the bibliographies of textbooks and review articles, and obtained full manuscripts of conference abstracts. Analyses retained for review met the following three criteria: (1) written in the English language, (2) contained information on interventions relevant to the United States, and (3) reported cost per year of life saved, or contained sufficient information to calculate this ratio. Most analyses were scientific journal articles or government regulatory impact analyses, but some were internal government memos, reports issued by research organizations, or unpublished manuscripts.

Two trained reviewers (from a total of 11 reviewers) read each document. Each reviewer recorded 52 items, including detailed descriptions of the nature of the life-saving intervention, the baseline intervention to which it was compared, the target population at risk, and cost per year of life saved. The two reviewers worked independently, then met and came to consensus on the content of the document.

Approximately 1200 documents were identified for retrieval. Of these 1200 documents, 229 met our selection criteria. The 229 documents contained sufficient information for reviewers to calculate cost/life-year saved for 587 interventions.

2.2. Definitional Goals

To increase the comparability of cost-effectiveness estimates drawn from different economic analyses, we established seven definitional goals. When an estimate failed to comply with a goal, reviewers attempted to revise the estimate to improve compliance.[8] In general, reviewers used only the irformation provided in the document to revise estimates. The seven definitional goals were:

1. Cost-effectiveness estimates should be in the form of "cost per year of life saved." Cost/life saved estimates should be transformed to cost/life-year by considering the average number of years of life saved when a premature death is averted.
2. Costs and effectiveness should be evaluated from the societal perspective.
3. Costs should be "direct." Indirect costs, such as foregone earnings, should be excluded.
4. Costs and effectiveness should be "net." Any resource savings or mortality risks induced by the intervention should be subtracted out.'
5. Future costs and life-years saved should all be discounted to their present value at a rate of 5%.
6. Cost-effectiveness ratios should be marginal or "incremental." Both costs and effectiveness should be evaluated with respect to a well-defined baseline alternative.
7. Costs should be expressed in 1993 dollars using the general consumer price index.

2.3. Categorization

Interventions were classified according to four-way typology. (1) Intervention Type (Fatal Injury Reduction, Medicine, or Toxin Control), (2) Sector of Society (Environmental, Health Care, Occupational, Residential, or Transportation), (3) Regulatory Agency (CPSC, EPA, FAA, NHTSA, OSHA, or None), and (4) Prevention Stage (Primary, Secondary, or Tertiary).

Interventions we classified as primary prevention are designed to completely avert the occurrence of disease or injury; those classified as secondary prevention are intended to slow, halt, or reverse the progression of disease or injury through early detection and intervention; and interventions classified as tertiary prevention include all medical or surgical treatments designed to limit disability after harm has occurred, and to promote the highest attainable level of functioning among individuals with irreversible or chronic disease.[6]

3. RESULTS

Cost-effectiveness estimates for more than 500 life-saving interventions appear in Appendix A. This table is separated into three sections according to the type of intervention: Fatal Injury Reduction, Toxin Control, and Medicine. The first column of Appendix A contains the reference number assigned to the document from which the cost-effectiveness estimate was drawn (references are in Appendix B.) The second column contains a very brief description of the life-saving intervention. The

[8] Appendices describing the cost-effectiveness formulas used operationalize these definitional goals, along with some examples of the calculations made by reviewers of the economic analyses, are available from Dr. Tengs.

[9] If savings exceed costs. the result could be negative, so that cost-effectiveness ratio might be ≤$0.

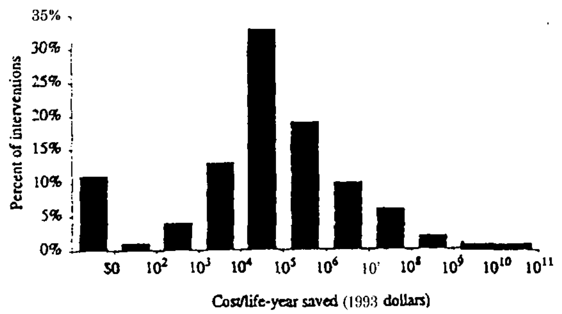

Fig. 1. Distribution of cost/life-year saved estimates (n = 587).

baseline intervention to which the life-saving intervention was compared appears parenthetically as "(vs. —)" when the author described it. The last column of Appendix A contains the cost per year of life saved in 1993 dollars.

As shown in Fig. 1, these interventions range from those that save more resources than they consume, to those costing more than 10 billion dollars per year of life saved. Furthermore. variation over 11 orders of magnitude exists in almost every category.

In addition to the large variation within categories, variation in cost-effectiveness also exists between categories. As summarized in Table I, while the median intervention described in the literature costs $42,000 per life-year saved (n = 587), the median medical intervention costs S19,000/life-year (n = 310); the median injury reduction intervention costs S48,000/life-year (n = 133); and the median toxin control intervention costs $2,800,000/life-year (n = 144).

Cost-effectiveness also varies as a function of the sector of society in which the intervention is found. For example, as shown in Table I, the median intervention in the transportation sector costs $56,000/life-year saved (n = 87), while the median intervention in the occupational sector costs $350,000/life-year (n = 36). Further dividing occupational interventions into those that avert fatal injuries and those that involve the control of toxins, reveals medians of $68,000/life-year (n = 16) and $1,400,000/life-year (n = 20), respectively.

As noted in Table II, the median cost-effectiveness estimate among those interventions classified as primary prevention is $79,000/life-year saved (n = 373), exceeding secondary prevention at $23,000/life-year (*n* = 111) and tertiary prevention at $22,000/life-year (n = 103). However, if medicine is considered in isolation, we find that primary prevention is more cost-effective that secondary or tertiary prevention at $5,000/life-year (*n* = 96).

Table I. Median of Cost/Life-Year Saved Estimates as a Function of Sector of Society and Type of Intervention

	Type of intervention			
Sector of society	Medicine	Fatal injury reduction	Toxin control	All
Health care	$ 19,000 (*n*=310)	N/A[a]	N/A	$ 19,000 (*n*=310)
Residential	N/A	$36,000 (*n*=30)	N/A	536.000 (*n*=30)
Transportation	N/A	956,000 (*n*=87)	NIA	$56,000 (*n*=87)
Occupational	N/A	568,000 (*n*= 16)	s1,400,000 (*n*=20)	$350,000 (*n*=36)
Environmental	N/A	NIA	S4.200,000 (*n*= 124)	$4,200,000 (*n*= 124)
All	s 19,000 (*n*=310)	$48,000 (*n*= 133)	S2,800,000 (*n*= 144)	$42,000 (*n*=587)

[a] Not applicable by definition.

Table II. Median of Cost/Life-Year Saved Estimates as a Function of Prevention Stage and Type of Intervention

	Type of intervetion			
Prevention stage	Medicine	Fatal injury reduction	Toxin *control*	All
Primary	$5,000 (*n*=96)	$48,000 (*n*=133)	S2,800,000 (*n*=144)	579,000 (*n*=373)
Secondary	$23,000 (*n*=111)	N/A	N/A	$23,000 (*n*=111)
Tertiary	$22,000 (*n*= 103)	N/A	N/A	522,000 (*n*=103)
All	$19,000 (*n*=310)	548,000 (*n*= 133)	S2,800,000 (*n*=144)	$42,000 (*n*=587)

The median cost-effectiveness of proposed government regulations for which we have data also varies considerably. Medians for each agency are as follows: Federal Aviation Administration, $23,000/life-year (n = 4); Consumer Product Safety Commission, $68,000/life-year (*n* = 11); National Highway Traffic Safety Administration, $78,000/life-year (n = 3 1); Occupational Safety and Health Administration, S88,000/life-year (*n* = 16); and Environmental Protection Agency, $7,600,000/life-year (*n* = 89).

4. LIMITATIONS

This compilation of existing data represents the most ambitious effort ever undertaken to amass cost-effectiveness information across all sectors of society. In addition, our work to bring diverse estimates into compliance with a set of definitional goals has improved the comparability of cost-effectiveness estimates that were originally derived by different authors using a variety of methods. Nevertheless, several caveats are warranted to aid the reader in interpreting these results.

First. the accuracy of the results presented herein is limited by the accuracy of the data and assumptions upon which the original analyses were based. There remains considerable uncertainty and controversy about the cost consequences and survival benefits of some interventions. This is particularly true for toxin control interventions where authors often extrapolate from animal data. In addition, due to insufficient information in some economic analyses, reviewers were not always successful in bringing estimates into conformity with definitional goals. For example, if the original author did not report the monetary savings due to the reduction in nonfatal injuries requiring treatment, we were unable to "net out" savings, and so the costs used to calculatcost-effectiveness ratios remain gross. While some of these omissions are important, others are largely inconsequential given the relative size of cost and effectiveness estimates.

Second, the life-saving interventions described in this report include those that are fully implemented, those that are only partially implemented, and those that are not implemented at all. These interventions are best thought of as opportunities for investment. While they may offer insight into actual investments in life-saving, the cost-effectiveness of possible and actual investments are not equivalent. Work on the economic efficiency of actual expenditures is in progress."'

Third, thisdataset may not represent a random sample of all life-saving interventions. so the generalizability of any descriptive statistics may be limited. This because interventions that have been subjected to economic analysis may not represent a random sample of all life-saving interventions due, for example, to publication bias. That is, those economic analyses that researchers have chosen to perform and journal editors have chosen to publish may be disproportionately expensive or inexpensive. However, the statistics presented herein are certainly applicable to the 587 life-saving interventions in our dataset which by themselves comprise a vast and varied set, worthy of interest even without generalization.

Finally, we recognize that many of these interventions have benefits other than survival, as well as adverse consequences other than costs. For example, interventions that reduce fatal injuries in some people may also reduce nonfatal injuries in others; interventions designed to control toxins in the environment may have short-term effects on survival, but also long-term cumulative effects on the ecosystem; medicine and surgery may increase quantity of life, while simultaneously increasing (or even decreasing) quality of life.

5. CONCLUSIONS

This compilation of available cost-effectiveness data reveals that there is enormous variation in the cost of saving one year of life and these differences exist both within and between categories. Such a result is important because efficiency in promoting survival requires that the marginal benefit per dollar spent be the same across programs. Where there are investment inequalities, more lives could be saved by shifting resources. It is our hope that this information will expand the perspective of risk analysts while aiding future resource allocation decisions.

APPENDIX A. FIVE-HUNDRED LIFE-SAVING INTERVENTIONS AND THEIR COST-EFFECTIVENESS

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
	Fatal injury reduction	
	Airplane safety	
174	Automatic fire extinguishers in airplane lavatory trash receptacles	516,000
173	Fiberglass fire-blocking airplane seat [illegible]	$17,000
14	Smoke detectors in airplane lavatories	$30,000
172	Emergency signs, floor lighting etc. (vs. upper lighting only) in airplanes	554,000
	Automobile design improvements	
190	Install windshields with adhesive bonding (vs. rubber gaskets) in cars	≤ $0
52	Dual master cylinder braking system in cars	$13,000
1128	Automobile dummy acceleration (vs. side door Strength) tests	$63,000
299	Collapsible (vs. traditional) steering columns in cars	567,000
189	Side Structure improvements in cars to reduce door intrusion upon crash	$110,000
52	Front disk (vs. drum) brakes in cars	5240,000
299	Dual master cylinder braking system in cars	$450,000
	Automobile occupant restraint systems	
1129	Driver automatic (vs. manual) belts in cars	≤ $0
59	Mandatory seat belt use law	$69
175	Mandatory seat belt use and child restraint law	$98
67	Driver and passenger automatic shoulder belt/knee pads (vs. manual belts) in cars	$1,300
59	Driver and passenger automatic shoulder/manual lap (vs. manual lap) belts in cars	$5,400
67	Airbag/manual lap belts (vs. manual lap belts only) in cars	$6,700
2	Airbag/lap belts (vs. lap/shoulder belts)	$ 17,000
56	Driver and passenger automatic (vs. manual) belts in cars	$32,000
1129	Driver airbag/manual lap belt (vs. manual lap/shoulder belt) in cars	$42,000
1129	Driver and passenger airbags/manual lap belts (vs. airbag for driver only and belts)	$61,000
59	Driver and passenger airbags/manual lap belts (vs. manual lap belts only) in cars	562,000
68	Child restraint systems in cars	573,000
1127	Rear outboard lap/shoulder belts in all (vs. 96%) cars	$74,000
56	Airbags (vs. manual lap belts) in cars	$120,000
1127	Rear outboard and center (vs. outboard only) lap/shoulder belts in all cars	5360,000
	Construction safety	
1137	Full (vs. partial) compliance with 1971 safety standard for concrete construction	≤ $0
1137	1988 (vs. 1971) safety standard for concrete construction	≤ $0
909	1989 (vs. no) safety standard for underground construction	$30,000
909	1989 (vs. 1972) safety standard for underground construction	$30,000
1132	1989 safety standard for underground gassy construction	$30,000
1132	Revised safety Standard for underground non-gassy construction	$46,000
106	Install canopies on underground equipment in coal mines	$ 170,000
910	Safety standard to prevent cave-ins during excavations at Construction sites	$ 190,000
1165	Full compliance with 1989 (vs. partial with 1971) safety standard for trenches	6350,000
1165	Full (vs. partial) compliance with 1971 safety standard for trenches	6400.000
	Fire, heat. and smoke detectors	
193	Federal law requiring smoke detectors in homes	≤ $0
13	Fire detectors in homes	≤ SO
306	Federal law requiring smoke detectors in homes	$920
19	Smoke and heat detectors in homes	$8,100
19	Smoke and heat detectors in bedroom area and basement stairwell	$150,000
303	Smoke detectors in homes	$2 10,000
	Fire prevention and protection, other	
122	Child-resistant cigarette lighters	$42,000
	Flammability standards	
292	Flammability standard for children's sleepwear size O-6X	≤ $0
306	Flammability standard for upholstered furniture	$300
292	Flammability standard for children's sleepwear size 7-14	$45,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
372	Flammability standard for upholstered furniture	$68,000
12	Flammability standard for children's sleepwear size 7-14	$160,000
292	Flammability standard for children's clothing size 0–6X	$220,000
292	Flammability standard for children's clothing size 7-14	$15,000,000
	Helmet promotion	
31	Mandatory motorcycle helmet laws	≤ $0
186	Federal mandatory motorcycle helmet laws (vs. state determined policies)	$2,000
175	Mandatory motorcycle helmet laws	$2,000
1006	Promote voluntary helmet use while riding All-Terram Vehicles	$44,000
	Highway improvement	
747	Grooved pavement on highways	$29,000
1105	Decrease utility pole density to 20 (vs 40) poles per mile on rural roads	$31,000
747	Channelized turning lanes at highway intersections	$39,000
747	Flashing lights at rail-highway crossings	$42,000
747	Flashing lights and gates at rail-highway crossings	$45,000
747	Widen existmg bridges on highways	$82,000
1107	Widen shoulders on rural two-lane roads to 5 (vs. 2) feet	$120,000
1105	Breakaway (vs. existing) utility poles on rural highways	$150,000
1107	Widen lanes on rural roads to 11 (vs. 9) feet	$150,000
1105	Relocate utility poles to 15 (vs. 8) feet from edge of highway	$420,000
	Light truck design improvements	
1091	Ceilings of 0–6000 lb light trucks withstand forces of 1.5 X vehicle's weight	$13,000
1091	Ceilings of O-10.000 lb light trucks withstand forces of 1.5 X vehicle's weight	$14,000
1091	Ceilings of O-8500 lb light trucks withstand forces of 1.5 X vehicle's weight	$78,000
1091	Ceilings of 0–10,000 lb light trucks withstand 5000 lb of force	$170,000
1126	Side door strength standard in light trucks to minimize front seat intrusion	$190,000
1091	Ceilings of O-6000 lb light trucks withstand 5000 lb of force	$1,100,000
1126	Side door strength standard in light trucks to minimize back seat intrusion	$10,000,000
	Light truck occupant restraint systems	
1089	Driver and passenger nonmotorized automatic (vs. manual) belts in light trucks	$14,000
834	Push-button release and emergency locking retractors on truck and bus seat belts	$14,000
1089	Driver and passenger motorized automatic (vs. manual) belts in light trucks	$50,000
1089	Driver airbag (vs. manual lap/shoulder belt) in light trucks	$56,000
1089	Driver and passenger airbags (vs. manual lap/shoulder belts) in light trucks	$67,000
	Natural disaster preparedness	
1221	Soils testing and improved site-grading in landslide-prone areas	≤ $0
1221	Ban residential growth in tsunami-prone areas	≤ $0
710	Strengthen unreinforced masonry San Francisco bldgs to LA standards	$21,000
710	Strengthen unreinforced masonry San Francisco bldgs to beyond LA standards	$1,000,000
1221	Triple the wind resistance capabilities of new buildings	$2,600,000
1221	Construct sea walls to protect against 100-year storm surge heights	$5,500,000
1221	Strengthen buildings in earthquake-prone areas	$18,000,000
	School bus safety	
1124	Seat back height of 24" (vs. 20") in school buses	$150,000
1124	Crossing control arms for school buses	$410,000
1124	Signal arms on school buses	$430,000
1124	External loud speakers on school buses	$590,000
1124	Mechanical sensors for school buses	$1,200,000
1124	Electronic sensors for school buses	$1,500,000
1124	Seat belts for passengers in school buses	$2,800,000
1124	Staff school buses with adult monitors	$4,900,000
	Speed limit	
9	National (vs. state and local) 55 mph speed limit on highways and interstates	$6,600
175	Full (vs. 50%) enforcement of national 55 mph speed limit	$16,000

APPENDIX A. Continued.

Ref no.*	Life-saving intervention^b	Cost/life-year^c
353	National (vs. state and local) 55 mph speed limit on highways and interstates	330,000
185	National (vs. state and local) 55 mph speed limit on highways	659.000
2	National (vs. state and local) 55 mph speed limit	889,000
185	National (vs. state and local) 55 mph speed limit on rural interstates	$5 10,000
Traffic safety education		
175	Driver improvement schools (suspending/revoking license) for bad drivers	≤ $0
175	Media campaign to increase voluntary use of seat belts	5310
175	Public pedestrian safety information campaign	$500
175	Improve traffic safety information for children grades K-12	$710
175	Motorcycle rider education program	$5,700
175	Improve motorcycle testing and licensing system	88,700
157	Improve basic driver training	$20,000
175	Alcohol safety programs for drunk drivers	$21,000
175	Multimedia retraining courses for injury-prone drivers	$23,000
175	Improve educational curriculum for beginning drivers	$84,000
175	First aid training for drivers	$180,000
1124	Improve pedestrian education programs for school bus passengers grades K-6	$280,000
175	Warning letters sent to problem drivers	$720,000
Vehicle inspection		
864	Random motor vehicle inspection	$1,500
1172	Compulsory annual motor vehicle inspection	$20,000
864	Periodic motor vehicle inspection	$21,000
64	Periodic motor vehicle inspection	$57,000
175	Periodic inspection of motor vehicle sample focusing on critical components	5390.000
175	Periodic motor vehicle inspection	$1,300,000
Injury reduction interventions. miscellaneous		
192	Terminate sale of three-wheeled All-Terrain Vehicles	≤ $0
175	Require front and rear lights to be on when motorcycle is in motion	$1,100
175	Selective traffic enforcement programs at high-risk times and locations	$5,200
217	Insulate omnidirectional CB antennae to avert electrocution	38,500
311	Oxygen depletion sensor systems for gas space heaters	$13,000
863	Require employers to ensure employees' motor vehicle safety	$25,000
372	"American" oxygen depletion sensor system for gas space heaters	$51,000
1160	Workplace practice standard for electric power generation operation	$59,000
175	Pedestrian and bicycle visibility enhancement programs	$73,000
315	Lock out or tag out of machinery in repair	599,000
372	"French" oxygen depletion sensor system for gas space heaters	$130,000
1005	Redesign chain saws to reduce rotational kickback injuries	8230,000
101	Ground fault circuit interrupters	$1,100,000
468	Ejection system for Air Force B-58 bomber	$1,200,000
1161	Equipment. work practices, and training standard for hazardous waste cleanup	$2,000,000

Toxin control

Arsenic control		
497	Arsenic emission standard (vs. capture and control) at high-emit copper smelters	$36,000
1216	Arsenic emission control at high-emitting copper smelters	$74,000
497	Arsenic emission standard (vs. capture and control) at glass plants	$2,300,000
1183	Arsenic emission control at low-emitting ASARCO/El Paso copper smelter	$2,600,000
1216	Arsenic emission control at glass plants	$2,900,000
497	Arsenic emission standard (vs. capture and control) at low-emit copper smelters	$3,900,000
881	Arsenic emission control at secondary lead plants	$7,600,000
1216	Arsenic emission control at low-emitting copper smelters	$16,000,000
1183	Arsenic emission control at low-emitting copper smelters	$29,000,000
881	Arsenic emission control at primary copper smelters	$30,000,000
881	Arsenic emission control at glass manufacturing plants	$5 1,000,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
1183	Arsenic emission control at low-emttting Copper Range/White Pine copper smelter	$890,000,000
Asbestos control		
881	Ban asbestos in brake blocks	$29.000
819	Asbestos exposure standard of 1 .0 (vs. 2.0) fibers/cc in asbestos cement industry	$55,000
881	Ban asbestos in pipeline wrap	$65.000
881	Ban asbestos in specialty paper	$80,000
651	Ban products containing asbestos (vs. 0.2 fibers/cc standard)	$220.000
651	Phase in ban of products containing asbestos (vs. 0.2 fibers/cc standard)	$240,000
819	Asbestos exposure standard of 1 .0 (vs. 2.0) fibers/cc in textile industry	$400,000
387	Asbestos exposure standard of 0.2 (vs. 2.0) fibers/cc in ship repair industry	$410.000
881	Ban asbestos in rooting felt	$550,000
881	Ban asbestos in friction materials	$580,000
881	Ban asbestos in non-roofing coatings	$790,000
881	Ban asbestos in millboard	$920,000
819	Asbestos exposure standard of 0.2 (vs. 0.5) fibers/cc in friction products industry	$1,200,000
819	Asbestos exposure standard of 0.2 (vs. 0.5) fibers/cc in cement industry	$1,900.000
881	Ban asbestos in beater-add gaskets	$2,000,000
881	Ban asbestos in clutch facings	$2,700,000
881	Ban asbestos in roof coatings	f5.200.000
881	Ban asbestos in sheet gaskets	$5,700,000
881	Ban asbestos in packing	$5,700,000
819	Ban products containing asbestos (vs. 0.5 fibers/cc) in textile industry	$6,800,000
881	Ban asbestos in reinforced plastics	$8,200.000
881	Ban asbestos in high grade electrical paper	$15,000,000
387	Asbestos exposure standard of 0.2 (vs. 2.0) fibers/cc in construction industry	$29,000.000
881	Ban asbestos in thread, yam. etc.	$34,000,000
819	Asbestos exposure standard of 1 .0 (vs. 2.0) fibers/cc in friction products industry	$41 ,000,000
881	Ban asbestos in sealant tape	$49,000,000
881	Ban asbestos in automatic transmission components	$66,000.000
881	Ban asbestos in acetylene cylinders	$350.000.000
881	Ban asbestos in missile liner	$420,000,000
881	Ban asbestos in diaphragms	$1,400,0000,000
Benzene control		
1139	Benzene exposure standard of 1 (vs. 10) ppm in rubber and tire industry	$76.000
881	Control of new benzene fugative emissions	$230.000
881	Control of existing benzene fugative emissions	$240,000
721	Benzene exposure standard of 1 (vs. 10) ppm	$240.000
881	Benzene emission control at pharmaceutical manufacturing plants	$460,000
881	Benzene emission control at coke by-product recovery plants	$1,400,000
1139	Benzene exposure standard of 1 (vs. 10) ppm in coke and coal chemicals industry	$3,000.000
881	Benzene emission control during transfer operations	$4,100.000
881	Control of benzene storage vessels	$14,000,000
881	Benzene emission control at ethylbenzene/styrene process vents	$14,000,000
881	Benzene emission control during waste operations	$19,000.000
881	Benzene emission control at maleic anhydride plants	$20,000,000
881	Benzene emission control at service stations storage vessels	$91,000,000
881	Control of benzene equipment leaks	$98,000,000
881	Benzene emission control at chemical manufacturing process vents	$180,000,000
881	Benzene emission control at bulk gasoline plants	$230,000,000
881	Benzene emission control at chemical manufacturing process vents	$530,000,000
881	Benzene emission control at rubber tire manufacturing plants	$20,000,000,000
Chlorination		
42	Chlorination of drinking water	$3.100
42	Chlorination, filtration and sedimentation of drinking water	$4,200
Coal and coke oven emissions control		
38	Coal-fired power plants emission control through high stacks etc.	≤ $0

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
38	Coal-fired power plants emission control through coal beneficiation etc.	$37,000
745	Coke oven emission standard for iron- or steel-producing plants	$130,000
745	Acrylonitrile emission control via best available technology	$9,000,000
	Formaldehyde control	
716	Ban urea-formaldehyde foam insulation in homes	$11,000
311	Ban urea-formaldehyde foam insulation in homes	$220,000
1164	Formaldehyde exposure standard of 1 (vs. 3) ppm in wood industry	$6,700,000
	Lead control	
1217	Reduced lead content of gasoline from 1.1 to 0.1 grams per leaded gallon	≤ $0
	1,3 Butadiene control	
1138	1.3 Butadiene exposure standard of 10 (vs. 1000) ppm PEL in polymer plants	$340,000
1138	1,3 Butadiene exposure standard of 2 (vs. 1000) ppm PEL in polymer plants	$770,000
	Pesticide control	
713	Ban chlorobenzilate pesticide on noncitrus	≤ $0
403	Ban amitraz pesticide on apples	≤ $0
403	Ban amitraz pesticide on pears	$350,000
713	Ban chlorobenzilate pesticide on citrus	$1,200,000
	Pollution control at paper mills	
844	Chloroform emission standard at 17 low cost pulp mills	≤ $0
844	Chloroform private well emission standard at 7 papergrade sulfite mills	$25,000
844	Chloroform private well emission standard at 7 pulp mills	$620,000
844	Chloroform reduction by replacing hypochlorite with chlorine dioxide at 1 mill	$990,000
844	Dioxin emission standard of 5 lbs/air dried ton at pulp mills	$4,500,000
844	Dioxin emission standard of 3 (vs. 5) lbs/air dried ton at pulp mills	$7,500,000
844	Chloroform emission standard of 0.001 (vs. 0.01) risk level at pulp mills	$7,700,000
844	Chloroform reduction by replace hypochlorite with chlorine dioxide at 70 mills	$8,700,000
844	Chloroform reduction at 70 (vs. 33 worst) pulp and paper mills	$15,000,000
844	Chloroform reduction at 33 worst pulp and paper mills	$57,000,000
844	Chloroform private well emission standard at 48 pulp mills	$99,000,000,000
	Radiation control	
468	Automatic collimators on X-ray equipment to reduce radiation exposure	$23,000
881	Radionuclide emission control at underground uranium mines	$79,000
881	Radionuclide emission control at Department of Energy facilities	$730,000
1216	Radionuclide control via best available technology in uranium mines	$850,000
44	Radiation standard "as low as reasonably achievable" for nuclear power plants	$1,100,000
468	Radiation levels of 0.3 [vs. 1.0) WL at uranium mines	$1,600,000
1215	Radiation standard "as low as reasonably achievable" for nuclear power plants	$2,500,000
881	Radionuclide emission control at surface uranium mines	$3,900,000
881	Radionuclide emission control at elemental phosphorous plants	$9,200,000
881	Radionuclide emission control at operating uranium mill tailings	$11,000,000
1216	Radionuclide control via best available technology in phosphorous mines	$16,000,000
881	Radionuclide emission control at phosphogypsum stacks	$29,000,000
881	Radionuclide emission control during disposal of uranium mill tailings piles	$40,000,000
1216	Rdiation emission standard for nuclear power plants	$100,000,000
468	Radiation emission standard for nuclear power plants	$180,000,000
926	Thin, flexible, protective leaded gloves for radiologists	$190,000,000
881	Radionuclide emission control at coal-fired industrial boilers	$260,000,000
881	Radionuclide emission control at coal-fired utility boilers	$2,400,000,000
881	Radionuclide emission control at NRC-licensed and non-DOE facilities	$2,600,000,000
881	Radionuclide emission control at uranium fuel cycle facilities	$34,000,000,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
	Radon control	
1266	Radon remediation in homes with level ≥ 2 pCi/L	$6,100
1267	Radon remediation in homes with level ≥ 8 pCi/L	$35,000
1030	Radon limit after disposal of uranium mill tailings of (p(i/m2s) 60)	$49,000
1265	Radon remediation in homes with ≥ 4 pCi/L	$140,000
1030	Radon limit after disposal of uranium mill tailings of (p(i/m2s). 6)	$260.000
881	Radon emission control at Department of Energy facilities	$5,100,000
	SO2 control	
923	SO2 controls by installation of capacity to desulphurize residual fuel oil	≤ $0
	Trichloroethylene control	
1215	Trichloroethylene standard of 2.11 microgram/L in drinking water	$34,000,000
	Vinyl chloride control	
881	Vinyl chloride emission control at EDCNC and PVC plants	$1,600,000
718	Vinyl chloride emission standard	$1,700,000
	VOC control	
1122	South Coast of California ozone control program	$610,000
	Toxin control, miscellaneous	
725	Process safety standard for management of hazardous chemicals	$77,000
	Medicine	
	Alpha antinypsin replacement therapy	
1004	Alpha antitrypsin replacement (vs. med) therapy for smoking men age 70	$31,000
1004	Alpha antitrypsin replacement (vs. med) therapy for smoking women age 40	$36,000
1004	Alpha antitrypsin replacement (vs. med) therapy for nonsmoking women age 30	$56,000
1004	Alpha antitrypsin replacement (vs. med) therapy for nonsmoking men age 60	$80,000
	Beta-blocker treatment following myocardial infarction	
952	Beta blockers for myocardial infarction survivors with no angina or hypertension	$360
952	Beta-blockers for myocardial infarction survivors	$850
176	Beta-blockers for high-risk myocardial infarction survivors	$3,000
176	Beta-blockers for low-risk myocardial infarction survivors	$17,000
	Breast cancer screening	
142	Mammography for women age 50	$810
283	Mammography every 3 years for women age 50-65	$2,700
658	Annual mammography and breast exam for women age 35-49	$10,000
658	Annual physical breast cancer exam for women age 35-49	$12,000
611	Annual mammography and breast exam (vs. just exam) for women age 40-64	$17,000
1230	Annual mammography and breast exam for women age 40-49	$62,000
1230	Annual mammography and breast exam (vs. just exam) for women age 40-49	$95,000
86	Annual mammography for women age 55-64	$110,000
1230	Annual mammography (vs. current screening practices) for women age 40-49	$190.000
	Breast cancer treatment	
1238	Postsurgical chemotherapy for premenopausal women with breast cancer	$18,000
1238	Postsurgical chemotherapy for women with breast cancer age 60	$22,000
1269	Bone marrow transplant and high (vs. standard) chemotherapy for breast cancer	$130,000
	Cervical cancer screening	
1316	Cervical cancer screening every 3 years for women age 65	≤ $0
120	Cervical cancer screening every 10 years for women age 30-39	$410
618	One time mass screening for cervical cancer for women age 38	$1,200
1316	Cervical cancer screening every 5 years for women age 65+	$1,900
1316	One time cervical cancer screening for women age 65+	52,100

APPENDIX A. Continued.

Ref no.*	Life-saving intervention'	Cost/life-year'
120	Cervical cancer screeningevery 2 (vs. 3) years for women age 30-39	$2,300
1316	Cervical cancer screening every 3 years for women 65+	52,800
120	Annual (vs. every2 years) cervical cancer screening for women age 30-39	$4,100
783	One time cervical cancer screening for never-screened poor women age 65	$5,000
707	Annual cervical cancer screening for women beginning at age 60	$11,000
81	Cervical cancer screening every years (vs. never) for women age 20	$12,000
88	One time mass screening for cervical cancer	$13,000
258	Cervical cancer screening every 5 years for women 35+ with 3+ kids	$32,000
1316	Cervical cancer screening every 3 years for regularly-screened women65+	$41,000
1316	Annual (vs. every 3 years) cervical cancer screening for women 65+	$49,000
707	Annual cervical cancer screening for women beginning at 2le	550.000
603	Annual cervical cancer screening for women beginning at age 20	$82,000
81	Cervical cancer screening every 3 (vs. 4) years for women age 20	$220,000
456	Annual cervical cancer screening for women beginning at age 20	5220,000
81	Cervical cancer screeningevery 2 (vs. 3) years for women age 20	$3 10,000
81	Annual (vs. every 2 years) cervical cancer screening for women age 20	$1,500,000
	Childhood immunization	
65	Immunization for all infants and pre-school children (vs. scattered efforts)	≤ $0
143	Pertussis, diphtheria. and tetanus (vs. just diphtheria and tetanus) immunization	≤ $0
349	Measles, mumps, and rubella immunization for children	≤ $0
8 12	Polio immunization for children age O-4	≤ $0
812	Rubella vaccination for children age 2	≤ $0
1178	National measles eradication program for children	≤ $0
	Cholesterol screening	
605	Cholesterol screening for boys age 10 and thfirst-degree relatives	$4,600
605	Cholesterol screening for boys ag10	$6,500
	Cholesterol treatment	
1071	Lovastatin for men age 35-54 with heart disease ≥a250 mg/dL	≤ $0
785	Low-cholesterol diet for men age 60 and 1mg/dL	$12,000
2	Low-cholesterol diet for men age 30	$19.000
1071	Lovastatin for men ag65–64 with heart disease an< 250 mg/dL	$20,000
791	Oat bran cholesterol reduction for men age 48 ≥a265 mg/dL	$24,000
785	Lovastatin/low cholesterol diet (vs. diet) for men age 60 and 3mg/dL	$26,000
785	Cholestyramine/low cholesterol diet (vs. diet) for men age 60 and 3mg/dL	$3 1,000
1071	Lovastatin for men age 45-54 with no heart disease ≥a300 mg/dL	$34,000
768	Cholestyramine/low cholesterol diet (vs. diet) for age 35-39 and 2mg/dL	$100,000
768	Cholestyramine/low cholesterol diet (vs. diet) for men age 50-54 and 2mg/dL	$150,000
791	Cholestyramine for men age 48 an≥ 265 mg/dL	$160,000
768	Cholestyramine/low cholesterol diet (vs. cholestyramine) age 35-39 2mg/dL	$200,000
1191	Cholestyramine for men with cholesterol levels above the 95th percentile	$230,000
785	Low-cholesterol diet for men age 20 and 1mg/dL	$360,000
1071	Lovastatin 40 (vs. 20) mg for women age 35-44 with heart dis≤a250 mg/dL	$360,000
768	Cholestyramine/low cholesterol diet (vs. diet) for men age 65-69 and 2mg/dL	$920,000
1071	Lovastatin for women ag35–44 with no heart disease an≥ 300 mg/dL	$1,200,000
785	Cholestyramine/low cholesterol diet (vs. diet) for men age 20 and 2mg/dL	$1,300,000
785	Cholestyramine/low cholesterol diet (vs. diet) for men age 20 and 2mg/dL	$1,800,000
	Clinical trials	
1134	Women's Health Trial to evaluate low-fat diet in reducing breast cancer	$18,000
1004	Clinical trial to evaluate alphantitrypsin replacement therapy	$53,000
	Colorectal screening	
86	Annual stool guaiac colon cancer screening for people 55+	≤ SO
96	One stool guaiac colon cancer screening for people 40+	$660
528	One hemoccult screening for colorectal cancer for asymptomatic people age 55	$1,300
1135	Colorectal cancer screening for people ag40+	$4,500
1135	Colonoscopy forcolorectal cancer screening for people ag40+	$90,000
96	Six (vs. five) stool guaiacs colon cancer screening for people 40+	$26,000,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
	Coronary artery bypass graft surgery (CABG)	
358	Left main coronary artery bypass graft surgery (vs. medical management)	$2,300
99	Left main coronary artery bypass graft surgery (vs. medical management)	$5,600
99	3-vessel coronary artery bypass graft surgery (vs. medical management)	$12,000
1200	3-vessel coronary artery bypass graft surgery (vs. PTCA) for severe angina	$23,000
358	2-vessel coronary artery bypass graft surgery (vs. medical management)	$28,000
99	2-vessel coronary artery bypass graft surgery (vs. medical management)	575,000
1200	3-vessel coronary artery bypass graft surgery (vs. PTCA) for mild angina	$ 100,000
1200	2-vessel coronary artery bypass graft surgery (vs. PTCA) for severe angina	$430,000
	Drug and alcohol treatment	
86	Occupational assistance programs for working problem-drinkers	≤ $0
650	Detoxification for heroin addicts	≤ $0
650	Methadone maintenance for heroin addicts	≤ $0
650	Narcotic antagonists for heroin addicts	≤ $0
	Emergency vehicle response	
987	Defibrillators in emergency vehicles for resuscitation after cardiac arrest	$39
987	Defibrillators in emergency vehicles staffed with paramedics (vs. EMTs)	$390
986	Defibrillators in ambulances for resuscitation after cardiac arrest	$460
987	Emergency vehicle response for cardiac arrest	$820
2	Advanced life support paramedical equipped vehicle	$5,400
237	Advanced resuscitative care (vs. basic emergency services) for cardiac arrest	$27,000
175	Combined emergency medical services for coordinated rapid response	$120,000
	Gastrointestinal screening and treatment	
578	Sclerotherapy (vs. medical therapy) for esophageal bleeding in alcoholics	≤ $0
148	Truss (vs. elective inguinal hemiorrhaphy) for inguinal hernia in elderly patients	≤ $0
352	Expectant management of silent gallstones in men age 30	≤ $0
797	Home (vs. hospital) parenteral nutrition for patients with acute loss of bowels	≤ $0
797	Home parenteral nutrition for patients with acute loss of bowels	≤ $0
584	Pre-operative total parenteral nutrition in gastrointestinal cancer patients	≤ $0
235	Ulcer therapy (vs. surgery) for duodenal ulcers	$6,600
577	Medical or surgical treatment for advanced esophageal cancer	$12,000
587	Surgery for liver cirrhosis patients with acute variceal bleeding	$17,000
1046	Ulcer (vs. symptomatic) therapy for episodic upper abdomen discomfort	$41.000
1067	Misoprostol to prevent drug-induced gastrointestinal bleed in at-risk patients	$47,000
587	Medical management for liver cirrhosis patients with acute variceal bleeding	$61,000
1067	Misoprostol to prevent drug-induced gastrointestinal bleed	$210,000
1046	Upper gastrointestinal X-ray and endoscopy (vs. ulcer therapy) for gastric cancer	$300,000
1046	Upper gastrointetinal X-ray and endoscopy (vs. antacids) for gastric cancer	$420,000
	Heart disease screening and treatment, miscellaneous	
518	Exercise stress test for asymptomatic men age 60	$40
358	Pacemaker implant (vs. medical management) for atrioventricular heart block	$1,600
251	Reconstruct mitral valve for symptomatic mitral valve disease	$6,700
350	Exercise stress test for age 60 with mild pain and no left ventricular dysfunction	$13,000
990	Implantable cardioverter-defibrillator (vs. medical therapy) for cardiac arrest	$23.000
1066	Coronary angiogaphy (vs. medical therapy) in men age 45-64 with angina	$28,000
346	Regular leisure time physical activity, such as jogging, in men age 35	$38,000
25 1	Replace (vs. reconstruct) mitral valve for symptomatic mitral valve disease	$150,000
	Heart transplantation	
544	Heart transplantation for patients age 55 or younger and favorable prognosis	$3,600
835	Heart transplantation for patients age 50 with terminal heart disease	$100,000
	HIV/AIDS screening and prevention	
6	Voluntary (vs. limited) screening for HIV in female drug users and sex partners	≤ $0
1097	Screen blood donors for HIV	$14,000
1100	Screen donated blood for HIV with an additional FDA-licensed test	$880,000

APPENDIX A. Continued.

Ref no.*	Life-saving intervention[b]	Cost/life-year[c]
1102	Universal (vs. category-specific) precautions to prevent HIV transmission	S890,000
	HIV/AIDS treatment	
1199	Zidovudine for asymptomatic HIV+ people	≤SO
1121	Oral dapsone for prophylaxis of PCP in HIV+ people	516,000
1121	Aerosolized pentamidine for prophylaxis of PCP in HIV+ people	520,000
1096	AZT for people with AIDS	826,000
1264	Prophylactic AZT following needlestick injury in health care workers	$41,000
1117	Zidovudine for asymptomatic HIV+ people	$45,000
	Hormone replacement therapy	
227	Estrogen for menopausal women age SO	≤ $0
748	Estrogen-progesrin for symptomatic monopausal women age 50	$15,000
748	Estrogen for symptomatic menopausal women age 50	$26,000
748	Estrogen-progestin for 15 years in asymptomatic menopausal women age SO	$30,000
748	Estrogen-progestm for 5 years in asymptomatic menopausal women age SO	532,000
90	Estrogen for post-menopausal women age 55-70	$36,000
227	Estrogen for menopausal women age 50	$42,000
90	Estrogen for asymptomatic post-menopausal women age SO-65	877,000
90	Estrogen for symptomatic post-menopausal women age 50–65	$81,000
748	Estrogen for asymptomatic menopausal women age 50	589,000
244	Hormone replacement for asymptomatic perimenopausal white women age SO	$120,000
227	Estrogen-progestin for post-menopausal women age 60	5130,000
90	Estrogen for asymptomatic post-menopausal women age 55–70	$250,000
	Hypertension drugs	
225	Antihypertensive drugs for men age 25+ and 125 mmHg	$3,800
225	Antihypertensive drugs for men age 25+ and 85 mmHg	$4,700
1068	Beta-blockers for hypertensive patients age 35–64 no heart disease and ≥ 95 mmHg	$14,000
91	Antihypertensive drugs for patients age 40 and ≥ 105 mmHg	816,000
91	Antihypertensive drugs for patients age 40 and 95–104 mmHg	632,000
1068	Captopril for people age 35–64 with no heart disease and ≥ 95 mmHg	$93,000
	Hypertension screening	
111	Hypertension screening for Black men age 55–64 and ≥ 90 mmHg	$5,000
761	Hypertension screening for men age 45-54	$5,200
111	Hypertension screening for White men age 45-54 and ≥ 90 mmHg	$6,500
111	Hypertension screening for Black women age 45–54 and ≥ 90 mmHg	$8,400
1202	Hypertension screening for asymptomatic men age 60	311,000
1202	Hypertension screening for asymptomatic women age 60	$17,000
1202	Hypertension screening for asymptomatic men age 40	$23,000
761	Hypertension screening every 5 years for men age 55-64	$31,000
1202	Hypertension screening for asymptomatic women age 40	$36,000
111	Hypertension screening for White women age 18-24 and ≥ 90 mmHg	537,000
1202	Hypertension screening for asymptomatic men age 20	$48,000
1202	Hypertension screening for asymptomatic women age 20	587,000
	Hysterectomy to prevent *uterine cancer*	
750	Hysterectomy without oopherectomy for asymptomatic women age 35	≤ $0
750	Hysterectomy with oopherectomy for asymptomatic women age 40	$51,000
758	Hysterectomy for asymptomatic women age 35	$230,000
	Influenza vaccination	
455	Influenza vaccination for all citizens	$140
156	Influenza vaccination for high risk people	$570
156	Influenza vaccination for people age 5+	$1.300
	Intensive care	
422	Coronary care unit for patients under age 65 with cardiac arrest	$390
125	Intensive care for young patients with barbiturate overdose	$490
1208	Intensive care and mechanical ventilation for acute respiratory distress syndrome	53,100

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention	Cost/life-year[c]
125	Intensive care for young patients with polyradiculitis	$3,600
1208	Intensive care and mechanical ventilation for acute respiratory failure	$4,700
854	Intensive care for unstable patients with unpredictable clinical course	$21,000
1208	Intensive care for patients with heart disease and respiratory failure	$21,000
125	Intensive care for patients with multiple trauma	$26,000
89	Coronary care unit for emergency patients with acute chest pain	$250,000
602	Intensive care for very ill patients undergoing major vascular surgery	$300,000
602	Intensive care for very ill patients with operative complications	$390,000
602	Intensive care for seriously ill patients with multiple trauma	$460,000
602	Intensive care for very ill patients undergoing neurosurgery for head trauma	$490,000
125	Intensive care for men with advanced cirrhosis, kidney and liver failure	$530,000
602	Intensive care for very ill patients with emergency abdominal catastrophes	$660,000
602	Intensive care for very ill patients undergoing neoplastic disease operations	$820,000
602	Intensive care for very ill patients undergoing major vascular operations	5850,000
602	Intensive care for very ill patients with gastrointestinal bleeding, cirhosis etc.	$950,000
	Leukemia treatment and infection control	
1095	Bone marrow transplant (vs. chemotherapy) for acute nonlymphocytic leukemia	512,000
1095	Bone marrow transplant for acute nonlymphocytic leukemia in adults	$20,000
1095	Chemotherapy for acute nonlymphocytic leukemia in adults	527,000
672	Therapeutic leukocyte transfusion to prevent infection during chemotherapy	$36,000
672	Prophylactic (vs. therapeutic) leukocyte transfusion to prevent infection	$210,000
1239	Intravenous immune globulin to prevent infections in leukemia patients	$7,100,000
	Neonatal intensive care	
335	Neonatal intensive care for infants weighing 1000-1499 grams	$5,700
83	Neonatal intensive care for infants weighing 751-1000 grams	$5,800
335	Neonatal intensive care for infants weighing 500-999 grams	$18,000
1249	Neonatal intensive care for low birth weight infants	$270,000
	Newborn screening	
1195	PKU genetic disorder screening in newborns	≤ $0
1196	Congenital hypothyroidism screening in newborns	≤ SO
1141	Sickle cell screening for Black newborns	$240
1141	Sickle cell screening for non-Black high risk newborns	5110,000~'
1141	Sickle cell screening for newborns	$65,000,000
1141	Sickle cell screening for non-Black low risk newborns	$34,000,000,000
	Organized health services	
1249	Special supplemental food program for women, infants, and children	$3,400
653	Comprehensive (vs. fragmented) health care services	$5,700
653	Comprehensive (vs. fragmented) health care services for mothers and children	$11,000
1249	Organized family planning services for teenagers	$16,000
1191	No cost-sharing (vs. cost sharing) for health care services	$74,000
1249	Community health care services for women and infants	$100,000
	Osteoporosis screening	
244	Bone mass screening and treat if < 0.9 g/(cm)^2 for perimenopausal women age 50	$13,000
244	Bone mass screening and treat if < 1.0 g/(cm)^2 for perimenopausal women age 50	$18,000
244	Bone mass screening and treat if < 1.1 g/(cm)^2 for perimenopausal women age 50	$41,000
	Percutaneous transluminal coronary angioplasty (PTCA)	
358	PTCA (vs. medical management) for men age 55 with severe angina	$5,300
1200	PTCA (vs. medical management) for men age 55 with severe angina	$7,400
358	PTCA (vs. medical management) for men age 55 with mild angina	$24,000
1200	PTCA (vs. medical management) for men age 55 with mild angina	$110,000
	Pneumonia vaccination	
8 12	Pneumonia vaccination for people age 65 +	$1,800
782	Pneumonia vaccination for people age 65+	$2,000
347	Pneumonia vaccination for people age 65+	$2,200

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year
693	Pneumoma vaccination for people age 65+	52,200
812	Pneumonia vaccination for high risk immunodeficient people age 65+	46,500
812	Pneumonia vaccination for people age 45-64	$ 10.000
782	Pneumonia vaccination for high risk people age 25–44	$14.000
812	Pneumonia vaccination for high nsk immunodeficient people age 45-64	$28.000
782	Pneumonia vaccination for low risk people age 25-W	$66.000
782	Pneumonia vaccination for children age 2–4	S 160,000
347	Pneumoma vaccination for children age 2-1	$170,000
693	Pneumonia vaccination for children age 23	5170,000
Prenatal care		
1253	Term guard uterine activity monitor (vs. self-palpation) to detect contractions	≤ $0
924	Financial incentive of $100 to seek prenatal care for low risk women	≤ $0
1250	Universal (vs. existing) prenatal care for women with < 12 years of education	≤ $0
1250	Universal (vs. existing) prenatal care for women with > 12 years of education	≤ $0
1250	Universal (vs. existing) prenatal care for women with 12 years of education	≤ $0
1251	Prenatal screening for hepatitis B in high risk women	≤ $0
1220	Brady method screening for group B streptococci colonization during labor	≤ $0
1256	Prenatal care for pregnant women	≤ $0
340	Antepartum Anti-D treatment for Rh-negative primiparae pregnancies	$1,100
1249	Prenatal care for pregnant women	52,100
340	Antepartum Anti-D treatment for Rh-negative multiparae pregnancies	$2,900
1220	Isada method screening for group B streptococci colonization during labor	55,000
Renal dialysis		
801	Home dialysis for chronic end-stage renal disease	520,000
1049	Home dialysis for end-stage renal disease	$22,000
157	Home dialysis for end-stage renal disease	$23,000
139	Home dialysis for people age 45 with chronic renal disease	$24.000
419	Home dialysis for people age 64 or younger with chronic renal disease	$25.000
1049	Hospital dialysis for end-stage renal disease	s3 1,000
418	Home dialysis for people age 55–60 with acute renal failure	532,000
357	Dialysis for people age 3.5 with end-stage renal disease	938,000
419	Hospital dialysis for people age 55-64 with chronic renal failure	$42,000
689	Home dialysis for end-stage renal disease	$46,000
418	Hospital dialysis for people age 55–60 with acute renal failure	$47,000
342	Dialysis for end-stage renal disease	$51,000
1049	Center dialysis for end-stage renal disease	955,000
1050	Center dialysis for end-stage renal disease	$63,000
157	Center dialysis for end-stage renal disease	$64,000
139	Center dialysis for people age 45 with chronic renal disease	$67,000
801	Center dialysis for end-stage renal disease	$68,000
689	Center dialysis for end-stage renal disease	$71,000
342	Hospital dialysis for end-stage renal disease	$74,000
689	Home dialysis (vs. transplantation) for end-stage renal disease	579,000
Renal dialysis and transplantation		
689	Home dialysis then transplant for end-stage renal disease	$40,000
689	Hospital dialysis then transplant for end-stage renal disease	$46,000
Renal transplantation and infection control		
1065	Cytomegalovirus immune globulin to prevent infection after renal transplant	$3,500
1065	Cytomegalovirus immune globulin to prevent infection after renal transplant	$14,000
157	Kidney transplant for end-stage renal disease	517,000
419	Kidney transplant and dialysis for people age 15–34 with chronic renal failure	$17,000
139	Kidney transplant for people age 45 with chronic renal disease	4 19,000
1050	Kidney transplant from live-related donor for end-stage renal disease	$19,000
357	Kidney transplant from cadaver with cyclosporine (vs. azatbioprine)	$27,000
357	Kidney transplant from cadaver with cyclospotine	$29,000
357	Kidney transplant from cadaver with azathioprine	$29,000

APPENDIX A. Continued.

Ref no.[a]	Life-saving intervention[b]	Cost/life-year[c]
1065	Cytomegalovirus immune globulin to prevent infection after renal transplant	$200,000
	Smoking cessation advice	
1185	Smoking cessation advice for pregnant women who smoke	≤ $0
952	Smoking cessation among patients hospitalized with myocardial infarction	≤ $0
773	Smoking cessation advice for men age 50-54	$990
773	Smoking cessation advice for men age 45-49	$1,100
773	Smoking cessation advice for men age 35-39	$1,400
773	Smoking cessation advice for women age 50-54	$1,700
773	Smoking cessation advice for women age 45-49	41.900
773	Smoking cessation advice for women age 35-39	$2,900
771	Nicotine gum (vs. no gum) and smokmg cessation advice for men age 45-49	$5,800
119	Nicotine gum (vs. no gum) and smoking cessation advice for men age 35-69	$7,500
771	Nicotine gum (vs. no gum) and smoking cessation advice for men age 65–69	$9,100
771	Nicotine gum (vs. no gum) and smoking cessation advice for women age 50-54	$9,700
86	Smoking cessation advice for people who smoke more than one pack per day	$9,800
119	Nicotine gum (vs. no gum) and smoking cessation advice for women age 35-69	$11,000
771	Nicotine gum (vs. no gum) and smoking cessation advice for women age 65-69	$13,000
	Tuberculosis treatment	
784	Isoniazid chemotherapy for high risk White male tuberculin reactors age 20	≤ $0
784	Isoniazid chemotherapy for low risk White male tuberculin reactors age 55	$17,000
	Venous thromboembolism prevention	
230	Heparin (vs. anticoagulants) to prevent venous thromboembolism	≤ $0
769	Compression stockings to prevent venous thromboembolism	≤ $0
770	Compression stockings to prevent venous thmmboembolism	≤ $0
170	Heparin to prevent venous thromboembolism	≤ $0
770	Hepatin and dihydroergotamine to prevent venous thromboembolism	≤ $0
770	Intermittent pneumatic compression to prevent venous thromboembolism	≤ $0
770	Heparin and stockings to prevent venous thromboembolism	≤ $0
770	Warfarin sodium to prevent venous thromboembolism	≤ $0
769	Intermittent pneumatic compression and stockings to prevent thromboembolism	$400
230	Dextran (vs. anticoagulants) to prevent venous thromboembolism	$640
769	Heparin to prevent venous thromboembolism	$960
769	Heparin and stockings to prevent venous thromboembolism	$1,000
769	Heparin and dihydroergotamine to prevent venous thromboembolism	$1,700
769	Intermittent pneumatic compression to prevent venous thromboembolism	$2,400
787	Heparin, 1 day, for women with prosthetic heart valves undergoing surgery	$5,100
769	Hepatin'dihydroergotamine (vs. stockings) to prevent venous thromboembolism	$42,000
787	Heparin, 3 days, for women with prosthetic heart valves undergoing surgery	$4,300,000
	Medicine miscellaneous	
443	Broad-spectrum chemotherapy for cancer of unknown primary origin	≤ $0
728	Cefoxitinigentamicin (vs. ceftizoxime) for intra-abdominal infection	$880
728	Mezlocillinfgentamicin (vs. ceftizoxime) for hospital acquired pneumonia	$1,400
646	Computed tomography in patients with severe headache	$4,800
709	Continuous (vs. nocturnal) oxygen for hypoxemic obstructive lung disease	$7,000
906	Preoperative chest X-rav to detect abnormalities in children	$360,000

[a] Reference numbers correspond to records in the database and to the references listed in Appendix B.

[b] Due to space limitations, life-saving interventions are described only briefly. When the original author compared the intervention to a baseline of "the status quo" or "do nothing" the baseline intervention is omitted here. Other baseline interventions appear as "(vs.)." Cost-effectiveness estimates are based on the particular life-saving intervention, base case intervention, target population, data, and methods as detailed by the original author(s). It is suggested the reader review the original document to gain a full appreciation of the origination of the estimates.

[c] All costs are in 1993 U.S. dollars and were updated with the general consumer price index. To emphasize the approximate nature of estimates. they are rounded to two significant figures.

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[a] Reference numbers correspond to records in the database and to interventions described in Appendix A. Missing numbers reflect documents that were retrieved but did not contain suitable cost-effectiveness data.

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Kennecott Uranium Company
Sweetwater Uranium Project
Catchment Basin Excavation
High Volume Air Samples

Sample Number	Date		Volume	Sample Lower Limit of Detection (LLD)	Natural Uranium	Thorium-230	Radium-226	Natural Uranium % of DAC	Thorium-230 - % of DAC	Radium-226 % of DAC	Natural Uranium % of Effluent Concentration	Thorium-230 % of Effluent Concentration	Radium-226 % of Effluent C\oncentration
	Start	Stop	(milliliters)	(microCurie per milliliter)	(microCurie per milliliter)	(microCurie per milliliter)	(microCurie per milliliter)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
Background	9-Feb-06	10-Feb-06	2.36E+09	1.00E-16	1.00E-16	4.03E-16	1.00E-16	0.0005	0.0067	0.0000	0.11	1.34	0.01
1	8-Mar-06	13-Mar-06	3.37E+09	1.00E-16	3.15E-15	1.35E-15	1.96E-15	0.0158	0.0225	0.0007	3.50	4.50	0.22
2	14-Mar-06	16-Mar-06	3.04E+09	1.00E-16	3.71E-15	1.53E-15	2.10E-15	0.0186	0.0255	0.0007	4.12	5.10	0.23
3	20-Mar-06	22-Mar-06	3.21E+09	1.00E-16	3.16E-16	1.00E-16	3.72E-16	0.0016	0.0017	0.0001	0.35	0.33	0.04
4	23-Mar-06	27-Mar-06	2.10E+09	1.00E-16	5.38E-15	3.62E-15	5.24E-14	0.0269	0.0603	0.0175	5.98	12.07	5.82
5	28-Mar-06	30-Mar-06	2.15E+09	1.00E-16	8.51E-15	2.84E-15	1.01E-13	0.0426	0.0473	0.0337	9.46	9.47	11.22
6	2-Apr-06	3-Apr-06	2.24E+09	1.00E-16	2.81E-15	1.03E-15	1.70E-15	0.0141	0.0172	0.0006	3.12	3.43	0.19
7	10-Apr-06	12-Apr-06	2.12E+09	1.00E-16	3.02E-15	9.91E-16	1.13E-14	0.0151	0.0165	0.0038	3.36	3.30	1.26
8	17-Apr-06	19-Apr-06	1.99E+09	1.00E-16	6.13E-15	1.96E-15	1.96E-15	0.0307	0.0327	0.0007	6.81	6.53	0.22
9	20-Apr-06	25-Apr-06	2.46E+09	1.00E-16	9.35E-16	3.66E-16	1.00E-16	0.0047	0.0061	0.0000	1.04	1.22	0.01
10	26-Apr-06	2-May-06	2.91E+09	1.00E-16	1.35E-14	4.26E-15	5.50E-15	0.0675	0.0710	0.0018	15.00	14.20	0.61
11	3-May-06	9-May-06	2.25E+09	1.00E-16	5.11E-15	2.67E-15	2.53E-15	0.0256	0.0445	0.0008	5.68	8.90	0.28
12	10-May-06	15-May-06	2.62E+09	1.00E-16	3.51E-15	1.00E-16	1.00E-16	0.0176	0.0017	0.0000	3.90	0.33	0.01
13	16-May-06	18-May-06	2.54E+09	1.00E-16	3.03E-15	1.46E-15	1.97E-15	0.0152	0.0243	0.0007	3.37	4.87	0.22
14	22-May-06	24-May-06	2.45E+09	1.00E-16	8.57E-15	3.76E-15	4.08E-15	0.0429	0.0627	0.0014	9.52	12.53	0.45
15	25-May-06	1-Jun-06	3.35E+09	1.00E-16	4.07E-15	2.24E-15	3.01E-15	0.0204	0.0373	0.0010	4.52	7.47	0.33
16	5-Jun-06	7-Jun-06	2.53E+09	1.00E-16	2.89E-15	1.34E-15	1.98E-15	0.0145	0.0223	0.0007	3.21	4.47	0.22
17	8-Jun-06	13-Jun-06	2.47E+09	1.00E-16	8.66E-15	2.23E-15	3.08E-15	0.0433	0.0372	0.0010	9.62	7.43	0.34
18	14-Jun-06	19-Jun-06	2.40E+09	1.00E-16	2.58E-15	1.25E-15	1.71E-15	0.0129	0.0208	0.0006	2.87	4.17	0.19
19	20-Jun-06	22-Jun-06	2.38E+09	1.00E-16	5.13E-15	9.24E-16	1.72E-15	0.0257	0.0154	0.0006	5.70	3.08	0.19
20	26-Jun-06	29-Jun-06	3.33E+09	1.00E-16	2.76E-15	1.47E-15	1.95E-15	0.0138	0.0245	0.0007	3.07	4.90	0.22
21	5-Jul-06	10-Jul-06	3.33E+09	1.00E-16	1.38E-14	6.31E-16	2.28E-15	0.0690	0.0105	0.0008	15.33	2.10	0.25
22	11-Jul-06	13-Jul-06	2.36E+09	1.00E-16	3.01E-15	7.63E-16	2.20E-15	0.0151	0.0127	0.0007	3.34	2.54	0.24
23	17-Jul-06	20-Jul-06	2.66E+09	1.00E-16	3.57E-15	5.26E-16	1.43E-15	0.0179	0.0088	0.0005	3.97	1.75	0.16
24	24-Jul-06	26-Jul-06	2.88E+09	1.00E-16	2.29E-15	8.33E-16	1.18E-15	0.0115	0.0139	0.0004	2.54	2.78	0.13
25	27-Jul-06	2-Aug-06	2.36E+09	1.00E-16	8.35E-15	3.05E-15	3.22E-15	0.0418	0.0508	0.0011	9.28	10.17	0.36
26	3-Aug-06	8-Aug-06	2.86E+09	1.00E-16	6.43E-15	2.90E-15	3.36E-15	0.0322	0.0483	0.0011	7.14	9.67	0.37
27	9-Aug-06	14-Aug-06	2.75E+09	1.00E-16	1.01E-14	3.13E-15	6.55E-15	0.0505	0.0522	0.0022	11.22	10.43	0.73
28	23-Aug-06	28-Aug-06	2.74E+09	1.00E-16	5.95E-15	4.45E-15	1.02E-14	0.0298	0.0742	0.0034	6.61	14.83	1.13
29	29-Aug-06	31-Aug-06	2.91E+09	1.00E-16	3.78E-15	2.44E-15	5.15E-15	0.0189	0.0407	0.0017	4.20	8.13	0.57
30	12-Sep-06	14-Sep-06	3.05E+09	1.00E-16	4.13E-15	2.20E-15	3.61E-15	0.0207	0.0367	0.0012	4.59	7.33	0.40
31	18-Sep-06	20-Sep-06	2.87E+09	1.00E-16	4.91E-15	1.85E-15	3.21E-15	0.0246	0.0308	0.0011	5.46	6.17	0.36
32	21-Sep-06	28-Sep-06	3.56E+09	1.00E-16	4.07E-15	4.61E-15	3.09E-15	0.0204	0.0768	0.0010	4.52	15.37	0.34
33	2-Oct-06	2-Oct-06	7.52E+08	1.00E-16	1.04E-14	7.18E-15	1.08E-14	0.0520	0.1197	0.0036	11.56	23.93	1.20
Average:			2.64E+09		5.29E-15	2.12E-15	7.78E-15	2.64E-02	3.54E-02	2.59E-03	5.88E+00	7.08E+00	8.65E-01

Derived Air Concentrations Used			**Environmental Air Concentrations Used**		
	microCurie per milliliter			**microCurie per milliliter**	
Natural Uranium	2.00E-11	Year	**Natural Uranium**	9.00E-14	Year
Radium-226	3.00E-10	Week	**Radium-226**	9.00E-13	Week
Thorium-230	6.00E-12	Year	**Thorium-230**	3.00E-14	Year

Notes:
Air samples were only collected when equipment was actually operating.
Air sampler was located near TMW-58 at the Northern edge of the excavation restricted area.
Air sampler was pointed Southwest into the prevailing wind to maximize radionuclide concentrations.
No sample exceeded effluent limits for natural uranium, radium-226 or thorium-230 during the entire course of the work.
If a concentration was listed as Non-Detect the Lower Limit of Detection (LLD) was used as a value to remain conservative.
These values are shown in red text

KENNECOTT URANIUM COMPANY

RADIATION DOSIMETRY RESULTS **2006**

Deep Dose

EMPLOYEE TITLE		EMPLOYER	January	February	March	April	May	June	July	August	September	October	November	December
FACILITY SUPERVISOR	FS	KENNECOTT URANIUM COMPANY	M	M	M	M	M	M	M	M	M	M	M	M
MILL FOREMAN	MF	KENNECOTT URANIUM COMPANY	M	M	M	M	M	M	M	M	M	M	M	M
SR. FACILITY TECHNICIAN	FT	KENNECOTT URANIUM COMPANY	M	M	M	M	M	M	Lost	M	M	M	M	M
Administrative Coordinator	AC	KENNECOTT URANIUM COMPANY	M	M	M	M	M	M	M	M	M	M	M	M
CONTRACT EMPLOYEE														
TITLE		**EMPLOYER**												
Project Manager	PM #1	ARCHER CONSTRUCTION, INC.	M	M	M	M	M	M	M	M	M	M	M	M
Project Manager	PM #2	ARCHER CONSTRUCTION, INC.	M	M	M	M	M	M	M	M	M	M	M	M
Equipment Operator	EO# 1	ARCHER CONSTRUCTION, INC.	M	M	M	M	M	M	M	M	M	M	M	M
Equipment Operator	EO# 2	ARCHER CONSTRUCTION, INC.	M	M	M	M	M	M	M	M	M	M	M	M
Equipment Operator	EO# 3	ARCHER CONSTRUCTION, INC.	M	M	M									
Equipment Operator	EO# 4	ARCHER CONSTRUCTION, INC.	M	M	M	M	M							
Equipment Operator	EO# 5	ARCHER CONSTRUCTION, INC.	M	M	M									
Equipment Operator	EO# 6	ARCHER CONSTRUCTION, INC.				M	M	M	M	M	M	M		
Equipment Operator	EO# 7	ARCHER CONSTRUCTION, INC.				M	M	M	M	M	M	M	M	M
Equipment Operator	EO# 8	ARCHER CONSTRUCTION, INC.					M	M	M	M	M	M	M	M
Equipment Operator	EO# 9	ARCHER CONSTRUCTION, INC.								M	M	M	M	M
Equipment Operator	EO# 10	ARCHER CONSTRUCTION, INC.								M	M	M	M	M
Equipment Operator	EO# 11	ARCHER CONSTRUCTION, INC.								M	M	M	M	M
Equipment Operator	EO # 12	ARCHER CONSTRUCTION, INC.										M	M	M
Equipment Operator	EO # 13	ARCHER CONSTRUCTION, INC.											Visitor # 3	M
Equipment Operator	EO # 14	ARCHER CONSTRUCTION, INC.												M
Equipment Operator	EO # 15	ARCHER CONSTRUCTION, INC.	Visitor # 3											
Equipment Operator	EO # 16	ARCHER CONSTRUCTION, INC.												Visitor # 1
Equipment Operator		ARCHER CONSTRUCTION, INC.	Visitor # 2											
VISITOR						M	M	M	M	M	M	M	M	M
VISITOR # 1			M	M	M	M	M	M	M	M	M	M	M	M
VISITOR # 2			M	M	M	M								
VISITOR # 3			M	M	M			M	M	M	M	M	M	M
Surveyor	SURV	ROBERT JACK SMITH AND ASSOCIATES**	M	M	M	M	M	M	M	M	M	M	M	M

M = Minimal repoting service of 1 MREM

Notes: Below lower limit of detection (LLD)

- (red) No longer employed by contractor.
- (green) Not yet hired
- (yellow) Never worked on site

Kennecott Uranium Company
Sweetwater Uranium Project
Catchment Basin Excavation
Breathing Zone Samples

Date	Task	Volume (milliliters)	Sample Lower Limit of Detection (LLD) (microCurie per milliliter)	Natural Uranium (microCurie per milliliter)	Thorium-230 (microCurie per milliliter)	Radium-226 (microCurie per milliliter)	Natural Uranium % of DAC (Percent)	Thorium-230 % of DAC (Percent)	Radium-226 % of DAC (Percent)
1-Mar-06	Truck Driver	1.22E+06	8.20E-15	8.20E-15	5.74E-14	8.20E-15	0.041	0.957	0.003
8-Mar-06	Loader Operator	9.33E+05	1.09E-14	5.79E-13	1.09E-14	1.09E-14	2.895	0.182	0.004
9-Mar-06	Truck Driver	6.27E+05	1.62E-14	7.17E-14	1.62E-14	1.62E-14	0.359	0.270	0.005
15-Mar-06	Truck Driver	8.01E+05	1.27E-14	2.50E-14	1.27E-14	1.27E-14	0.125	0.212	0.004
16-Mar-06	Truck Driver	1.35E+06	7.51E-15	1.85E-14	7.51E-15	7.51E-15	0.093	0.125	0.003
20-Mar-06	Loader Operator	1.52E+06	6.69E-15	1.32E-14	6.69E-15	6.69E-15	0.066	0.112	0.002
21-Mar-06	Truck Driver	1.42E+06	7.13E-15	1.05E-14	7.13E-15	7.13E-15	0.053	0.119	0.002
22-Mar-06	Trackhoe Operator	1.27E+06	7.97E-15	1.18E-14	7.97E-15	7.97E-15	0.059	0.133	0.003
27-Mar-06	Truck Driver	1.26E+06	7.94E-15	7.94E-15	7.94E-15	7.94E-15	0.040	0.132	0.003
27-Mar-06	Loader Operator	1.38E+06	7.25E-15	7.25E-15	2.90E-14	7.25E-15	0.036	0.483	0.002
29-Mar-06	Truck Driver	5.99E+05	1.67E-14	1.67E-14	1.67E-14	1.67E-14	0.084	0.278	0.006
30-Mar-06	Loader Operator	1.18E+06	8.47E-15	8.47E-15	3.39E-14	8.47E-15	0.042	0.565	0.003
3-Apr-06	Truck Driver	1.29E+06	7.75E-15	7.75E-15	7.75E-15	7.75E-15	0.039	0.129	0.003
5-Apr-06	Loader Operator	1.08E+06	9.26E-15	9.26E-15	9.26E-15	9.26E-15	0.046	0.154	0.003
6-Apr-06	Truck Driver	1.19E+08	8.40E-15	8.40E-15	8.40E-15	8.40E-15	0.042	0.140	0.003
10-Apr-06	Water Truck Operator	1.20E+06	8.33E-15	8.33E-15	3.33E-14	8.33E-15	0.042	0.555	0.003
12-Apr-06	Trackhoe Operator	1.29E+06	7.75E-15	7.75E-15	7.75E-15	7.75E-15	0.039	0.129	0.003
17-Apr-06	Trackhoe Operator	6.41E+05	1.56E-14	1.56E-14	1.56E-14	1.56E-14	0.078	0.260	0.005
17-Apr-06	Truck Driver	7.54E+05	1.33E-14	1.33E-14	6.63E-14	1.33E-14	0.067	1.105	0.004
19-Apr-06	Truck Driver	1.50E+06	6.67E-15	6.67E-15	6.67E-15	6.67E-15	0.033	0.111	0.002
19-Apr-06	Backhoe Operator	1.09E+06	9.17E-15	9.17E-15	1.28E-13	9.17E-15	0.046	2.133	0.003
20-Apr-06	Truck Driver	1.23E+06	8.13E-15	1.63E-14	8.13E-15	8.13E-15	0.082	0.136	0.003
20-Apr-06	Loader Operator	8.97E+05	1.11E-14	1.11E-14	1.11E-14	1.11E-14	0.056	0.185	0.004
24-Apr-06	Truck Driver	1.27E+06	7.87E-15	3.45E-14	7.87E-15	7.87E-15	0.173	0.131	0.003
24-Apr-06	Loader Operator	1.12E+06	8.93E-15	8.93E-15	8.93E-15	8.93E-15	0.045	0.149	0.003
25-Apr-06	Truck Driver	1.38E+06	7.25E-15	7.25E-15	3.26E-14	7.25E-15	0.036	0.543	0.002
25-Apr-06	Trackhoe Operator	1.22E+06	8.20E-15	8.20E-15	8.20E-15	8.20E-15	0.041	0.137	0.003
26-Apr-06	Trackhoe Operator	1.31E+06	7.63E-15	7.63E-15	7.63E-15	7.63E-15	0.038	0.127	0.003
26-Apr-06	Truck Driver	1.08E+06	9.26E-15	9.26E-15	9.26E-15	9.26E-15	0.046	0.154	0.003
1-May-06	Loader Operator	1.47E+06	6.80E-15	6.80E-15	6.80E-15	6.80E-15	0.034	0.113	0.002
1-May-06	Truck Driver	1.39E+06	7.19E-15	7.19E-15	1.80E-14	7.19E-15	0.036	0.300	0.002
2-May-06	Truck Driver	1.24E+06	8.06E-15	8.06E-15	1.61E-14	8.06E-15	0.040	0.268	0.003
2-May-06	Truckhoe Operator	1.50E+06	6.68E-15	6.68E-15	6.68E-15	6.68E-15	0.033	0.111	0.002
3-May-06	Truckhoe Operator	1.53E+06	6.54E-15	6.54E-15	6.54E-15	6.54E-15	0.033	0.109	0.002
3-May-06	Truck Driver	1.25E+06	8.01E-15	8.01E-15	2.40E-14	8.01E-15	0.040	0.400	0.003
8-May-06	Truck Driver	1.55E+06	6.45E-15	6.45E-15	6.45E-15	6.45E-15	0.032	0.108	0.002
8-May-06	Truck Driver	1.45E+06	6.90E-15	6.90E-15	6.90E-15	6.90E-15	0.035	0.115	0.002
9-May-06	Truck Driver	8.32E+05	1.20E-14	1.20E-14	1.20E-14	1.20E-14	0.060	0.200	0.004
10-May-06	Truck Driver	1.35E+06	7.41E-15	7.41E-15	7.41E-15	7.41E-15	0.037	0.124	0.002
11-May-06	Loader Operator	1.51E+06	6.62E-15	6.62E-15	6.62E-15	6.62E-15	0.033	0.110	0.002
15-May-06	Truckhoe Operator	1.50E+06	6.67E-15	6.67E-15	6.67E-15	6.67E-15	0.033	0.111	0.002
16-May-06	Truck Driver	1.41E+06	1.35E-13	1.35E-13	1.35E-13	1.35E-13	0.675	2.250	0.045
17-May-06	Truckhoe Operator	1.42E+06	1.34E-13	1.34E-13	1.34E-13	1.34E-13	0.670	2.233	0.045
18-May-06	Loader Operator	1.13E+06	1.68E-13	1.68E-13	1.68E-13	1.68E-13	0.840	2.800	0.056
22-May-06	Truck Driver	7.63E+05	2.49E-13	2.49E-13	2.49E-13	2.49E-13	1.245	4.150	0.083
22-May-06	Truck Driver	1.15E+06	1.65E-13	1.65E-13	1.65E-13	1.65E-13	0.825	2.750	0.055
23-May-06	Loader Operator	1.48E+06	1.28E-13	1.28E-13	1.28E-13	1.28E-13	0.640	2.133	0.043
24-May-06	Truck Driver	1.41E+06	1.35E-13	1.35E-13	1.35E-13	1.35E-13	0.675	2.250	0.045
30-May-06	Truck Driver	1.20E+06	1.67E-13	1.67E-13	1.67E-13	1.67E-13	0.835	2.783	0.056
30-May-06	Truck Driver	1.20E+06	1.67E-13	1.67E-13	1.67E-13	1.67E-13	0.835	2.783	0.056
31-May-06	Truck Driver	1.36E+06	1.40E-13	1.40E-13	1.40E-13	1.40E-13	0.700	2.333	0.047
7-Jun-06	Truck Driver	1.29E+06	7.75E-15	7.75E-15	7.75E-15	7.75E-15	0.039	0.129	0.003
12-Jun-06	Truckhoe Operator	1.26E+06	7.94E-15	7.94E-15	7.94E-15	7.94E-15	0.040	0.132	0.003
13-Jun-06	Truck Driver	1.23E+06	8.13E-15	8.13E-15	8.13E-15	8.13E-15	0.041	0.136	0.003
13-Jun-06	Loader Operator	1.25E+06	1.52E-13	1.52E-13	1.52E-13	1.52E-13	0.760	2.533	0.051
19-Jun-06	Loader Operator	1.29E+06	7.75E-15	7.75E-15	7.75E-15	7.75E-15	0.039	0.129	0.003
20-Jun-06	Truck Driver	1.14E+06	8.77E-15	8.77E-15	8.77E-15	8.77E-15	0.044	0.146	0.003
21-Jun-06	Truckhoe Operator	1.19E+06	8.40E-15	8.40E-15	8.40E-15	8.40E-15	0.042	0.140	0.003
22-Jun-06	Truck Driver	1.45E+06	6.90E-15	6.90E-15	6.90E-15	6.90E-15	0.035	0.115	0.002
27-Jun-06	Truckhoe Operator	1.46E+06	6.85E-15	6.85E-15	6.85E-15	2.40E-14	0.034	0.114	0.008
28-Jun-06	Truckhoe/Loader Op	1.08E+06	9.26E-15	9.26E-15	9.26E-15	9.26E-15	0.046	0.154	0.003
10-Jul-06	Truck Driver	1.37E+06	7.30E-15	7.30E-15	7.30E-15	1.82E-14	0.037	0.122	0.006
11-Jul-06	Truck Driver	1.57E+06	6.37E-15	6.37E-15	6.37E-15	6.37E-15	0.032	0.106	0.002
12-Jul-06	Truck Driver	1.30E+06	7.69E-15	7.69E-15	7.69E-15	7.69E-15	0.038	0.128	0.003
13-Jul-06	Truck Driver	1.37E+06	7.30E-15	7.30E-15	7.30E-15	7.30E-15	0.037	0.122	0.002
17-Jul-06	Truck Driver	1.15E+06	1.66E-13	1.66E-13	1.66E-13	1.66E-13	0.830	2.767	0.055
17-Jul-06	truck	1.44E+06	6.94E-15	6.94E-15	6.94E-15	6.94E-15	0.035	0.116	0.002
18-Jul-06	Truck Driver	1.29E+06	7.75E-15	7.75E-15	7.75E-15	7.75E-15	0.039	0.129	0.003
19-Jul-06	Loader Operator	1.23E+06	8.13E-15	8.13E-15	8.13E-15	8.13E-15	0.041	0.136	0.003

Date	Task	Volume	Sample Lower Limit of Detection (LLD)	Natural Uranium	Thorium-230	Radium-226	Natural Uranium % of DAC	Thorium-230 % of DAC	Radium-226 % of DAC
		(milliliters)	(microCurie per milliliter)	(microCurie per milliliter)	(microCurie per milliliter)	(microCurie per milliliter)	(Percent)	(Percent)	(Percent)
20-Jul-06	Truck Driver	1.42E+06	7.04E-15	7.04E-15	7.04E-15	7.04E-15	0.035	0.117	0.002
24-Jul-06	Trackhoe Operator	1.50E+06	6.67E-15	6.67E-15	6.67E-15	6.67E-15	0.033	0.111	0.002
25-Jul-06	Truck Driver	1.28E+06	7.81E-15	7.81E-15	7.81E-15	7.81E-15	0.039	0.130	0.003
27-Jul-06	Truck Driver	1.04E+06	9.62E-15	9.62E-15	9.62E-15	9.62E-15	0.048	0.160	0.003
27-Jul-06	Trackhoe Operator	1.53E+06	6.54E-15	6.54E-15	6.54E-15	6.54E-15	0.033	0.109	0.002
28-Jul-06	Loader Operator	1.26E+06	7.94E-15	7.94E-15	7.94E-15	7.94E-15	0.040	0.132	0.003
1-Aug-06	Trackhoe Operator	1.74E+06	5.75E-15	5.75E-15	5.75E-15	5.75E-15	0.029	0.096	0.002
2-Aug-06	Truck Driver	1.11E+06	9.01E-15	9.01E-15	9.01E-15	9.01E-15	0.045	0.150	0.003
3-Aug-06	Truck Driver	1.14E+06	8.77E-15	8.77E-15	8.77E-15	8.77E-15	0.044	0.146	0.003
7-Aug-06	Trackhoe Operator	1.37E+06	7.30E-15	7.30E-15	7.30E-15	7.30E-15	0.037	0.122	0.002
10-Aug-06	Truck Driver	1.57E+06	6.37E-15	6.37E-15	6.37E-15	6.37E-15	0.032	0.106	0.002
14-Aug-06	Truck Driver	5.53E+05	1.81E-14	1.81E-14	1.81E-14	1.81E-14	0.091	0.302	0.006
29-Aug-06	Loader Operator	1.38E+06	7.25E-15	7.25E-15	7.25E-15	7.25E-15	0.036	0.121	0.002
30-Aug-06	Truck Driver	1.51E+06	6.62E-15	6.62E-15	6.62E-15	6.62E-15	0.033	0.110	0.002
31-Aug-06	Trackhoe Operator	1.40E+06	7.14E-15	7.14E-15	7.14E-15	7.14E-15	0.036	0.119	0.002
5-Sep-06	Truck Driver	1.51E+06	6.62E-15	6.62E-15	6.62E-15	6.62E-15	0.033	0.110	0.002
6-Sep-06	Truck Driver	1.13E+06	8.85E-15	8.85E-15	8.85E-15	8.85E-15	0.044	0.148	0.003
7-Sep-06	Truck Driver	1.01E+06	9.90E-15	9.90E-15	9.90E-15	9.90E-15	0.050	0.165	0.003
11-Sep-06	Truck Driver	1.51E+06	6.62E-15	6.62E-15	6.62E-15	6.62E-15	0.033	0.110	0.002
11-Sep-06	Truck Driver	1.33E+06	7.52E-16	7.52E-16	7.52E-16	7.52E-16	0.004	0.013	0.000
12-Sep-06	Trackhoe Operator	1.54E+06	6.49E-15	6.49E-15	6.49E-15	6.49E-15	0.032	0.108	0.002
13-Sep-06	Truck Driver	1.06E+06	9.43E-15	9.43E-15	9.43E-15	9.43E-15	0.047	0.157	0.003
14-Sep-06	Dozer Operator	1.43E+06	6.99E-15	6.99E-15	6.99E-15	6.99E-15	0.035	0.117	0.002
18-Sep-06	Truck Driver	1.42E+06	7.04E-15	7.04E-15	7.04E-15	7.04E-15	0.035	0.117	0.002
19-Sep-06	Truck Driver	9.22E+05	1.08E-14	1.08E-14	1.08E-14	1.08E-14	0.054	0.180	0.004
20-Sep-06	Trackhoe Operator	1.23E+06	8.13E-15	8.13E-15	8.13E-15	8.13E-15	0.041	0.136	0.003
21-Sep-06	Trackhoe Operator	1.47E+06	6.80E-15	6.80E-15	6.80E-15	6.80E-15	0.034	0.113	0.002
Average:		2.49E+06	2.71E-14	3.43E-14	3.08E-14	2.74E-14	1.72E-01	5.13E-01	9.13E-03

Notes: All results listed on the laboratory reports as being less than the specific sample's Lower Limit of Detection (LLD) are entered at the LLD value.

Air sample results to date show that the excavation workers are unlikely to receive in excess of 10% of the applicable ALI thus individual monitoring of intakes is not required.

Derived Air Concentrations Used

	microCurie per milliliter	
Natural Uranium	2.00E-11	Year
Radium-226	3.00E-10	Week
Thorium-230	6.00E-12	Year