NWI Land Management

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August 24, 1999

Mr. Mike McCann
U.S. Nuclear Regulatory Commission
Region III
801 Warrenville Rd.
Lisle, IL 60532

Re: Former Michigan Chemical Company Low Level Radioactive Disposal Site Breckenridge, Michigan

Dear Mr. McCann:

This correspondence is submitted pursuant to the June 11, 1999 submittal from NWI Land Management (NWI) regarding the former Michigan Chemical Company low level radioactive disposal site (Site or Breckenridge Disposal Site) in Breckenridge, Michigan. The June 11, 1999 submittal proposed phases of activities to be performed to bring this site to an acceptable closure. The submittal indicated that all historical data would be reviewed to supplement the existing characterization data. The previous characterization data and historical data would be included in a report that would be submitted to the Nuclear Regulatory Commission (NRC) by August 15, 1999. Subsequent communications with the NRC provided that the submittal date would be August 24, 1999.

Attached is a report prepared by SCIENTECH NES, Inc., entitled Radiological Evaluation of the Breckenridge Disposal Site, dated August, 1999 (Report). The Report compares the results of the historical site assessment and site characterization activities, and estimates the actual values of radioactive materials buried at the Breckenridge Disposal Site. To facilitate your review, a copy of the historic references is also attached.

We believe that the next objective is to conduct a dose assessment of the buried material as it is characterized in the Report. We believe that a meeting between the NRC and NWI may be helpful to define the procedures for performing the dose assessment. I will contact you to schedule this meeting.

If you have any questions regarding this matter, please feel free to contact me.

Sincerely,

Lori Peck for

John Hock
Environmental Project Manager

JH:lp
cc: Mike Prattke *w/o attachment*
Ken Kasper, NES *w/ attachment*
Erin Isaacson, VCC *w/ attachment*

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RADIOLOGICAL

EVALUATION OF THE

BRECKENRIDGE DISPOSAL SITE

AUGUST 1999

Prepared for NWI Land Management
by
SCIENTECH NES, Inc.
44 Shelter Rock Road
Danbury, CT 06810

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1.0 INTRODUCTION

The Michigan Chemical Company (MCC) owned and operated a plant in St. Louis, Michigan that manufactured an array of chemical products. Among the products manufactured were fire retardant materials, insecticides, animal food supplements, and rare earth oxides (NRC 1983). From 1967 through 1970, MCC operated an extraction facility as part of the rare earth oxide manufacturing process at the St. Louis plant. Waste products from the extraction process contained small quantities of naturally occurring radioactive materials including thorium and uranium. The solid waste product was a filter cake that was disposed of by burial in accordance with 10 CFR 20.304, *"Disposal by Burial in the Soil"* at a site near Breckenridge known as the former Michigan Chemical Company low level radioactive disposal site. In January 1977, the Michigan Chemical Company merged with Velsicol Chemical Corporation (VCC). The St. Louis plant ceased production in September 1978. In October 1986, ownership of the Breckenridge Property was transferred to NWI Land Management Corporation (NWI).

1.1 Site Description

In this document, the full area of the land near Breckenridge that is owned by NWI Land Management Corporation (NWI) is referred to as the Breckenridge Property. The affected area within the Breckenridge Property that is believed to contain the radioactive material is referred to as the Disposal Site. The Breckenridge Property is located on Madison Road in Bethany Township, Gratiot County, approximately 7.5 km east-northeast of St. Louis, Michigan. The disposal site has been identified as approximately 0.7 acres located on a narrow, triangular shaped parcel of land, within the of 2.2 acre Breckenridge Property. The parcel is bounded on the north by Madison Road and on the east by Bush Creek. The land is basically level. The southern tip of the property is covered with tall trees and brush (NRC 1996). At the northern end is a deep chemical disposal well, which is capped and no longer used. The depth of the well is over 1100 meters (Michigan 1980). The surrounding land use is primarily agricultural; the nearest residence is approximately 0.2 km east of the Breckenridge Property. Figure 1 is a diagram of the Breckenridge Property.

1.2 Background

In 1981, Oak Ridge Associated Universities (ORAU) performed a radiological assessment of the Breckenridge Property under contract with the NRC. The assessment examined the surface and outer boundaries of the disposal area. The report from the survey indicated that the average level of radionuclides was below the NRC guideline for areas accessible to the public and that no migration of materials from the Disposal Site was identified.

In September 1996, an environmental consultant performed shallow trenching at the Disposal Site to investigate reports of improperly buried material. In October, 1996, the Nuclear Regulatory Commission (NRC) was contacted by the Michigan Department of Environmental Quality (MDEQ) to investigate the Disposal Site since the buried waste may have been disturbed during the environmental investigation. The NRC, assisted by the MDEQ, performed a radiological scoping survey of the Breckenridge Property. The NRC report from the survey indicated that no significant risk was identified (NRC 1996). However, since the survey identified levels in excess of the NRC guidelines for unrestricted use, the NRC requested, in a letter dated December 10, 1996, that additional characterization activities be performed.

In July, 1997, NES, Inc. (became SCIENTECH-NES in 1999) performed radiological measurements and sampling to further characterize the Disposal Site in accordance with processes outlined in NUREG/CR-5849, "*Manual for Conducting Radiological Surveys in Support of License Termination* (NRC 1993)." The characterization effort included surface activity measurements, surface dose rate measurements, down-hole activity measurements, and soil sampling at various depths. Due to some analytical irregularities identified by the NRC, the site samples were reanalyzed in 1998. The NRC was provided with the revised analytical data in February of 1999.

During March of 1999, NWI met with the NRC to discuss the findings of the radiological characterization survey and to discuss the Disposal Site's disposition. On April 14, 1999, the NRC issued a letter to NWI directing NWI to bring the Disposal Site to an acceptable closure under the regulatory framework of 10 CFR 20, Subpart E, "Radiological Criteria for License Termination." NWI submitted a proposal for site resolution on June 11, 1999. The June 11, 1999 submittal proposed phases of activities to be performed to bring the Disposal Site to an acceptable closure. The NWI submittal indicated that all historical data would be reviewed to supplement the existing site characterization data in determining the nature and extent of radioactive materials at the site. The previous characterization data and historical data would be included in a report that would be submitted to the NRC by August 15, 1999. Subsequent communications with the NRC provided that the submittal would be August 24, 1999 for the report.

This report includes a review of all available historical information and a summary of the previous site characterization data. The information that follows in Section 2 is a compilation of data resulting from the Historical Site Assessment. Section 3 summarizes site characterization activities after site closure. Section 4 provides an evaluation of the historical data and the characterization data. Section 5 provides a summary of the findings from the radiological evaluation.

2.0 HISTORICAL SITE ASSESSMENT

The information that follows in Section 2 is a compilation of data resulting from the Historical Site Assessment (HSA) of the Disposal Site. The HSA generally consisted of accumulating and reviewing all available historical documents (i.e. prior to the late 1990s) regarding the Disposal Site for information pertinent to a radiological evaluation. The historical documents were believed at the onset to fall into two time periods:

- The active manufacturing and disposal period in the 1960s and early 1970s
- The investigation of the Disposal Site by the NRC in the early 1980s (Oak Ridge evaluation performed in conjunction with the closure of the plant site)

The historical documents were reviewed to better determine the type, quantity, activity, location, burial depth, cover soil depth, and any other relevant data associated with the waste material

2.1 Document Accumulation and Review Process

The NRC Public Document Room was contacted via email with a request for a listing of all documents pertaining to License No. SMB-0833. Through this request, the NRC provided copies of all related documents including license requests, radioactive materials licenses, and other related documents.

NWI requested the original or copies of all active and archived project files regarding the Disposal Site from VCC. The files were received by NWI in April 1999. These documents included radioactive material licenses, correspondence to and from State and Federal regulatory agencies and inter-office correspondence. NWI compiled all documents from those files from the 1960s and early 1970s and sent the information to NES for review. NWI also reviewed all of the documents from the early 1980s. Except for a July, 1982 final report by Oak Ridge Associated Universities and directly associated correspondence, all of the documents from this time period pertained to the closure and dismantling of the main plant site and did not provide any significant information regarding the Disposal Site. No documents from any other time period were present.

A representative from NWI reviewed the public record files regarding the Disposal Site at the NRC Regional office in Lisle, Illinois on June 14, 1999. The public record files were compared against the documents previously compiled from the Public Document Room and the NWI files. No additional relevant documents were obtained during this review.

The former MCC waste control engineer was contacted and interviewed to attempt to verify information found during the document review and to attempt to fill data "gaps". The interview occurred on August 9, 1999 and August 19, 1999 (Lincoln 1999).

2.2 Source Material License Summary

Early records show that in January 1961, MCC had requested that the Atomic Energy Commission (AEC) grant a license so that MCC could store monazite sand at the St. Louis, Michigan site (MCC 1961). The monazite was eventually to be used for its rare earth metal content. The AEC granted a possession license to store and study the monazite under AEC License STC-76 in February 1961 (AEC 1961). In May of 1965, MCC applied for a Source Material License to conduct laboratory and pilot plant studies for a rare earth extraction facility (MCC 1965). Later

that month, the AEC granted such a license, License Number STC-833 (AEC 1965a), which allowed the possession of up to 2,250 pounds of feedstock. This license was amended in November of 1965 to allow the possession of 50 pounds of thorium and the processing of 15 pounds of thorium contained in rare earth feedstocks for additional laboratory and pilot plant studies (AEC 1965b). In September of 1966, MCC requested a license amendment to construct and operate a plant to process yttrium (a rare earth metal) bearing feeds. A license amendment allowing 700 pounds of uranium and thorium was granted in November of 1966. At this time, the License number designation changed to SMB-0833 (AEC 1966). In November of 1968, the AEC granted a license renewal to MCC and increased allowable quantities to 2000 pounds of uranium and thorium (AEC 1968). This amended license was in place until April of 1971, when it was terminated (AEC 1971).

2.3 Waste Generation Process

The waste disposed at the Disposal Site was a single waste stream (i.e. a filter cake) that was generated from the rare earth extraction process at the former MCC main plant site in St. Louis. The filter cake was composed primarily of diatomaceous earth, calcium hydroxide and other metal hydroxides (Lincoln 1999).

The details of the rare earth extraction processes (including uranium and thorium removal) was provided in a letter from MCC to the AEC in 1966 (MCC 1966), which was in reference to a license amendment. The following is taken directly from that letter.

> "The presence of thorium and uranium is undesirable in feed materials accordingly it will be necessary for us [MCC] to remove the thorium and uranium before carrying out further processing of the feed material. The thorium will be removed by dissolving the feed material in sulfuric acid under controlled conditions such that thorium does not dissolve. The thorium compounds will then be separated from the solution by filtration."
>
> "Uranium will be removed from the solution by passing it through an anion exchange column to extract the uranyl sulfate. The uranium will be subsequently leached from the columns with a slightly acidified solution in a closed circuit. Uranium will be precipitated from the eluate by the addition of ammonia. The precipitated ammonia urinate will be filtered. The wet filtercake will be drummed and shipped to one of the uranium processors for purification."

Two years later, in November 1968, an additional description of the rare earth extraction process is provided in a letter from MCC to the AEC (MCC 1968). In the letter, MCC requested permission to continue processing of rare earth feedstocks containing thorium and natural uranium. The ThO_2 and U_3O_8 contents were noted each as generally being in the range of 0.1 percent to 0.3 percent but it also noted that values as high as one percent would be received occasionally. The memorandum stated that thorium and uranium are essentially removed by pre-processing at the vendor's facility [feedstock sources included uranium mill tailings and thorium recovery residues (NRC 1996)]. The thorium and uranium that remained was separated from the rare earth in the process described below.

> "Incoming feed concentrate is leached in acid to dissolve the rare earths. Certain large volume, non-rare earth wastes are precipitated by careful control of leaching conditions. Appreciable quantities of thorium and uranium remain in the insoluble cake, which is

> recovered by filtration. The cake is washed, packaged, and buried according to AEC regulations in a fenced burial site [the Disposal Site]."
>
> "The rare earths and any soluble thorium and uranium are further separated by solvent extraction techniques. This produces a fraction rich in yttrium and a waste fraction that contains most of the uranium and thorium. Uranium is removed from the product fraction by anion exchange."

The memorandum also notes that the solid waste was handled and packaged wet to prevent dust problems. It was noted that the "solids are sticky and should not provide dust problem under normal atmosphere drying." Dr. G. Hoyt Whipple, a certified health physicist who was employed by the University of Michigan at the time, provided radiological safety oversight for MCC's extraction process which he helped design.

According to MCC's former waste control engineer, nearly all of the feedstock came from a byproduct of uranium extraction processes in Canada. The uranium extraction process resulted in two streams. One of the streams was a precipitated "yellow cake," which contained high concentrations of uranium. The other stream was the byproduct of the extraction process known as "green liquor". The rare earth materials were precipitated from the "green liquor". The precipitate from the "green liquor" was the primary feedstock for MCC's rare earth extraction process (Lincoln 1999).

Yttrium was the major rare earth material that resulted from the MCC extraction process. It was used as a phosphor for color televisions and to produce synthetic diamonds and crystals that were used in various electronic devices (Lincoln 1999).

2.4 Regulatory Compliance Overview

Memorandums and letters from within MCC and external to MCC indicate that the Disposal Site was operated in accordance with the regulations that were in place at the time. The regulation that provided requirements for radioactive material burial was the U.S. Code of Federal Regulations, Title 10, Part 20, Paragraph 20.304, "Disposal by burial in soil." This regulation has specific requirements on total amount of buried material (including total number of burials per year), burial depth, and spacing of buried material (AEC 1969). In all reviewed documents, MCC appeared to be completely adhering to all of the requirements. Several communications, including NRC inspection reports, echo this conclusion.

In a memorandum from the AEC to MCC in July of 1968, the AEC noted that it had finished its inspection of MCC and that no item of noncompliance was found (AEC 1968a). Form AEC-591, Inspection Findings and Licensee Acknowledgement, dated June 27, 1968 was attached to this memorandum and restated the findings.

Two years later, in an inter-office memorandum (P. Lincoln to W. Martin), the MCC waste control engineer notes that the AEC had conducted an inspection of MCC records on feed plant operations and disposal of radioactive materials (MCC 1970). The memorandum includes an attachment (form AEC-591) of the Inspection Findings and Licensee Acknowledgement. The attachment reconfirms the 1968 findings - "no item of noncompliance was found."

In August 1972, Michigan's Department of Public Health requested that MCC provide information about its stored and or buried radioactive material (Michigan 1972a). In its response, MCC noted that the Disposal Site's final burial was in March of 1970 and that solid wastes were buried in accordance with AEC regulations for depth, cover layer, and water table (MCC 1972b).

The former MCC waste control engineer noted also that burial operations were monitored by either a maintenance engineer or the waste control engineer to ensure proper waste disposal (Lincoln 1999).

References to Depth of Waste Burial

In the Oak Ridge Report on the Disposal Site (ORAU 1982, Report discussed in Section 2.7), the individual who performed the burials and was interviewed indicated that the trenches were excavated with a backhoe to a minimum depth of approximately 2.8 meters (9 feet) and covered with an overburden of 1.2 meters (4 feet).

The Oak Ridge Report also included analysis of the Breckenridge Property using ground-penetrating radar. The exact locations of the burial trenches were not determined using this technology; however, the depth of the subsurface disturbances ranged from about 1.2 meters (about 4 feet) to 3 meters (about 10 feet). The report also noted that the waste material was probably buried in bulk rather than in metal containers, as suggested by the lack of buried metallic objects. This information, however, is not consistent with statements made by MCC's former waste control engineer (see Section 2.5), who stated that the filtercake material was disposed in fiberboard drums with a metal top, bottom, and ring clamp (Lincoln 1999).

2.5 Quantity and Activity of Buried Material

In a letter from MCC to the Michigan Department of Public Health, the MCC waste control engineer (P Lincoln) clearly describes the Disposal Site and the wastes contained therein (MCC 1972b). In this letter, a legal description of the Breckenridge Property is provided along with quantities and associated radioactivity of wastes buried at the Disposal Site. This document appears to contain the most definitive information on the buried material at the Disposal Site. The former waste control engineer indicated that the filtercake was placed in lined pressed-paper (fiberboard) drums with steel tops and steel bottoms for disposal, and that each drum was weighed after it was filled. The weight totals in the document were calculated from the sum of the weights of the individual drums (Lincoln 1999). The document was written in 1972, the year after the closure of the St. Louis processing facility. The data in the document is summarized below. The units used in Table 2.3 and Table 2.4 are picocuries per gram (pCi/gm).

Table 2.1 - Quantities of Filtercake Disposed

Date	Wet Solids (tons)
1967	47
1968	38
1969 to 1970	66
Total	151

Table 2.2 - Quantity of Filtercake Disposed (microcuries)

Year	Uranium	Thorium
1967	122.7	14,280.0
1968	151.4	17,618.7
1969 to 1970	248.6	28, 931.0
Total Buried Activity (microcuries)	522.7	60,829.7

Table 2.3 - Specific Activity of Filtercake Disposed (pCi/gm)

Year	Uranium	Thorium
1967	2.89	336.00
1968	4.33	505.00
1969 to 1970	4.12	480.00
Total*	3.80	442.00

*(Total multi-year activity/total multi-year weight using Table 2.1 and Table 2.2 data)

Another source of specific activity comes from a November 1967 letter from MCC's analytical contractor (Tracerlab). The specific activity of the filtercake is noted in Table 2.4 (Tracerlab 1967a) and is fairly consistent with the specific activity values used five years later in the 1972 report.

Table 2.4 - Specific Activity of Buried Material from Tracerlab (pCi/gm)

Uranium	Thorium
3.47	402

There is one additional document that discusses quantities and the radioactivity of buried materials. This is in an attachment to an inter-office memorandum (P. Lincoln to W. Martin) that discussed an AEC inspection (MCC 1970). In the memorandum's attachment entitled " Summary of Rare Earth Feed Plant Operations," several relevant issues are noted.

- The processing plant received the last incoming rare earth feed material in October 1967.
- The plant did not operate between April, 1968 and September 1969.
- Plant operations resumed in September 1969 and were completed by March of 1970.

This document also has a section describing the "cake to burial" and details the solid waste stemming from the final 1969 to 1970 run of the extraction facility. The summary uses the same specific activity values as the 1967 Tracerlab values (Tracerlab 1967a). The quantity of material is consistent with the letter from MCC to the Michigan Department of Public Health (MCC 1972b) – 152,771 pounds of filtercake. The total deposit activity is slightly different than the MCC report to the Michigan Department of Public Health. The two sets of data are compared below.

Table 2.5 - Activity Comparison of Filtercake (microcuries)

Year	Uranium	Thorium
1969 to 1970 (Attachment to MCC 1970)	209.1	24,231
1969 to 1970 (MCC 1972b)	248.6	28,931

The reason for the average 16% increase in the total buried activity between the 1970 and 1972 reports was not determined except that the difference was based on a change in specific activity since the weight was constant between the two reports.

Radioactivity Balance

In February of 1968, the University of Michigan consultant to the MCC rare earth extraction process (G. Whipple) issued a memorandum to MCC (D. James) to help MCC set production parameters based on allowable waste quantities generated (Whipple 1968). The memorandum noted that there was an imbalance between the amount of radioactivity going into the extraction process and the combined radioactivity of the wastes and products.

The radioactivity balance noted that the products of the extraction process (product plus all wastes) had over six times the quantity of thorium than the feed material. It also noted that the products only accounted for about one-third of the uranium coming in from the feed material. The memorandum did not include a determination but did suggest possible causes of the imbalance. The former waste control engineer for MCC believed that the matter was discussed between Whipple and the AEC and was determined to not be a significant matter (Lincoln 1999). Follow up documentation on the imbalance issue was not found. Table 2.5 and Table 2.6 show the radioactivity balances that were noted explicitly in the report (Whipple 1968) and derived from another report (MCC 1970).

Table 2.6 - Thorium Activity Balances

	From Whipple 1968		From MCC 1970	
	Millicuries	% of feedstock activity	Millicuries	% of feedstock activity
Feedstock	175	–	28	–
Filtercake	148	85%	24	86%
Liquid Waste	852	487%	109	389%
Product	282	161%	55	196%
% of Feedstock Thorium Activity in Product and Wastes		733%		671%

Table 2.7 - Uranium Activity Balances

	From Whipple 1968		From MCC 1970	
	Millicuries	% of feedstock activity	millicuries	% of feedstock activity
Feedstock	434	--	68	--
Filtercake	1.3	0%	0.2	0%
Liquid Waste	70	16%	9	13%
Product	63	15%	12	18%
% of Feedstock Uranium Activity in Product and Wastes		33%		31%

Relative Accuracy of Concentration Values

In an AEC license application letter (MCC 1965), MCC noted that the expected filtercake water content would be about 60% (with 40% solids). The letter goes on to state that this is generally the same proportion of liquid to solids that is seen in the feedstock. This information shows that the feedstock and the filtercake were very similar in physical form.

If the specific activity, which is taken from the Tracerlab report (1.8 E-4 microcuries per gram), is used to calculate the fraction of thorium in the feedstocks, the derived value is about 0.09 % ThO_2[1]. This value is somewhat below but near the value used in the November 1968 MCC letter to the AEC (MCC 1968), which states that the ThO_2 content of the feedstocks were noted as generally being in the range of 0.1 percent to 0.3 percent. This information suggests that the specific activity of the feedstock, used by MCC from the Tracerlab report, is reasonably accurate. Since the physical form of the feedstock and the filtercake were relatively similar the relative [illegible] measurements that were also reasonably accurate.

The specific activity used for the feedstock (4.47 E-4 microcuries per gram) in the equations used to derive the feedstock uranium activity in Table 2.6 also appear to be fairly accurate since this activity correlates to about 0.0076 U_3O_8[2], which is somewhat below but near the expected feedstock concentrations of 0.1% to 0.3% (MCC 1968). Again, there appears to be a general level of accuracy in the feedstock values and may suggest relative accuracy in the filtercake activity values.

Some of the unaccounted uranium may be attributable to material resulting from ion exchange processes used to remove dissolved uranium (described in Section 2.3). This material does not appear to be accounted for in the University of Michigan's radioactivity balance calculations.

[1] This calculation assumes that Th-232 and Th-228 are in secular equilibrium and the specific activity is twice that of Th-232 or 2.18 E-7 curies per gram.

[2] This calculation assumes that U-238 and U-234 are in secular equilibrium and the specific activity is twice that of U-238 or 6.66 E-7 curies per gram.

2.6 Location of Disposed Material

The August, 1972 letter (MCC 1972) also states that wastes were buried at a company owned site with the following legal description.

> A parcel of land commencing at the NW corner of the NW ¼ of the NE ¼ of Section 23, Town 12N – Range 2W, hence south on ¼ line to a point where said ¼ line intersects with the center of Bush Creek, hence North-Easterly along the center of Bush Creek to the N line of Section 23, hence West along said N line to place of beginning.

This legal description corresponds to the description on the Certificate of Survey for the Breckenridge Property (Lapham 1996). The letter also states that the burial site is to the south of the brine well and that the fence is approximately 60 feet from the well. All waste burials were performed inside the fenced area (Lincoln 1999 and Oak Ridge 1982). The July, 1982 final report by Oak Ridge clearly shows the location of that fence. The area within the low wire fence is about 0.9 acres. This low wire fence was removed and replaced in 1997 with a chain link fence that encompasses the entire property perimeter.

2.7 Oak Ridge's Radiological Assessment of the Disposal Site

Another important document in the Breckenridge Historical Site Assessment is the report entitled "Radiological Assessment of the Breckenridge Disposal Site, Velsicol Chemical Corporation, St. Louis, Michigan," (ORAU 1982). Oak Ridge Associated Universities on behalf of the U.S. Nuclear Regulatory Commission conducted the radiological assessment, which is the basis for the report. The objectives of the radiological assessment included the following:

1. Define the locations and depths of burials.
2. Determine direct radiation levels and radionuclide concentrations on the site.
3. Determine if radionuclides were migrating from the burial trenches.

Matters for consideration in the evaluation included the radiological status of the disposal site and the evaluation of the potential impact of the wastes at the site on public health and the safety and protection of the environment.

As part of the survey, a walkover radiation survey was conducted using a sodium-iodide scintillation detector. Several areas displaying elevated radioactivity were noted. These locations were mainly small isolated areas of a few centimeters in diameter; however, a few were as large as several meters in diameter. It also noted that the locations that were 10 microroentgen per hour (greater than background) at 1 meter were all directly over the locations of these elevated contact levels. The average radiation level was noted as being less than 10 microroentgen per hour above background.

The survey also included ex situ surface soil sampling and analysis. Forty such samples were taken. Ten were biased - taken from locations where elevated activity was noted during the walkover scan. The other thirty samples were systematic. The biased samples indicated thorium and uranium activity significantly above background. The systematic soil samples did not contain radioactivity in concentrations outside the ranges of the baseline samples. The results of the biased samples are provided in Table 2.8.

Table 2.8 Results of the Oak Ridge Assessment, Biased Samples (pCi/gm)

Uranium-238	Thorium-232
5	16
3	7
5	26
15	60
17	23
30	8
22	66
134	88
170	101
8	9
41 average	40 average

In addition to the surface soil sampling conducted on top of the Disposal Site, 19 groundwater samples were taken from boreholes around the perimeter of the Disposal Site and four site vegetation samples, three creek sediment samples and seven surface water samples were collected. The analysis of these samples showed the absence of elevated radioactivity levels and that the waste material was not migrating off of the Breckenridge Property.

2.8 Site Inspection by the NRC

In response to an inquiry from the Michigan Department of Environmental Quality, Radiological Protection Section, the NRC conducted a site inspection of the Breckenridge Property on October 31, 1996. The NRC inspectors conducted a walkover survey of the entire Breckenridge Property. The inspectors identified a number of areas with elevated radiation levels ranging up to about 40 microroentgens per hour at one meter from the surface. In addition, six soil samples taken from areas of elevated gamma measurements were collected and analyzed (NRC 1996).

Table 2.9 - Results of the NRC Site Inspection, Biased Samples (pCi/gm)

Uranium (natural)	Thorium (natural)
82	28
0	29
0	31
35	72
121	126
390	302
105 average	98 average

Measurements performed by the NRC inspectors in areas adjoining the property did not identify any migration of radiological contamination off-site. These measurements included a walk over survey immediately outside of the security fence and along Bush Creek. In addition, a soil sample across from Madison Road and two surface water samples from drain tile along Bush Creek were collected and analyzed. These three samples were noted as having less than 1 pCi/gm of thorium and uranium.

2.9 References to Potential Sources of Surface Activity

The Oak Ridge Report (ORAU 1982) noted that the NRC had previously conducted a limited survey of the Breckenridge Property (during 1980) and found small regions of surface contamination in the area of the trenches. The report notes that "it has been suggested that this contamination may be the result of small quantities of waste accidentally dropped during the burial operation."

On September 11, 1996 Memphis Environmental Center, Inc. conducted a hazardous material evaluation at the Breckenridge Property (MEC 1996). A total of five trenches were dug during the course of the evaluation. The MEC report states that trenches were dug to approximately three feet below the surface and were 5 to 8 feet in length and 2 to 5 feet in width. Radiological analysis of the excavated material was not conducted. In a response letter from Michigan's Department of Environmental Quality, at least one trench is noted as being three to four feet deep (Michigan 1996).

3.0 SITE CHARACTERIZATION

A radiological characterization of the former Breckenridge Property was conducted from July 14, 1997 to August 1, 1997 by NES under contract to NWI Land Management. The objective of the characterization was to determine the content and extent of radiological material at the site. Several types of radiological measurement processes were employed to determine the distribution of radioactive materials at the Disposal Site.

On November 11, 1997, a characterization report detailing the results of the characterization effort was submitted to the NRC for review. The review effort noted several issues associated with the gamma spectroscopy process including the lack of proper detector linearity with respect to gamma energies. As a result, NES initiated a reanalysis of all Breckenridge samples by another radioanalytical laboratory. The results of the second, ex-situ analyses were submitted to the NRC on February 4, 1999. The following section is a summary of the information contained in the November 11, 1997 and February 4, 1999 submittals. Additional details of the characterization activities and soil analyses can be found in the referenced reports.

3.1 Purpose, Scope And Objective Of Characterization Activities

The objective of the characterization was to determine the magnitude and extent of radiological materials distributed throughout the Disposal Site. Survey activities consisted of several measurement processes including:

- dose rate measurements at 1 meter above the surface,
- activity measurements at the surface,
- downhole activity measurements, and
- soil sample collection and analysis.

Characterization activities were performed in accordance with the guidelines established in NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination" (NRC 1993). To begin characterization activities, the property was gridded into 10-meter by 10-meter grids and marked with yellow flags. Each grid was assigned an alphanumeric label as shown in Figure 2.

3.2 Characterization Survey Processes

The following information describes the radiological measurements processes used to support the site characterization.

<u>Dose Rate Measurements (at 1 meter above the surface)</u>

A gamma dose rate survey was performed at 1 meter above the surface of the Breckenridge Property using a Bicron microroentgen (microR) survey meter. Readings were recorded directly above the flags denoting the intersections of site grid lines and also where the property perimeter fence intersected the gridlines (See Figure 3).

Activity Measurements at the Surface

To select a location for core sampling within each grid, a Ludlum 2220 with a 44-9 pancake probe was used to scan the selected grid locations. Every other grid was scanned for sampling in the northern third of the site (Rows 1 - 6) where radioactive material was not expected, based on site history. Beginning with Row 7, each grid was scanned. Scanning consisted of keeping the detector as close to the ground as possible and moving it back and forth in a serpentine motion while walking over the surface at a speed of about 0.5 meters per second. During scanning, areas of elevated activity were noted by changes in the audible signal from the survey meter. Five 1-minute counts were taken within each grid and the highest reading logged. This location was marked with spray paint as a guide for core sampling. Figure 4 shows the surface scan map with the highest reading in each grid. Readings are in gross counts per minute (cpm). A core location map is shown in Figure 5 with the marking indicating the approximate sampling location within each grid.

Downhole Activity Measurements

To further verify the quantity of radioactive materials present and upon suggestion from the NRC, gamma radiation levels were recorded at a depth between about 4 and 5 feet within each core location. Levels were measured in cpm using a Ludlum 2220 with a SPA-3 Sodium Iodide probe. Upon removing the drill auger from many core locations after sampling down to 8 feet, one to six inches of water was observed in the bottom of the borehole. To avoid submerging the detector the bottom of the boreholes were not surveyed.

Soil Sample Collection and Analysis

During the surface scan survey, locations were identified within each grid for core sampling. The area was then scanned with a metal detector in an effort to avoid drilling into areas that may contain metal objects near the surface. Samples were collected using standard split spoon sampling techniques utilizing a diesel powered, truck mounted, hollow stem auger, drill rig. The hollow stem auger was fitted with 2-inch diameter by 2-foot long spoons containing plastic liners. The volume of material collected in the 2-foot liner was capped on both ends and used as one sample. Upon split spoon opening, the samples were field screened using a Ludlum 2220 with a 44-9 probe and the outsides of the liners were decontaminated. Emptied split spoons were cleaned between each sample and drill augers were scanned before moving to the next grid. If elevated activity was present, the augers were set aside for decontamination. Samples were taken at increments of 2 feet below the surface to a depth of 8 feet. If elevated readings were evident, an additional sample was taken at a depth of 10 feet. Samples were labeled immediately with the alphanumeric grid location, A-1, followed by a second number representing the core depth, A-1-3 (1=2', 2=4', 3=6', 4=8', etc.).

3.3 Survey Results (except soil sampling)

The following information describes the results of the radiological measurements used to conduct the Breckenridge Property characterization. The northern four rows (1-4) of the property were used to characterize natural background in the area. The historical data and survey results support the designation of this area as unaffected. Based on the soil activity measurements, the affected area at the Breckenridge Property is identified (a posteriori) as quadrants A-6 through A-18, A-20, B-7 through B-20, C-7 and C-11, which is approximately the southern two-thirds of the property. The noted affected area is the defined area of the Disposal Site.

Dose Rate Measurements (at 1 meter above the surface)

The results of the 1-meter dose rate measurements are posted on Figure 3. The background dose rate ranged from 2-10 microR/hr. For comparative purposes, background was noted at the higher portion of the background range—approximately 10 microR/hr. Dose rates in the affected area range between 10-35 microR/hr. The only location found to be reading more than 10 microR/hr above the designated background was at grid location A-12.

Activity Measurements at the Surface

The results of the direct surface activity measurements are shown on Figure 4. Readings ranged from about 80 to 300 cpm (gross counts including background) in the southern two-thirds of the property. Background for the property was approximately 50 counts per minute.

Downhole Activity Measurements

Results of the downhole activity survey are depicted in Figure 6. Background gamma radiation levels were approximately 2000 cpm for the property. Readings in the southern two-thirds of the property range from background up to 30,000 cpm. Elevated downhole readings are generally apparent where soil sample analysis also indicated elevated activity; however, since the distribution of the radioactive materials is not uniform, there is no consistent mathematical correlation between the two sets of data.

Soil Sample Collection and Analysis

Details of the soil sample analysis and interpretation of the data results is provided in Section 3.4. In addition, full analytical back up data (approximately 2000 pages) is available and has been provided previously to the NRC (Paragon 1998).

3.4 Soil Analytical Process and Results

For analytical services, NES transferred the Breckenridge soil samples to a laboratory that specializes in gamma spectroscopy, Paragon Analytics, Inc., located in Fort Collins, Colorado. Paragon performed gamma spectroscopy analyses of 229 soil samples and two sediment samples from the Breckenridge Property. Paragon prepared the Breckenridge samples to attain a standard geometry and then counted the samples for a minimum of thirty minutes. The following summarizes the soil sampling campaign and the results of the Paragon analyses.

Analyses Overview

Paragon analyzed 229 soil samples and 2 sediment samples for the following isotopes:

- Th-228
- Th-232
- U-235
- U-238

The most abundant gamma emissions of Pb-212, Tl-208, and Bi-212 were used to determine the quantity of Th-228. Th-232 was quantified by measuring the emissions of its decay daughter – Ac-228. The accuracy of the results depends on the equilibrium conditions between the measured nuclides and the nuclides of interest. Because of its very long half-life (1.4 E 10 years), Th-232 is the activity-controlling radionuclide in its own decay chain. There is very good agreement between the calculated activity of Th-228 and Th-232; therefore, secular equilibrium between Th-232 and its decay progeny is implied. Since the calculated values of Th-228 and Th-232 activity are indications of the same Th-232 decay chain, only the highest of the two values is used.

Uranium-238 was quantified through measurement of its decay daughters, Th-234 and Pa-234m. This approach assumes that U-238 is in secular equilibrium with Th-234. U-235 is quantified directly from its own gamma emissions. Since U-235 and U-238 exist in separate decay chains, their associated activity is added. As a quality assurance measure and as a method to validate equilibrium assumptions, six samples with positive U-238 results were subjected to alpha spectroscopy to directly measure the U-235 and U-238 activities. The results of the comparison are provided discussed further in the Survey Quality Assurance Section below.

Of the 229 soil samples analyzed from the Breckenridge Property, 46 were used for background analysis, 122 samples were indicative of activity levels in the designated affected area, and 61 samples were found to have activities at or below background levels and were outside of the affected area. All of the analytical data from the soil sample analysis is provided in Attachment 3. Attachment 4 provides a review of the background analytical approach and Attachment 5 provides a statistical analysis of the soil sampling data.

Background Analyses

All of the soil samples taken in rows 1, 2, 3 and 4 were chosen to represent background. These include 46 individual samples and associated analyses. The selection of background sample points is thought to be appropriate since there is no evidence to suggest that waste material was buried in these locations.

Thorium Background

The radiological data supports the supposition that the chosen background area is not affected. Typical Th-232 concentration values range from about 0.5 to 1.6 pCi/gm within the U.S. The average Th-232 concentration in this background area that was in the detectable activity range was about 0.76 pCi/gm.

The vendor supplying the soil and sediment sample analysis used gamma spectroscopy equipment with protocols that reported in "less than minimum detectable activity (MDA)" values for very low-level activity. Ideally, sample results would have been reported entirely using actual results of the analytical process. Since the subsurface soil analyses were reported, in many cases, using "< MDA values," three approaches were evaluated for the determination of background levels of thorium. One approach replaced the non-detect values with zeros. Another approach used the reported MDA values as actuals. A final approach, which is the one that was used, substituted one-half of the reported MDA values for nondetects (Table 3.1). The approach established in Table 3.1 (substituting one-half of the reported MDA values as actual values) appeared to strike a satisfactory balance between the other two approaches and was deemed suitable.

Table 3.1 – Background Analysis Using One-Half of MDA Values as Actual Values –pCi/gm (selected method)[1]

	Th-228	Th-232
Mean	0.53	0.42
Median	0.52	0.31
Standard deviation (σ)	0.21	0.27
Mean + 2(σ)[criteria]	0.95	0.96

Uranium Background

Using the Paragon data, it is not possible to determine the exact background concentrations of naturally occurring uranium isotopes since all background area measurements were below the process' detection limit for uranium. Using one-half of the reported MDA values as actual values (similar approach as that used in Table 3.1), the following data is derived (Table 3.2).

Table 3.2 – Uranium Background Analysis Using One-Half of MDA Values as Actual Values – pCi/gm[1]

	U-235	U-238
Mean	0.33	0.95
Median	0.27	0.85
Standard deviation (σ)	0.18	0.51
Mean + 2(σ)	0.69	1.98

The average MDA in the background area was 1.9 pCi/gm. Typical U-238 concentration values range from about 0.6 to 1.7 pCi/gm within the United States (values derived from Table 8.1 of NRC 1998). The mean established in Table 3.2 for U-238 satisfactorily falls into this range.

Determination Of Affected Area

Substituting one-half of the reported MDA values as actual values (Table 3.1), the mean plus two times the standard deviation was used as the criteria for determining which areas are "affected" with regard to thorium activity. Ninety-five percent of natural background values are expected to reside within the area bounded by +/- 2 standard deviations of the mean. If measured values exceeded either the Th-232 or the Th-228 Table 3.1 criteria, the quadrant was deemed to be affected. Using this approach, the affected area was identified as quadrants A-6 through A-18, A-20, B-7 through B-20, C-7 and C-11 (see Figure 7). There is one outlier using this approach. This occurs at sample location C-15-3 where the reported Th-228 activity is 1.00 pCi/gm. This level of activity is 0.05 pCi/gm over the criteria of 0.95 pCi/gm but is well below three standard deviations of the background mean (value at which >99% of the background population is expected to reside) established in Table 3.1. In addition the difference between the reported value and the criteria is not significant in regards to the calculated accuracy of the measurement (+/- 0.42 pCi/gm). Because of its marginal activity, location C-15-3 and its associated quadrant (C-15) were excluded from the affected area.

All but two of the quadrants in the 30-quadrant affected area contain some measure of thorium activity above the established criteria (Table 3.1 Mean plus 2σ). The two quadrants that did not contain activity above the noted criteria (A-10 and B-10) are included in the affected since these quadrants were centrally located within the affected area. All positive (detectable) measurements of uranium are included within the defined affected area. The depth of the affected area is eight feet except at B-7, and at B-11. The depth at these locations has been extended to 10 feet because elevated activity was detected during the sample collection process and sample analysis indicated activity greater that the established criteria.

Sediment Sample Results

Two samples were taken from the sediments in Bush Creek, which runs nearly parallel to the Breckenridge Property's eastern boundary. The results of the sediment analysis showed no radioactivity greater than background levels.

Thorium Activity Found

Out of the 122 soil samples analyzed from the affected area, 57 samples showed thorium activity above background levels. The thorium activity ranged from levels that were near background to about 33 pCi/gm. There was one sample location that was a significant outlier. This was at location A-12-3. Both the A-12-3 and the A-12-4 sample points were substantially higher that anywhere else in the affected area. The thorium radioactivity level there was found to be 1,210 pCi/gm and 287 pCi/gm at A-12-3 and A-12-4 respectively.

Uranium Activity Found

Out of the 122 soil samples analyzed from the affected area, only seven indicated the presence of uranium activity above the analytical detection limit. The total uranium activity ranged from 3 pCi/gm to 83 pCi/gm.

Depth Profile

Using the data from Attachment 5, the following depth profile is developed for the Disposal Site:

Table 3.3 – Activity Depth Profile

	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft
# Samples	30	30	30	30	2
Thorium	5%	4%	72%	19%	1%
Uranium	22%	26%	18%	34%	0%

The thorium information has much greater statistical significance and, therefore, is a better indication of spatial distribution since only seven sample points were found to contain elevated levels of uranium. It should be noted that the high activity noted at sample location A-12-3 skews the depth profile considerably.

Data Irregularities

In all, 229 soil samples were analyzed. In addition, two sediment samples were evaluated. In the data detailing the sample results, there are two samples noted as B-12-3. The data also showed that sample B-16-2 was missing. Since this was probably a transcription error, B-16-2 was assigned the higher of the two B-12-3 values since it had the higher down-hole reading.

The data also showed two A-11-2 samples and a missing A-4-2 (background) sample. The highest reading was assigned to the A-11-2 sample location. The lower of the two readings was disregarded. The data from sample A-18-2 was missing. The highest of the other three measurements taken at location A-18 (A-18-1) was used in lieu of the missing A-18-2 data.

Source Term Development

The 30-quadrant affected area was identified as quadrants A-6 through A-18, A-20, B-7 through B-20, C-7 and C-11 with a depth of eight feet except at B-7 and at B-11, which was noted as being at a depth of 10 feet. The volume of the defined affected area is about 7500 cubic meters.

Even though the NES sampling campaign involved the measurement of 231 samples, the limited quantity of buried filtercake presents unique analytical circumstances. Because the quantity of buried material only represents about 8/10ths of a percent of the volume of the affected area (derivation in Table 4.1), only a very small portion of the Disposal Site contains significant amounts of radioactive contaminants. In the absence of solid historical information, an approach similar to the one used in Table 3.4 and Table 3.5 would be necessary to develop an inventory of radiological material. Because the inventory shown below was calculated using biased data (i.e. borings and soil samples were performed at locations of highest surface readings within the grid), the calculated inventory is also skewed high and should be considered an upper bound to the actual inventory. As discussed in Section 5, the data from past operations is believed to be more accurate and representative of the Disposal Site's actual radioactive source inventory because of the inhomogeneous nature of the contaminants within the Disposal Site and the availability of historical operational documents.

Table 3.4 – Calculated Total Thorium Inventory Using Soil Samples

Average Thorium Activity (pCi/gm)	Quantity of Soil Represented by each sample(m^3)	Number of Samples*	gm/cm^3 (Default value used in ResRad)	cm^3/m^3	microcurie/ picocurie	Calculated Th-232 Activity in Affected Area (microcuries)
14.617	61	122	1.5	1E+06	1E-06	163,000

Table 3.5 – Calculated Total Uranium Inventory Using Soil Samples

Average Uranium (pCi/gm)	Quantity of Soil Represented by each sample(m^3)	Number of Samples*	gm/cm^3 (Default value used in ResRad)	cm^3/m^3	microcurie/ picocurie	Calculated Total Uranium Activity in Affected Area (microcuries)
2.00	61	122	1.5	1E+06	1E-06	22,000

* Note – One sample, A-18-2 was missing and the specific activity for that sample point was estimated (see data irregularities section).

Survey Quality Assurance

Characterization activities at the Breckenridge Property were performed in accordance with the NES Quality Assurance Manual (NES 1997). Upon receipt of field radiological instruments, calibration certificates were reviewed. In addition, instrument response checks were performed daily. Field radiological equipment data can be found in Attachment 1.

Quality assurance methods used as part of the gamma spectroscopy analytical method are detailed in the gamma spectroscopy results (Paragon 1998). The methods include: calibration using a NIST traceable source in the appropriate counting geometry (for Breckenridge samples); daily instrument source check using a source with a broad energy spectrum; regular blank measurements, and regular duplicate analyses.

As an additional quality assurance measure and as a method to validate equilibrium assumptions, six samples with positive uranium-238 results were subjected to alpha spectroscopy to directly measure the uranium-235 and uranium-238 activities. The uranium analysis using alpha spectroscopy is compared with the analysis using gamma spectroscopy in Attachment 2. Overall, the comparison shows that the gamma spectroscopy (used in the source term development) overestimates the activity of uranium by about 27%, which is conservative. The results also show that U-238 and U-234 are in secular equilibrium. This validates the use of Th-234 and Pa-234m as proper indicators of U-238 activity (see Attachment 2). The probable reasons for the differences between the gamma and alpha spectroscopy are outlined in a memorandum from Paragon Analytics spectroscopist, Bob Shannon. This memo is included in Attachment 2.

Survey Grid Reproduction

The following measurements were taken from permanent structures within the Breckenridge Property. The instructions presented below (also see Figure 2) will allow accurate reproduction of the property grid used during the characterization.

Grid point D1: To relocate D1, begin at the NE corner of the property inside the fence. Step down to the first fence pole on the east fence. With a long tape measure, form a straight line with the base of the pole and the base of the bent cast iron rod in the middle of the northern third of the Disposal Site. At 25 feet 6 inches from the fence online between these two points, place a marker (flag). This is the intersection of Column D and Row 1 of the site grid.

Grid point D3: To relocate D3, begin at the NE corner of the property inside the fence. Step down to the ninth fence pole on the east fence. With a long tape measure, form a straight line with the base of the pole and the base of the bent cast iron rod in the middle of the northern third of the property. At 22 feet from the fence online between these two points, place a marker (flag). This is the intersection of Column D and Row 3 of the property grid.

Grid point B2: To relocate B2, begin at the NW corner of the property inside the fence. Step down to the third fence pole on the north fence. With a long tape measure, form a straight line with the base of the pole and the base of the bent cast iron rod in the middle of the northern third of the property. At 68 feet from the fence online between these two points, place a marker (flag). This is the intersection of Column B and Row 2 of the property grid.

Grid point B3: To relocate B3, begin at the NW corner of the property inside the fence. Step down to the sixth fence pole on the east fence. With a long tape measure, form a straight line with the base of the pole and the base of the bent cast iron rod in the middle of the northern third of the property. At 68 feet from the fence online between these two points, place a marker (flag). This is the intersection of Column B and Row 3 of the property grid.

3.5 Radiological Protection Practices used During Characterization

The following paragraphs highlight some of the radiological control practices used by NES during the field investigation of the Breckenridge Property.

Radiological Work Permits (RWPs)

An RWP, governing all surveying and sampling tasks, was completed for the Breckenridge Property. The RWP provided the controls to ensure the work was accomplished in a radiologically safe manner while maintaining personnel radiation exposure as low as was reasonably achievable (ALARA).

Contamination Control

All NES personnel working at the Disposal Site were trained as radiation workers in accordance with 10 CFR 19.12. Workers were briefed on a daily basis about the facility conditions. Engineering controls was utilized to contain contamination. Personal protective equipment was worn as stated in the RWP. This included hard hats, safety glasses, latex gloves with cotton liners, work boots, and plastic shoe covers. All equipment and personnel were surveyed upon leaving the controlled area.

Personnel Monitoring and Protection

All NES personnel, including the drilling contractors, participated in a bioassay program including baseline in-vitro examination (i.e., urinalysis) at the start of work and again upon completion of the project. Results show that the maximum total effective dose equivalent (TEDE) received during the characterization was 0.4 millirem. Air samples were also taken continuously during characterization activities and analyzed on a daily basis to ensure permissible limits were not exceeded.

4.0 RADIOLOGICAL EVALUATION

The following section provides an evaluation of the Disposal Site radioactivity based on historical information and on characterization data provided in this report.

4.1 Thorium Evaluation

It is believed that the specific activity for the filtercake from the Tracerlab report (Tracerlab 1967a) is relatively accurate. There are several issues that lead to this conclusion.

As noted in Section 2.5, in an AEC license application letter (MCC 1965), MCC noted that the expected filtercake water content would be about 60% (with 40% solids). The letter goes on to state that this is generally the same proportion of liquid to solids that is seen in the feedstock. This information shows that the feedstock and the filtercake were similar in physical form.

If the specific activity, taken from the Tracerlab report, is used to calculate the fraction of thorium in the relatively wet feedstocks, the derived value is about 0.09 % ThO_2. This value is in fairly good agreement with data used in the November 1968 MCC letter to the AEC (MCC 1968), which states that the ThO_2 content of the feedstocks were noted as generally being in the range of 0.1 percent to 0.3 percent. Although this letter and the respective license amendment do not specifically state that the noted fractions are in terms of wet weight, it is implied. In addition, previous documents (MCC 1965, AEC 1965a) explicitly state that fractions used are in terms of wet weight. The thorium fractions used in these documents are in line with the values used in the 1968 MCC letter where the 0.1 to 0.3 percent values are also noted.

The concentration values of the feedstocks used by MCC appear to be relatively accurate; therefore, it is reasonable to believe that the filtercake concentration values were also relatively accurate because of their similar physical form. In addition, even though the activity balances, shown in Table 2.5, are obviously incorrect on an overall basis, the fraction of thorium activity that partitions off to the filtercake (about 85%) appears to be reasonable. Initial licensing documents from MCC noted that most of the thorium would be precipitated out in the filtercake. This again suggests relative accuracy in the reported thorium concentration values used for the feedstock and the filtercake.

The data suggests that specific activity values for thorium in filtercake were fairly accurate and were reported and used in terms of wet weight. The MCC report to the State of Michigan (MCC 1972) states that 60,830 microcuries of thorium were contained in 303,174 pounds of wet filtercake that was disposed of at the Disposal Site. This corresponds to 1105 picocuries per gram of thorium on a dry weight basis. The sampling done by Oak Ridge, the NRC, and NES was reported in terms of dry weight. When thorium activity was noted, the specific activity values seen in these surveys were much lower than 1105 picocuries per gram. This may be attributable to the mixing of clean soil with the filtercake within the analytical sample.

When the filtercake is viewed in terms of volume, assuming that the material has roughly the density of concrete (2.36 grams per cubic centimeter), only about 8/10ths of one percent of the volume within the NES-defined affected area (7500 cubic meters) contains the filtercake (Table 4.1). Of the 122 samples taken by NES in the defined affected area, theoretically, only a single sample point would be a sample directly of the filtercake material. In fact, it appears that only one of the sampling boreholes actually sampled the filtercake completely. Activity at this borehole (grid point A-12) was 1210 picocuries per gram at the 4'-6' depth. This correlates well with the buried material's activity, which was derived from the MCC report (1105 picocuries per gram).

Table 4.1 – Fractional Volume of Filtercake in Disposal Site

Volume of Affected Area	Weight of Filtercake (lbs.)	Density of Filtercake (gm/cm^3)	grams per pound	cm^3 per m^3	Volume of Filtercake (m^3)	Volume Fraction of Filtercake in affected area
7500 m3	303,174	2.36	454	1 E6	58.3	.008

The historical records appear to be the best indication of the buried radioactivity. In addition, the records appear to be reasonably accurate when compared and analyzed against the present-day survey data. Based on this deduction, the total thorium activity provided in the MCC report to Michigan in 1972 (MCC 1972) is presumed to be best indicator of the Disposal Site's actual thorium content. This value is 60,830 microcuries of total thorium.

4.2 Uranium Evaluation

The survey results also reveal that uranium was not always present in the filtercake. Only about 12 percent of the NES samples, which contained thorium activity (≥ 1 pCi/gm), also contained uranium activity. Conversely, when uranium activity was seen, varying proportions of thorium activity were present.

The variation in uranium concentration could have resulted from variations in feedstock uranium concentration or could have stemmed from varying levels of solubility of the uranium compounds within the extraction process. The MCC historical documents suggest that the uranium compounds could be quite soluble. A 1966 MCC letter notes that "uranium will be removed from the solution by passing it through an anion exchange column" (MCC 1966). In the Tracerlab Activity Report (Tracerlab 1967a), the concentration values provided showed that, of the uranium compounds in the incoming feedstock, 99.9% of the activity was in the form of soluble compounds. The remaining 0.1% was found to be insoluble. The Tracerlab does not make reference to the nature of solution by which the solubility is gauged.

This letter also notes that the uranium, which was later leached from ion exchange columns (for regeneration purposes), was subsequently transferred to uranium processors. This also suggests that a significant portion of the uranium activity in the process' initial feedstock did indeed partition off into the liquid phase of the extraction process and was subsequently removed by the ion exchange columns.

As described in the previous section on thorium activity, the physical state of the feedstock and the filtercake were quite similar (about 40% solids, 60% liquids). As with the thorium, the expected level of U_3O_8 in the feedstock was about 0.1 to 0.3 percent. The specific activity of the feedstock, used by MCC (Tracerlab 1967a) correlates to about 0.08 percent. Again, this suggests that the analytical processes used on the feedstock had some level of accuracy and that this accuracy would likely have been carried over to the uranium in the filtercake since their physical makeup was similar. As presented in Table 2.6, only a very small fraction of the feedstock's activity partitioned off to the filtercake.

Based on their assumed relative accuracy, the uranium concentration values derived during the time of operation along with the values of total deposited uranium activity are assumed to be fairly accurate and the best source for evaluating the uranium inventory. The buried total uranium value, taken from the MCC report to the State of Michigan (MCC 1972) is 523 microcuries.

5.0 CONCLUSIONS

The historical data suggests that MCC operated the Disposal Site conscientiously and in accordance with AEC regulations in place at the time. In addition, the quantities of radioactive materials buried at the Disposal Site were documented by MCC during the time of plant operations and shortly after the site's closure. The values that are reported in the MCC historical documents appear to be the best available indication of the buried material's total activity. These values are as follows:

- Total thorium 60,830 microcuries
- Total uranium 523 microcuries

Since MCC appears to have adhered to the regulations that were in place at the time of burial, the surface activity noted by the post-closure surveys is believed to have originated from relatively small container breaches during the burial process. In addition, some added activity could have been brought to the surface during the 1996 MEC environmental sampling activities.

6.0 REFERENCES

Lapham 1996. Certificate of Survey for Memphis Environmental Center, Inc. of the Breckenridge Property conducted by Paul B. Lapham and Associates, Inc., August 1996.

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Memphis Environmental Center, Inc. (MEC) 1996. Letter from MEC (J. Phillips) to the Michigan Department of Environmental Quality (K. Sakowski) regarding the Investigation of Disposal Well No. 1-Initial Reconnaissance, September 26, 1996.

Michigan Chemical Company (MCC) 1961. Letter from MCC (A. Gammill) to the AEC (Materials Branch, Division of Licensing and Regulations) regarding license to receive and handle thorium-bearing materials, January 13, 1961.

MCC 1965. Letter from MCC (D. Williams) to AEC (A. Nussbaumer) regarding application to conduct laboratory and pilot plant studies of rare earth extraction processes, May 4, 1965.

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MCC 1968. Memorandum from MCC (E. Trio) to AEC (D. Nussbaumer) regarding STC-833 license renewal, November 8, 1968.

MCC 1970. Interoffice memorandum from P. Lincoln to W. Martin regarding AEC inspection of rare earth feed plant operations, May 18, 1970.

MCC 1972a. MCC interoffice memorandum from P. Lincoln to C. Touzeau regarding communications with the Michigan Department of Public Health, Division of Radiological Health, August 14, 1972.

MCC 1972b. Memorandum from MCC (P. Lincoln) to Michigan Department of Public Health (D. VanFarowe) regarding MCC radioactive byproduct burial site, August 17, 1972.

NES 1999. Site Characterization Report and Risk Analysis for the Breckenridge Disposal Site, Draft, March 1999.

State of Michigan (Michigan) 1975. Memorandum from Michigan Department of Public Health (J. Camburn) to MCC (P. Lincoln) regarding registration of radioactive material, November 10, 1975.

Michigan 1980. Mineral Well Plugging Record, issued by the State of Michigan, Department of Natural Resources, Geological Survey Division on August 26, 1980.

Michigan 1996. Letter from the Michigan Department of Environmental Quality (K. Sakowski) to MEC (J. Phillips) regarding comments from the review of the document detailing the investigation of disposal well #1, initial reconnaissance review report, Oct. 21, 1996.

NES 1997. SCIENTECH NES, Inc. Document Number 80A9086, "Quality Assurance Manual," Revision 9, August 1997.

Oak Ridge Associated Universities (ORAU) 1982. "Radiological Assessment of the Breckenridge Disposal Site, Velsicol Chemical Corporation, St. Louis, Michigan," conducted by Oak Ridge Associated Universities on behalf of the U.S. Nuclear Regulatory Commission, July 1982.

Paragon Analytics, Inc (Paragon) 1998. Result of Breckenridge Site samples provided to NES by Paragon, Work Order Number 98-09-043, October 9, 1998.

Tracerlab 1967a. Letter from Tracerlab (P. Russo) of Waltham, Massachusetts to MCC (D. James) regarding analytical results of samples including filtercake, November 17, 1967.

Tracerlab 1967b. Letter from Tracerlab (P. Russo) of Waltham, Massachusetts to MCC (D. James) regarding uranium analytical results, December 1, 1967.

United States Atomic Energy Commission (AEC) 1961. AEC Source Material License STC-76 for MCC allowing 100 tons of monazite, February 6, 1961.

AEC 1965a. AEC Source Material License STC-833 for MCC allowing 30 pounds of thorium, May 18, 1965.

AEC 1965b. AEC Source Material License STC-833 for MCC allowing possession of 50 pounds of thorium and processing of no more than 15 pounds of thorium, November 5, 1965.

AEC 1966. AEC Source Material License SMB-833 for MCC allowing the processing of 700 pounds of thorium and uranium, November 8, 1966.

AEC 1968a. Memorandum from AEC (D. Foster) to MCC (D. Pond) regarding the results of the inspection on June 27, 1968. Form AEC-591, Inspection Findings and Licensee Acknowledgments, was attached, July 16, 1968.

AEC 1968b. AEC Source Material License SMB-833 for MCC allowing the processing of 2000 pounds of thorium and uranium, November 25, 1968.

AEC 1969. NRC Regulations in 10CFR20, "Standards for Protection Against Radiation" sections 302, 304 and Appendix C. 1968 – 1970.

AEC 1971. Memorandum from AEC (R. Lavfield) to MCC (J. Gowan) regarding the termination of AEC License number SMB-833, April 23,1971.

NRC 1981. NRC Notice, SECY-81-576, "Disposal or Onsite Storage of Residual Thorium and Uranium from Past Operations," October 23, 1981.

NRC 1983. Letter from NRC (R. Page) to Velsicol Chemical Corporation (J. Rademacher) regarding a review of adequacy of the St. Louis Site closure, June 9, 1983.

NRC 1993. NRC Regulatory Guide NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License termination," December 1993.

NRC 1996. Report on the inspection of the Breckenridge Disposal Site by NRC Region III, October 31, 1996 (date of field inspection).

NRC 1998. NRC Regulatory Guide NUREG-1507, "Minimum Detectable Concentrations With Radiation Survey Instruments for Various Contaminants and Field Conditions," June 1998.

Whipple 1968. Memorandum from the University of Michigan (G. Whipple) to MCC (D. James) regarding rare earth process with Canadian feed material. February 29, 1968.

ATTACHMENT 1

BRECKENRIDGE FIELD RADIOLOGICAL EQUIPMENT

Table 1 provides a summary of survey instrumentation used during characterization of the Breckenridge Site. Daily background measurements were performed prior to use of all instruments during on-site characterization activities.

Table 1 Survey Instrumentation

Instrument	Use	Calibration Date	Cal. Due Date	Serial Number Meter/Probe
Ludlum 2220 ratemeter/scaler w/ 44-9 probe	Beta-gamma direct scans and measurement surveys	07/16/97	07/16/98	52833/067932
Ludlum 2220 ratemeter/scaler w/ PG-2 probe	Alpha direct scans and measurement surveys	07/17/97	07/17/98	52823/718194
Ludlum 2220 ratemeter/scaler w/ 43-5 probe	Alpha direct scans and measurement surveys	07/17/97	07/17/98	52836/010575
Ludlum 2221 ratemeter/scaler w/ 43-5 probe	Alpha direct scans and measurement surveys	04/21/97	10/21/97	73687/037504
Ludlum 2929 phoswich scaler w/ 43-10 detector	Smear sample alpha and beta-gamma counter	03/14/97	09/14/97	69660/061489
Eberline RAS-1, low volume air sampler	Routine air samples during sample preparation	03/18/97	03/18/98	569
Radeco-809, high volume air sampler	Routine air samples field work area	08/06/97	08/06/98	5387
Radeco-809, high volume air sampler	Routine air samples field work area	08/06/97	08/06/98	5389
Canberra MCA w/ HPGe detector	Gamma spectroscopy sample analysis	08/20/97	as neeeded	794333
Bicron MicroR meter	General area dose rate measurements	07/28/97	07/28/98	B218L

Radiation instruments used during characterization of the Disposal Site were each calibrated within the last year with a NIST traceable source standard. Daily source checks were performed on each instrument before use with an appropriate NIST traceable source (beta-gamma sensitive instruments with a Tc-99 source, alpha sensitive with a Pu-239 source, and gamma sensitive with a Cs-137 source).

ATTACHMENT 2

URANIUM ACTIVITY ANALYSIS

Sample ID	Isotope	Activity (pCi/gm) Alpha Spec	Activity (pCi/gm) Gamma Spec	Comparison (Delta/Alpha)
A-17-3	U-234	2.77	3.20	16%
A-17-3	U-235	0.20	0.00	
A-17-3	U-238	3.60	3.20	-11%
B-7-2	U-234	22.70	25.50	12%
B-7-2	U-235	1.60	0.00	
B-7-2	U-238	21.00	25.50	21%
B-7-3	U-234	62.00	25.80	-58%
B-7-3	U-235	4.50	8.00	78%
B-7-3	U-238	69.00	25.80	-63%
B-11-4	U-234	52.50	83.00	58%
B-11-4	U-235	3.20	0.00	
B-11-4	U-238	50.00	83.00	66%
B-16-1	U-234	38.10	52.90	39%
B-16-1	U-235	2.01	0.00	
B-16-1	U-238	40.30	52.90	31%
B-17-2	U-234	22.20	37.70	70%
B-17-2	U-235	0.98	0.00	
B-17-2	U-238	19.90	37.70	89%
			Average	27%

Paragon Analytics, Inc.

Memorandum

To: Ken Kasper

From: Bob Shannon 2/22/99

Date: 02/22/99

Re: MEC Soil Samples

This is in confirmation of our conversation this afternoon. I have had a chance to check further into the preparation of the solid samples you referenced (B-7-3 and B-11-4). As you were aware, these samples had been diluted with sugar prior to delivery at Paragon a fact which lead to a variety of problems in the analysis of the samples.

The gamma spectroscopy fractions were analyzed and report on an 'as received' basis using the quantities recorded on the sample labels as the aliquot mass in calculations. By visual inspection, the samples appeared to have been dried and ground prior to the sugar being added. The sugar had been only partially mixed with the solids so the samples were further homogenized by tumbling prior to gamma spec analysis. It was noted that the sugar appeared to have transferred some moisture back to the samples. Several inconsistencies in the recorded masses were also noted and reported in the case narratives for these samples.

The samples were analyzed for isotopic uranium by alpha spectroscopy. All samples were muffled in at 600 degrees Celsius to destroy any organics including the added sugar prior to initiation of chemical separations. Samples were subsequently processed and results reported on an 'ash' weight basis. During the muffling process the analyst reported difficulties with sugar expanding and overflowing the sample container. Any organic and many volatile substances in the original sample would have been thus removed prior to measurement of the aliquot mass and are not reflected in the weight used for calculations. Reporting 'ash weight' as opposed to 'dry' weight would lend a high bias to alpha spectroscopy results since the sample would be effectively concentrated by the ashing process.

Additionally it is noted that, non-homogeneity of the sample matrix is common in environmental samples and can occasionally cause significant problems with reproducibility in results. It is generally prudent to place more confidence in a test run with a larger aliquot size (e.g. gamma spec) than a test with smaller aliquot size (e.g. alpha spec) since the subsampling uncertainties associated with a larger aliquot size in general, gamma spectroscopy results. This is of course assumes that the test are capable of delivering the required specificity and precision (sensitivity).

In this case, I might suggest that quantitation of U-238 (Th-234) and U-235 concentrations by gamma spectroscopy may be more reliable due to the fact that results were reported on an 'ash weight' basis with a relatively larger aliquot (71 grams versus 2 grams). The alpha spectroscopy results, on the other hand, would be the most dependable method of determining the qualitative character of uranium present (ratio of U-234:U-238).

Please feel free to contact me if you have any further questions or concerns.

ATTACH. 3
SUMMARY OF SOIL SAMPLING DATA

Sample ID	Th-228	Th-232	U-235	U-238	Batch #	
A-1-1	0.55	< 0.54	< 0.76	< 2.1	849	
A-1-2	< 0.30	< 0.67	< 0.87	< 2.6	849	
A-1-3	0.59	< 0.39	< 0.4	< 1.1	849	
A-2-1	0.79	< 0.52	< 0.73	< 1.9	849	
A-2-2	0.74	< 0.37	< 0.56	< 1.5	849	
A-2-3	0.5	< 0.33	< 0.43	< 1.2	849	
A-2-4	0.41	< 0.19	< 0.27	< 0.71	849	
A-3-1	0.6	< 1.3	< 1.2	< 2.6	849	
A-3-2	0.58	0.59	< 0.27	< 0.72	849	
A-3-4	0.65	<.61	<.53	<1.4	399	
A-3-3	0.67	0.59	< 0.69	< 1.9	849	
A-4-1	1.03	< 1.4	< 1.6	< 4.3	849	
A-4-3	0.76	< 0.6	< 0.43	< 1.7	849	
A-4-4	0.48	<.34	<.36	<1.1	399	
A-6-1	0.81	1.26	<.77	<2.2	775	
A-6-2	0.65	<.94	<1.0	<3	775	
A-6-3	0.62	0.5	<.37	<1.3	775	
A-6-4	1.06	1.17	< 0.34	< 0.94	849	
A-7-1	0.870	1.410	<.5	<1.5	399	
A-7-2	< 0.44	< 1.1	< 1.3	< 3.7	849	
A-7-3	0.900	0.780	< 0.53	< 1.5	849	
A-7-4	0.410	<.42	<.4	<1.2	775	
A-8-1	1.370	1.290	<.26	<.8	775	
A-8-2	0.810	<.54	<.56	<1.5	399	
A-8-3	0.600	0.630	<.28	<.69	399	
A-8-4	0.670	< 0.78	< 0.72	< 1.6	849	
A-9-1	1.100	1.040	<.63	<2.1	775	
A-9-2	0.930	<0.77	< 0.95	< 2.4	849	
A-9-3	0.450	<.3	<.34	<1	399	
A-9-4	0.670	0.520	<.26	<.79	775	
A-10-1	0.550	<.55	<.55	<1.8	775	
A-10-2	<.23	<.74	<.61	<1.6	775	
A-10-3	0.470	<.41	<.42	<.97	399	
A-10-4	0.340	<.41	<.41	<1.1	399	
A-11-1	0.860	<.62	<.54	<1.8	775	
A-11-2	1.600	< 1.6	< 1.5	< 4.7	849	
A-11-2	0.730	<.5	<.59	<1.5	775	packing list has 2
A-11-3	0.490	0.720	<.42	<1.3	775	
A-11-4	0.490	<.39	<.4	<1.3	775	
A-12-1	1.190	<.84	<.62	<2.1	775	
A-12-2	5.170	5.220	< 0.24	< 0.75	775	
A-12-3	1180.00	1210.000	< 16	< 55	849	
A-12-4	285.000	287.000	< 6.7	< 23	775	
A-13-1	7.900	8.400	< 1.1	< 3.8	775	
A-13-2	6.600	6.400	< 1.1	< 3.3	775	
A-13-3	7.100	7.800	< 1.9	< 5.8	849	

ATTACH. 3
SUMMARY OF SOIL SAMPLING DATA

Sample ID	Th-228	Th-232	U-235	U-238	Batch #	
A-13-4	1.110	<.69	<.68	<1.9	775	
A-14-1	1.990	<1.6	<1.1	<3.4	775	
A-14-2	0.440	<.42	<.47	<1.4	775	
A-14-3	<.13	<.37	<.4	<1.2	775	
A-14-4	0.410	<.61	<.68	<1.7	775	
A-15-1	1.090	< 0.55	< 0.50	< 1.5	849	
A-15-2	0.610	<.43	<.39	<1.4	775	
A-15-3	0.710	0.700	<.44	<1.4	399	
A-15-4	0.980	0.780	<.49	<1.6	399	
A-16-1	2.110	2.360	< .91	< 2.9	849	
A-16-2	0.740	< 0.4	< 0.5	< 1.4	849	
A-16-3	0.910	< 0.7	< 0.73	< 2.4	849	
A-16-4	0.630	0.570	<.3	<.96	775	
A-17-1	4.500	4.100	< 1.0	< 3.8	775	
A-17-2	1.580	< 0.6	< 0.73	< 2.5	849	
A-17-3	2.020	1.880	< 0.54	3.200	849	duplicate says no U
A-17-4	1.900	2.140	<.77	<2.3	775	
A-18-1	8.200	8.200	< 1.3	< 4.4	775	
A-18-2				missing...used highest available A-18 reading		
A-18-3	2.160	2.250	<.36	<1.1	399	
A-18-4	7.100	7.100	<.93	<3.5	775	
A-19-1	0.820	<.5	<.46	<1.4	775	
A-19-2	0.750	<.65	<.53	<1.8	775	
A-19-3	<.24	<.74	<.63	<2.1	775	
A-19-4	0.520	0.550	<.27	<.88	775	
A-20-1	0.830	0.830	<.56	<1.9	775	
A-20-2	1.060	1.160	<.2	<.59	775	
A-20-3	0.510	0.750	<.3	<.94	775	
A-20-4	0.700	<.35	<.45	<1.3	775	
A-20-5	0.370	<.43	<.38	<1.1	775	
B-3-1	0.85	0.83	< 0.43	< 1.0	849	
B-3-2	0.43	< 0.53	< 0.35	< 1.1	849	
B-3-3	0.49	0.5	< 0.27	< 0.70	849	
B-3-4	0.69	< 0.63	< 0.6	< 1.7	849	
B-5-1	< 0.27	< 0.71	< 0.92	< 2.0	849	
B-5-2	0.71	0.61	< 0.35	< 1.1	849	
B-5-3	0.45	0.59	<.34	<1	399	
B-5-4	0.56	0.74	< 0.29	< 0.98	849	
B-7-1	0.870	< 0.47	< 0.59	< 1.5	849	
B-7-2	3.850	4.200	< 2.0	25.500	849	
B-7-3	13.700	14.800	8.000	25.800	775	
B-7-4	1.960	2.450	<.69	<2.2	399	
B-7-5	1.170	< 0.47	< 0.51	< 1.6	849	
B-8-1	5.8	6.500	< 1.2	< 4.0	775	
B-8-2	0.650	<.66	<.58	<1.9	775	
B-8-3	0.560	<.34	<.36	<1.2	399	
B-8-4	0.650	0.650	<.24	<.81	775	
B-9-1	2.070	2.450	<.95	<3.0	775	

SUMMARY OF SOIL SAMPLING DATA

Sample ID	Th-228	Th-232	U-235	U-238	Batch #	
B-9-2	1.400	1.070	< 0.63	< 2.0	849	
B-9-3	0.620	< 0.4	< 0.42	< 1.1	849	
B-9-4	0.440	<.55	<.44	<1.2	775	
B-10-1	0.800	<.42	<.41	<1.2	775	
B-10-2	<.19	<.4	<.6	<1.9	775	
B-10-3	0.680	0.580	<.28	<.77	399	
B-10-4	0.450	0.490	<.24	<.74	775	
B-11-1	<.31	<.86	<1.1	<2.8	775	
B-11-2	0.900	< 0.52	< 0.52	< 1.8	849	
B-11-3	34.000	31.700	< 3.2	< 10	849	
B-11-4	28.700	28.400	< 2.6	83.000	849	
B-11-5	9.600	10.400	< 2.2	< 6.7	775	
B-12-1	7.400	7.600	< 0.76	< 2.5	849	
B-12-2	1.470	1.630	<.94	<3.2	775	
B-12-3	0.590	<.52	<.52	<1.5	775	
B-12-4	0.660	<.8	<.85	<2.1	399	
B-13-1	6.900	7.300	< 1.4	< 4.6	775	
B-13-2	1.130	<.57	<.66	<1.8	775	
B-13-3	0.720	<.77	<.57	<1.6	775	
B-13-4	1.480	1.590	<.29	<.84	775	
B-14-1	0.910	<1.0	<1.0	<3	775	
B-14-2	1.120	<1.4	<1.2	<3.7	775	
B-14-3	0.590	<.43	<.45	<1.2	399	
B-14-4	<.12	<.29	<.26	<.99	775	
B-15-1	0.600	0.620	< 0.44	< 1.4	849	
B-15-2	5.600	5.400	< 0.90	< 2.8	849	
B-15-3	0.710	0.700	<.44	<1.4	399	
B-15-4	< 0.23	< 0.83	< 0.85	< 2.1	849	
B-16-1	22.100	22.800	<1.4	52.900	849	
B-16-2	13.400	15.300	< 1.8	< 6.2	775	
B-16-3	2.320	2.050	<.56	<1.7	775	
B-16-4	1.010	0.880	<.41	<1.5	399	
B-17-1	10.000	8.800	< 2.4	< 8.3	849	
B-17-2	21.800	22.700	< 2.1	37.700	849	
B-17-3	3.11	2.82	< 0.53	8	775	
B-17-4	1.940	1.790	<.53	<1.6	775	
B-18-1	1.530	<.77	<.91	<2.5	775	
B-18-2	2.970	<.98	<.98	<3.1	775	
B-18-3	0.680	0.760	<.42	<1.2	399	
B-18-4	0.720	0.850	<.55	<1.8	849	
B-19-1	5.150	4.800	< 0.93	< 3.1	849	
B-19-2	0.820	0.560	<.39	<1.1	775	
B-19-3	0.520	<.4	<.59	<1.4	399	
B-19-4	0.440	0.490	<.27	<.85	775	
B-20-1	1.540	1.580	<.56	<2	775	
B-20-2	0.940	0.970	<.42	<1.2	775	
B-20-3	0.840	<.57	<.59	<1.6	775	
B-20-4	0.530	0.480	< 0.36	< 1.0	849	

SUMMARY OF SOIL SAMPLING DATA

Sample ID	Th-228	Th-232	U-235	U-238	Batch #	
C-1-1	0.43	< 1.1	< 1.0	< 3.4	849	
C-1-2	< 0.37	< 1.4	< 1.0	< 3.2	849	
C-1-3	0.49	< 0.62	< 0.73	< 2.3	849	
C-1-4	< 0.3	< 0.66	< 0.96	< 2.6	849	
C-2-1	0.44	< 0.64	< 0.74	< 1.9	849	
C-2-2	0.51	< 0.39	< 0.54	< 1.3	849	
C-2-3	0.45	< 0.61	< 0.48	< 1.7	849	
C-2-4	0.26	< 0.25	< 0.28	< 0.92	849	
C-4-1	< 0.54	< 1.4	< 1.7	< 4.9	849	
C-4-2	0.61	<.44	<.53	<1.4	775	
C-4-3	< 0.38	< 1.4	< 1.5	< 4.3	849	
C-4-4	0.52	<.57	<.34	<1.1	775	
C-6-1	0.62	<.58	<.64	<1.8	775	
C-6-2	0.74	<.26	<.25	<.79	775	
C-6-3	0.69	< 0.34	< 0.38	< 1.1	849	
C-6-4	0.76	<.85	<.8	<2.3	775	
C-7-1	1.210	< 0.48	< 0.54	<1.5	849	
C-7-2	<.31	<.85	<.77	<2.9	775	
C-7-3	0.530	<.39	<.38	<1.2	399	
C-7-4	0.680	0.770	<.39	<1.1	399	
C-8-1	0.700	< 0.85	< 0.76	< 2.5	849	
C-8-2	0.450	< 0.3	< 0.37	< 1.2	849	
C-8-3	<.14	<.55	<.49	<1.3	399	
C-8-4	0.880	< 0.65	< 0.65	< 2.0	849	
C-9-1	<.29	<1.2	<1.1	<3	775	
C-9-2	0.710	0.620	<.47	<1.5	775	
C-9-3	0.690	< 0.55	< 0.57	<1.6	849	
C-9-4	0.230	<.3	<.36	<.99	775	
C-10-1	<.38	<.63	<.85	<3.2	775	
C-10-2	0.610	0.430	<.29	<.93	775	
C-10-3	0.520	<.43	<.39	<1.1	399	
C-10-4	0.620	< 0.32	< 0.41	<1.2	849	
C-11-1	1.190	<1.1	<.84	<2.7	775	
C-11-2	0.510	<.47	<.58	<1.6	775	
C-11-3	0.610	<.53	<.64	<1.6	775	
C-11-4	0.500	< 0.62	< 0.61	< 1.5	849	
C-12-1	0.610	<.55	<.43	<1.3	775	
C-12-2	0.590	<.36	<.33	<1.1	399	
C-12-3	0.760	< 0.68	< 0.61	< 1.7	849	
C-12-4	< 0.23	< 0.7	< 0.65	< 2.3	849	
C-13-1	0.630	0.950	<.66	<1.9	775	
C-13-2	0.550	0.440	< 0.34	< 0.92	849	
C-13-3	0.600	0.540	<.25	<.64	399	
C-13-4	0.590	<.67	<.57	<1.7	775	
C-14-1	< 0.29	< 0.91	< 0.86	< 2.5	849	
C-14-2	<.35	<.94	<1	<2.7	775	
C-14-3	0.700	< 0.50	< 0.55	< 1.5	849	
C-14-4	0.710	0.940	<.36	<1.1	775	

SUMMARY OF SOIL SAMPLING DATA

Sample ID	Th-228	Th-232	U-235	U-238	Batch #	
C-15-1	< 0.37	< 1.4	< 1.3	< 3.8	849	
C-15-2	<.29	<.64	< 0.84	< 2.3	849	
C-15-3	1.000	<1.3	<1.3	<3.7	775	
C-15-4	0.470	0.860	<.65	<2.2	775	
D-3-1	< 0.34	< 1.0	< 1.1	< 3.1	849	
D-3-2	0.64	< 0.84	< 0.80	< 2.7	849	
D-3-3	0.63	< 0.46	< 0.54	<1.9	849	
D-3-4	0.47	< 0.26	< 0.34	< 0.89	849	
D-5-1	< 0.38	< 1.2	< 1.5	< 3.9	849	
D-5-2	< 0.5	< 1.5	< 1.6	< 4.2	849	
D-5-3	0.6	0.73	< 0.40	< 1.2	849	
D-5-4	0.37	0.87	< 0.98	< 2.8	849	
D-7-1	<.34	<.58	<1	<2.9	775	
D-7-2	0.460	0.700	<.41	<1.2	399	
D-7-3	0.670	< 0.29	< 0.38	< 1.0	849	
D-7-4	0.620	0.630	< 0.29	< 0.97	849	
D-8-1	0.390	< 0.81	< 0.91	< 2.0	849	
D-8-2	0.690	<.23	<.59	<1.6	775	
D-8-3	0.530	0.560	<.43	<1.1	775	
D-8-4	0.450	0.520	<.24	<.63	399	
D-9-1	<.23	<.64	<.56	<1.7	775	
D-9-2	0.500	<.44	<.38	<1.1	399	
D-9-3	0.490	<.38	<51	<1.2	775	
D-9-4	0.510	<.47	<.65	<2	775	
E-1-1	0.75	1.16	< 0.85	< 2.5	849	
E-1-2	0.77	1.26	< 0.72	< 2.2	849	
E-1-3	0.66	0.91	< 0.45	< 1.5	849	
E-1-4	0.34	< 0.43	< 0.45	< 1.4	849	
E-2-1	0.52	0.39	< 0.19	< 0.61	849	
E-2-2	0.53	< 0.97	< 0.89	< 2.8	849	
E-2-3	0.93	< 0.50	< 0.49	< 1.3	849	
E-2-4	0.47	< 0.35	< 0.35	< 1.0	849	
E-4-1	< 0.33	< 1.3	< 1.2	< 3.3	849	
E-4-2	0.7	< 0.60	< 0.58	< 1.7	849	
E-4-3	0.62	<.3	<.34	<1	399	
E-4-4	0.51	0.61	<.39	<1.2	399	
E-6.1	<.39	<1.1	<1.1	<3.3	399	
E-6-2	< 0.31	< 0.85	<1.0	< 2.4	849	
E-6-3	0.47	0.5	< 0.4	< 1.2	849	
E-6-4	0.62	0.78	<.34	<1.2	775	
Creek D	<.18	<.4	<.41	<1.5	775	
Creek U	<.19	<.49	<.67	<1.7	775	

ATTACH. 4
BACKGROUND DATA

Non-Detects Are Replace by One-Half the Reported MDA				
Sample ID	Th-228	Th-232	U-235	U-238
A-1-1	0.55	**0.27**	**0.38**	**1.05**
A-1-2	**0.15**	**0.34**	**0.44**	**1.30**
A-1-3	0.59	**0.20**	**0.20**	**0.55**
A-2-1	0.79	**0.26**	**0.37**	**0.95**
A-2-2	0.74	**0.19**	**0.28**	**0.75**
A-2-3	0.50	**0.17**	**0.22**	**0.60**
A-2-4	0.41	**0.10**	**0.14**	**0.36**
A-3-1	0.60	**0.65**	**0.60**	**1.30**
A-3-2	0.58	0.59	**0.14**	**0.36**
A-3-3	0.67	0.59	**0.35**	**0.95**
A-3-4	0.65	**0.31**	**0.27**	**0.70**
A-4-1	1.03	**0.70**	**0.80**	**2.15**
A-4-3	0.76	**0.30**	**0.22**	**0.85**
A-4-4	0.48	**0.17**	**0.18**	**0.55**
B-3-1	0.85	0.83	**0.22**	**0.50**
B-3-2	0.43	**0.27**	**0.18**	**0.55**
B-3-3	0.49	0.50	**0.14**	**0.35**
B-3-4	0.69	**0.32**	**0.30**	**0.85**
C-1-1	0.43	**0.55**	**0.50**	**1.70**
C-1-2	**0.19**	**0.70**	**0.50**	**1.60**
C-1-3	0.49	**0.31**	**0.37**	**1.15**
C-1-4	**0.15**	**0.33**	**0.48**	**1.30**
C-2-1	0.44	**0.32**	**0.37**	**0.95**
C-2-2	0.51	**0.20**	**0.27**	**0.65**
C-2-3	0.45	**0.31**	**0.24**	**0.85**
C-2-4	0.26	**0.13**	**0.14**	**0.46**
C-4-1	**0.27**	**0.70**	**0.85**	**2.45**
C-4-2	0.61	**0.22**	**0.27**	**0.70**
C-4-3	**0.19**	**0.70**	**0.75**	**2.15**
C-4-4	0.52	**0.29**	**0.17**	**0.55**
D-3-1	**0.17**	**0.50**	**0.55**	**1.55**
D-3-2	0.64	**0.42**	**0.40**	**1.35**
D-3-3	0.63	**0.23**	**0.27**	**0.95**
D-3-4	0.47	**0.13**	**0.17**	**0.45**
E-1-1	0.75	1.16	**0.43**	**1.25**
E-1-2	0.77	1.26	**0.36**	**1.10**
E-1-3	0.66	0.91	**0.23**	**0.75**
E-1-4	0.34	**0.22**	**0.23**	**0.70**
E-2-1	0.52	0.39	**0.10**	**0.31**
E-2-2	0.53	**0.49**	**0.45**	**1.40**
E-2-3	0.93	**0.25**	**0.25**	**0.65**
E-2-4	0.47	**0.18**	**0.18**	**0.50**
E-4-1	**0.17**	**0.65**	**0.60**	**1.65**
E-4-2	0.70	**0.30**	**0.29**	**0.85**
E-4-3	0.62	**0.15**	**0.17**	**0.50**
E-4-4	0.51	0.61	**0.20**	**0.60**
mean	0.53	0.42	0.33	0.95
median	0.52	0.31	0.27	0.85
std dev	0.21	0.27	0.18	0.51
mean + 2(std dev)	0.95	0.96	0.69	1.98
mean + 3(std dev)	1.16	1.22	0.87	2.49
* Bolded numbers are previous non-detects				

ATTAC
DATA ANALYSIS OF ECTED AREA

	Sample ID	Th-228	minus bkgd 0.53	Th-228 minus bkgd 0.53 0.42	Th-232	minus bkdg 0.42	Th-232 minus bkdg 0.42 0.54	Total Th	U-235	U-23
1	A-6-1	0.810	0.280	0.280	1.260	0.840	**0.840**	0.840	0.000	0.00
2	A-6-2	0.650	0.120	0.120	0.000	-0.420	0.000	0.120	0.000	0.00
3	A-6-3	0.620	0.090	0.090	0.500	0.080	0.080	0.090	0.000	0.00
4	A-6-4	1.060	0.530	**0.530**	1.170	0.750	**0.750**	0.750	0.000	0.00
5	A-7-1	0.870	0.340	0.340	1.410	0.990	**0.990**	0.990	0.000	0.00
6	A-7-2	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
7	A-7-3	0.900	0.370	0.370	0.780	0.360	0.360	0.370	0.000	0.00
8	A-7-4	0.410	-0.120	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
9	A-8-1	1.370	0.840	**0.840**	1.290	0.870	**0.870**	0.870	0.000	0.00
10	A-8-2	0.810	0.280	0.280	0.000	-0.420	0.000	0.280	0.000	0.00
11	A-8-3	0.600	0.070	0.070	0.630	0.210	0.210	0.210	0.000	0.00
12	A-8-4	0.670	0.140	0.140	0.000	-0.420	0.000	0.140	0.000	0.00
13	A-9-1	1.100	0.570	**0.570**	1.040	0.620	**0.620**	0.620	0.000	0.00
14	A-9-2	0.930	0.400	0.400	0.000	-0.420	0.000	0.400	0.000	0.00
15	A-9-3	0.450	-0.080	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
16	A-9-4	0.670	0.140	0.140	0.520	0.100	0.100	0.140	0.000	0.00
17	A-10-1	0.550	0.020	0.020	0.000	-0.420	0.000	0.020	0.000	0.00
18	A-10-2	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
19	A-10-3	0.470	-0.060	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
20	A-10-4	0.340	-0.190	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
21	A-11-1	0.860	0.330	0.330	0.000	-0.420	0.000	0.330	0.000	0.00
22	A-11-2	1.600	1.070	**1.070**	0.000	-0.420	0.000	1.070	0.000	0.00
23	A-11-3	0.490	-0.040	0.000	0.720	0.300	0.300	0.300	0.000	0.00
24	A-11-4	0.490	-0.040	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
25	A-12-1	1.190	0.660	**0.660**	0.000	-0.420	0.000	0.660	0.000	0.00
26	A-12-2	5.170	4.640	**4.640**	5.220	4.800	**4.800**	4.800	0.000	0.00
27	A-12-3	1180.000	1179.470	**1179.470**	1210.000	1209.580	**1209.580**	1209.580	0.000	0.00
28	A-12-4	285.000	284.470	**284.470**	287.000	286.580	**286.580**	286.580	0.000	0.00
29	A-13-1	7.900	7.370	**7.370**	8.400	7.980	**7.980**	7.980	0.000	0.00
30	A-13-2	6.600	6.070	**6.070**	6.400	5.980	**5.980**	6.070	0.000	0.00
31	A-13-3	7.100	6.570	**6.570**	7.800	7.380	**7.380**	7.380	0.000	0.00
32	A-13-4	1.110	0.580	**0.580**	0.000	-0.420	0.000	0.580	0.000	0.00
33	A-14-1	1.990	1.460	**1.460**	0.000	-0.420	0.000	1.460	0.000	0.000
34	A-14-2	0.440	-0.090	0.000	0.000	-0.420	0.000	0.000	0.000	0.000
35	A-14-3	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.000
36	A-14-4	0.410	-0.120	0.000	0.000	-0.420	0.000	0.000	0.000	0.000
37	A-15-1	1.090	0.560	**0.560**	0.000	-0.420	0.000	0.560	0.000	0.000

Spreadsheet uses 1/2 MDA as background (where background is reported as MDA), and 2 STD as criteria

ATTAC' S
DATA ANALYSIS OF ECTED AREA

	Sample ID	Th-228	minus bkgd 0.53	Th-228 minus bkgd	Th-232	minus bkdg 0.42	Th-232 minus bkdg	Total Th	U-235	U-23
38	A-15-2	0.610	0.080	0.080	0.000	-0.420	0.000	0.080	0.000	0.00
39	A-15-3	0.710	0.180	0.180	0.700	0.280	0.280	0.280	0.000	0.00
40	A-15-4	0.980	0.450	**0.450**	0.780	0.360	0.360	0.450	0.000	0.00
41	A-16-1	2.110	1.580	**1.580**	2.360	1.940	**1.940**	1.940	0.000	0.00
42	A-16-2	0.740	0.210	0.210	0.000	-0.420	0.000	0.210	0.000	0.00
43	A-16-3	0.910	0.380	0.380	0.000	-0.420	0.000	0.380	0.000	0.00
44	A-16-4	0.630	0.100	0.100	0.570	0.150	0.150	0.150	0.000	0.00
45	A-17-1	4.500	3.970	**3.970**	4.100	3.680	**3.680**	3.970	0.000	0.00
46	A-17-2	1.580	1.050	**1.050**	0.000	-0.420	0.000	1.050	0.000	0.00
47	A-17-3	2.020	1.490	**1.490**	1.880	1.460	**1.460**	1.490	0.000	**3.20**
48	A-17-4	1.900	1.370	**1.370**	2.140	1.720	**1.720**	1.720	0.000	0.00
49	A-18-1	8.200	7.670	**7.670**	8.200	7.780	**7.780**	7.780	0.000	0.00
50	A-18-2	8.200	7.670	**7.670**	8.200	7.780	**7.780**	7.780	0.000	0.00
51	A-18-3	2.160	1.630	**1.630**	2.250	1.830	**1.830**	1.830	0.000	0.00
52	A-18-4	7.100	6.570	**6.570**	7.100	6.680	**6.680**	6.680	0.000	0.00
53	A-19-1	0.820	0.290	0.290	0.000	-0.420	0.000	0.290	0.000	0.00
54	A-19-2	0.750	0.220	0.220	0.000	-0.420	0.000	0.220	0.000	0.00
55	A-19-3	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
56	A-19-4	0.520	-0.010	0.000	0.550	0.130	0.130	0.130	0.000	0.00
57	A-20-1	0.830	0.300	0.300	0.830	0.410	0.410	0.410	0.000	0.00
58	A-20-2	1.060	0.530	**0.530**	1.160	0.740	**0.740**	0.740	0.000	0.00
59	A-20-3	0.510	-0.020	0.000	0.750	0.330	0.330	0.330	0.000	0.00
60	A-20-4	0.700	0.170	0.170	0.000	-0.420	0.000	0.170	0.000	0.00
61	A-20-5	0.370	-0.160	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
62	B-7-1	0.870	0.340	0.340	0.000	-0.420	0.000	0.340	0.000	0.00
63	B-7-2	3.850	3.320	**3.320**	4.200	3.780	**3.780**	3.780	0.000	**25.50**
64	B-7-3	13.700	13.170	**13.170**	14.800	14.380	**14.380**	14.380	**8.000**	**25.80**
65	B-7-4	1.960	1.430	**1.430**	2.450	2.030	**2.030**	2.030	0.000	0.00
66	B-7-5	1.170	0.640	**0.640**	0.000	-0.420	0.000	0.640	0.000	0.00
67	B-8-1	5.800	5.270	**5.270**	6.500	6.080	**6.080**	6.080	0.000	0.00
68	B-8-2	0.650	0.120	0.120	0.000	-0.420	0.000	0.120	0.000	0.00
69	B-8-3	0.560	0.030	0.030	0.000	-0.420	0.000	0.030	0.000	0.00
70	B-8-4	0.650	0.120	0.120	0.650	0.230	0.230	0.230	0.000	0.00
71	B-9-1	2.070	1.540	**1.540**	2.450	2.030	**2.030**	2.030	0.000	0.00
72	B-9-2	1.400	0.870	**0.870**	1.070	0.650	**0.650**	0.870	0.000	0.00
73	B-9-3	0.620	0.090	0.090	0.000	-0.420	0.000	0.090	0.000	0.00
74	B-9-4	0.440	-0.090	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
75	B-10-1	0.800	0.270	0.270	0.000	-0.420	0.000	0.270	0.000	0.00
76	B-10-2	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
77	B-10-3	0.680	0.150	0.150	0.580	0.160	0.160	0.160	0.000	0.00
78	B-10-4	0.450	-0.080	0.000	0.490	0.070	0.070	0.070	0.000	0.00
79	B-11-1	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00

Spreadsheet uses 1/2 MDA as background (where background is reported as MDA), and 2 STD as criteria

Breckenridge Disposal Site

ATTAC
DATA ANALYSIS OF EFFECTED AREA

	Sample ID	Th-228	minus bkgd 0.53	Th-228 minus bkgd	Th-232	minus bkdg 0.42	Th-232 minus bkdg	Total Th	U-235	U-23
80	B-11-2	0.900	0.370	0.370	0.000	-0.420	0.000	0.370	0.000	0.00
81	B-11-3	34.000	33.470	**33.470**	31.700	31.280	**31.280**	33.470	0.000	0.00
82	B-11-4	28.700	28.170	**28.170**	28.400	27.980	**27.980**	28.170	0.000	83.0
83	B-11-5	9.600	9.070	**9.070**	10.400	9.980	**9.980**	9.980	0.000	0.00
84	B-12-1	7.400	6.870	**6.870**	7.600	7.180	**7.180**	7.180	0.000	0.00
85	B-12-2	1.470	0.940	**0.940**	1.630	1.210	**1.210**	1.210	0.000	0.00
86	B-12-3	0.590	0.060	0.060	0.000	-0.420	0.000	0.060	0.000	0.00
87	B-12-4	0.660	0.130	0.130	0.000	-0.420	0.000	0.130	0.000	0.00
88	B-13-1	6.900	6.370	**6.370**	7.300	6.880	**6.880**	6.880	0.000	0.00
89	B-13-2	1.130	0.600	**0.600**	0.000	-0.420	0.000	0.600	0.000	0.00
90	B-13-3	0.720	0.190	0.190	0.000	-0.420	0.000	0.190	0.000	0.00
91	B-13-4	1.480	0.950	**0.950**	1.590	1.170	**1.170**	1.170	0.000	0.00
92	B-14-1	0.910	0.380	0.380	0.000	-0.420	0.000	0.380	0.000	0.00
93	B-14-2	1.120	0.590	**0.590**	0.000	-0.420	0.000	0.590	0.000	0.00
94	B-14-3	0.590	0.060	0.060	0.000	-0.420	0.000	0.060	0.000	0.00
95	B-14-4	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
96	B-15-1	0.600	0.070	0.070	0.620	0.200	0.200	0.200	0.000	0.00
97	B-15-2	5.600	5.070	**5.070**	5.400	4.980	**4.980**	5.070	0.000	0.00
98	B-15-3	0.710	0.180	0.180	0.700	0.280	0.280	0.280	0.000	0.00
99	B-15-4	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
100	B-16-1	22.100	21.570	**21.570**	22.800	22.380	**22.380**	22.380	0.000	**52.90**
101	B-16-2	13.400	12.870	**12.870**	15.300	14.880	**14.880**	14.880	0.000	0.00
102	B-16-3	2.320	1.790	**1.790**	2.050	1.630	**1.630**	1.790	0.000	0.00
103	B-16-4	1.010	0.480	**0.480**	0.880	0.460	**0.460**	0.480	0.000	0.00
104	B-17-1	10.000	9.470	**9.470**	8.800	8.380	**8.380**	9.470	0.000	0.00
105	B-17-2	21.800	21.270	**21.270**	22.700	22.280	**22.280**	22.280	0.000	**37.70**
106	B-17-3	3.110	2.580	**2.580**	2.820	2.400	**2.400**	2.580	0.000	**8.00**
107	B-17-4	1.940	1.410	**1.410**	1.790	1.370	**1.370**	1.410	0.000	0.00
108	B-18-1	1.530	1.000	**1.000**	0.000	-0.420	0.000	1.000	0.000	0.00
109	B-18-2	2.970	2.440	**2.440**	0.000	-0.420	0.000	2.440	0.000	0.00
110	B-18-3	0.680	0.150	0.150	0.760	0.340	0.340	0.340	0.000	0.00
111	B-18-4	0.720	0.190	0.190	0.850	0.430	**0.430**	0.430	0.000	0.00
112	B-19-1	5.150	4.620	**4.620**	4.800	4.380	**4.380**	4.620	0.000	0.00
113	B-19-2	0.820	0.290	0.290	0.560	0.140	0.140	0.290	0.000	0.00
114	B-19-3	0.520	-0.010	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
115	B-19-4	0.440	-0.090	0.000	0.490	0.070	0.070	0.070	0.000	0.00
116	B-20-1	1.540	1.010	**1.010**	1.580	1.160	**1.160**	1.160	0.000	0.00
117	B-20-2	0.940	0.410	0.410	0.970	0.550	**0.550**	0.550	0.000	0.00
118	B-20-3	0.840	0.310	0.310	0.000	-0.420	0.000	0.310	0.000	0.00
119	B-20-4	0.530	0.000	0.000	0.480	0.060	0.060	0.060	0.000	0.00
120	C-7-1	1.210	0.680	**0.680**	0.000	-0.420	0.000	0.680	0.000	0.00
121	C-7-2	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00

Spreadsheet uses 1/2 MDA as background (where background is reported as MDA), and 2 STD as criteria

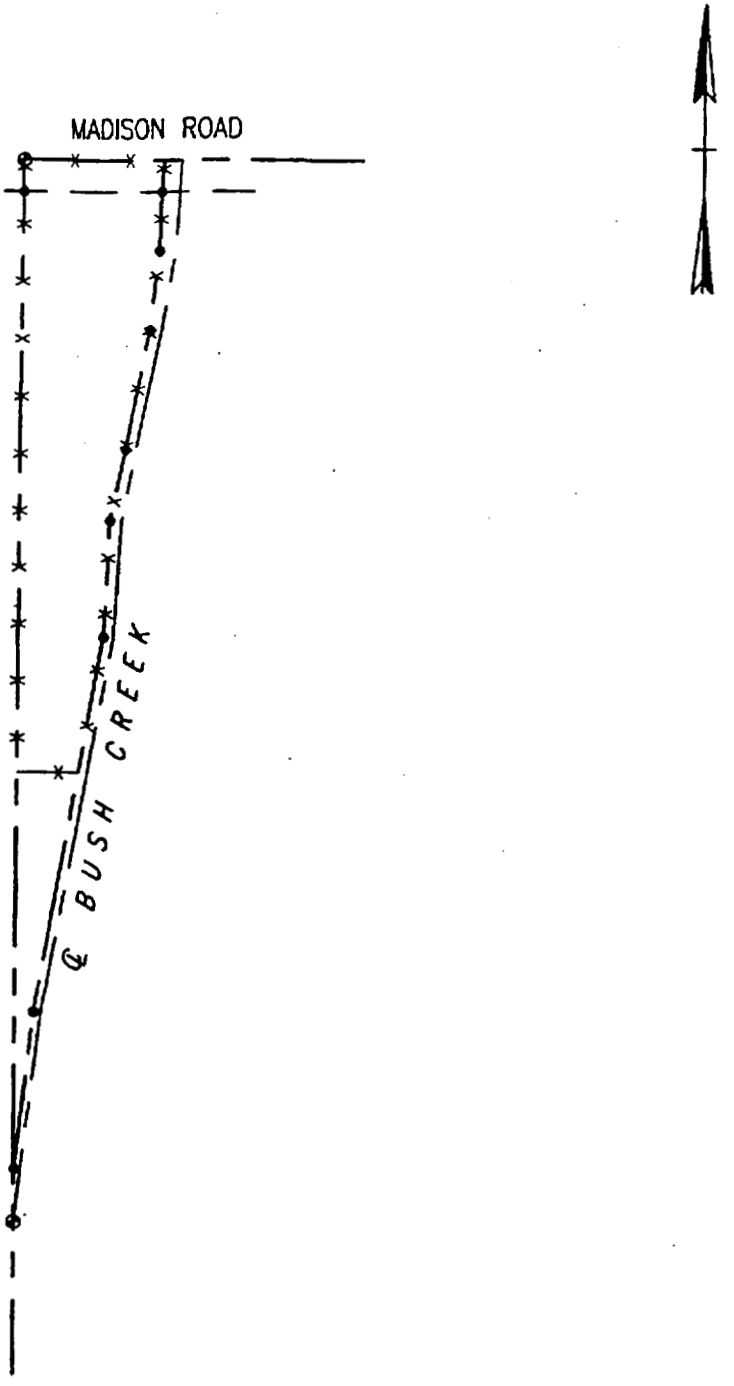
Breckenridge Disposal Site

ATTA(
DATA ANALYSIS OF ..FECTED AREA

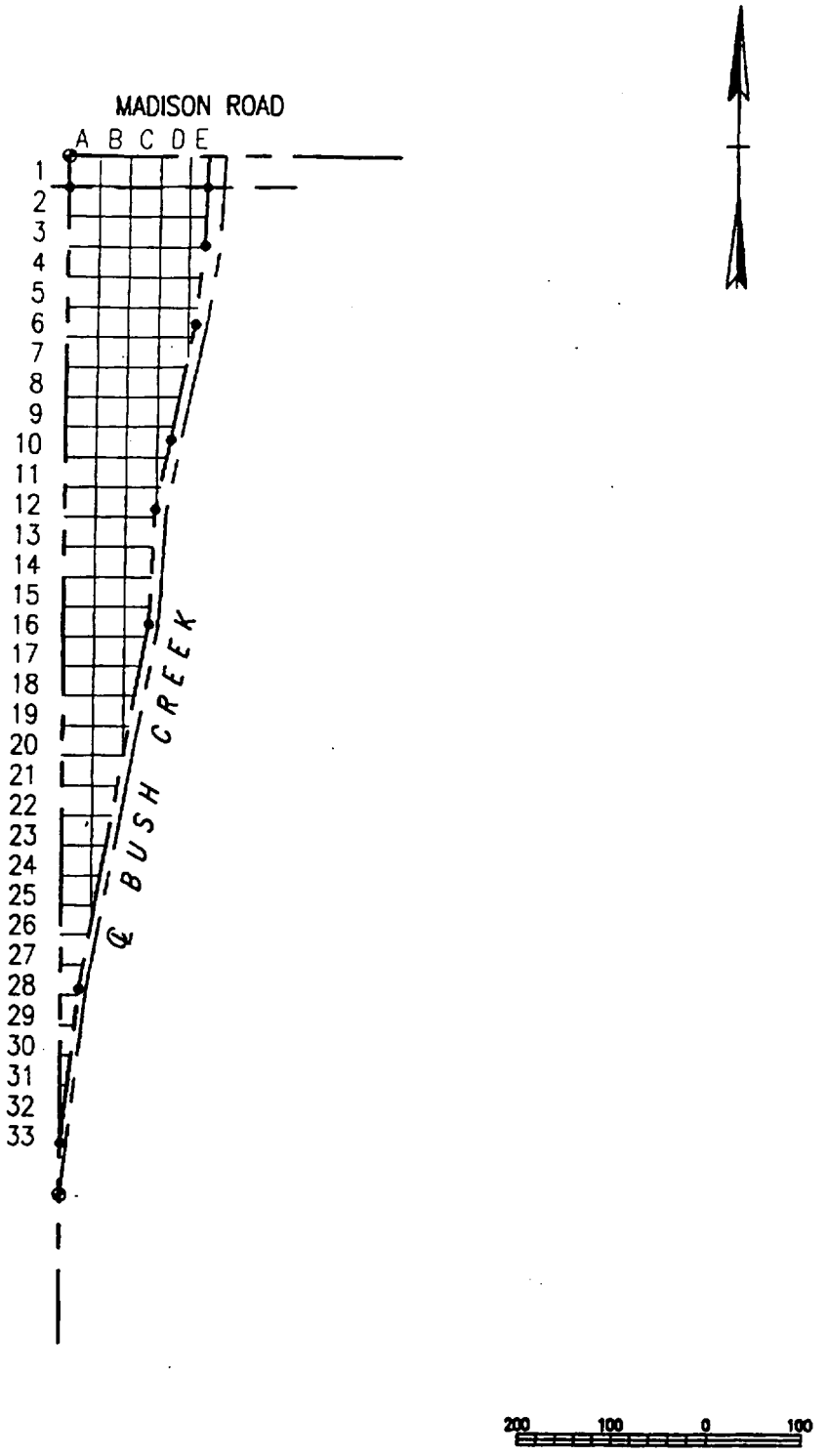
	Sample ID	Th-228	minus bkgd 0.53	Th-228 minus bkgd	Th-232	minus bkdg 0.42	Th-232 minus bkdg	Total Th	U-235	U-23
122	C-7-3	0.530	0.000	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
123	C-7-4	0.680	0.150	0.150	0.770	0.350	0.350	0.350	0.000	0.00
124	C-8-1	0.700	0.170	0.170	0.000	-0.420	0.000	0.170	0.000	0.00
125	C-8-2	0.450	-0.080	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
126	C-8-3	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
127	C-8-4	0.880	0.350	0.350	0.000	-0.420	0.000	0.350	0.000	0.00
128	C-9-1	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
129	C-9-2	0.710	0.180	0.180	0.620	0.200	0.200	0.200	0.000	0.00
130	C-9-3	0.690	0.160	0.160	0.000	-0.420	0.000	0.160	0.000	0.00
131	C-9-4	0.230	-0.300	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
132	C-10-1	0.000	-0.530	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
133	C-10-2	0.610	0.080	0.080	0.430	0.010	0.010	0.080	0.000	0.00
134	C-10-3	0.520	-0.010	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
135	C-10-4	0.620	0.090	0.090	0.000	-0.420	0.000	0.090	0.000	0.00
136	C-11-1	1.190	0.660	0.660	0.000	-0.420	0.000	0.660	0.000	0.00
137	C-11-2	0.510	-0.020	0.000	0.000	-0.420	0.000	0.000	0.000	0.00
138	C-11-3	0.610	0.080	0.080	0.000	-0.420	0.000	0.080	0.000	0.00
139	C-11-4	0.500	-0.030	0.000	0.000	-0.420	0.000	0.000	0.000	0.00

	Th-228	Th-232	Total Th	U-235	U-23
largest value	1179.47	1209.58	1209.58	8.00	83.0
mean	13.17	13.37	13.54	0.06	1.79
median	0.31	0.07	0.35	0.00	0.00
std dev	105.32	107.91	107.90	0.70	9.60

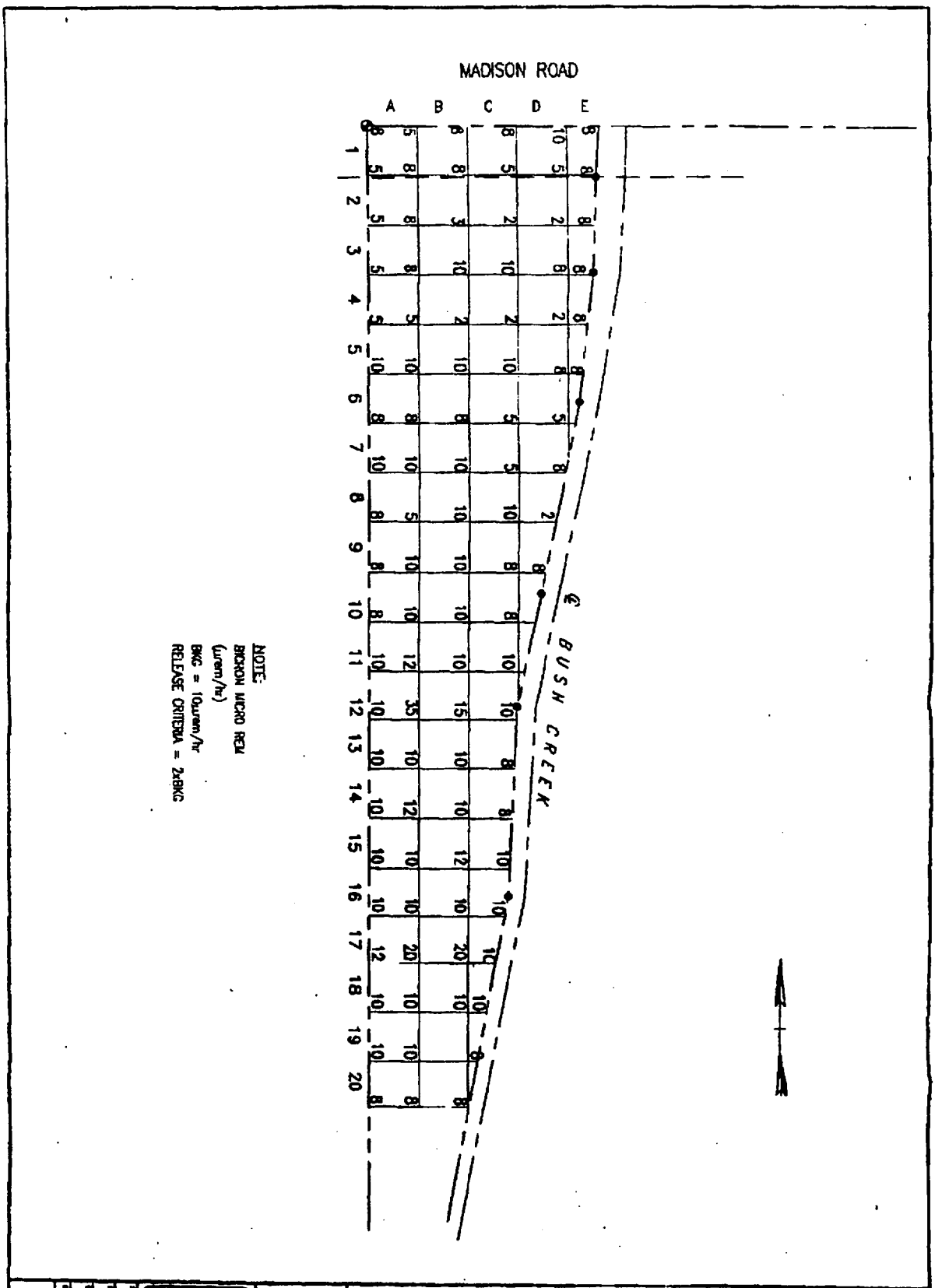
Spreadsheet uses 1/2 MDA as background (where background is reported as MDA), and 2 STD as criteria



DOCUMENT CONTROL NO.	PROJECT	CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE	NES, Inc.	PROJECT # 3023-101
				FILENAME: 3023101A
REVISION NO.	DRAWING	SITE MAP		SCALE: 1" =200' DATE: 9/11/97
				BY: AD CK:
				FIGURE # 1



DOCUMENT CONTROL NO.	PROJECT	CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE	NES® NES, Inc.	PROJECT # 3023-101
				FILENAME: 3023101A
REVISION NO.	DRAWING	GRID MAP		SCALE: 1" =200' / DATE: 9/11/97
				BY: AD / CK:
				FIGURE # 2

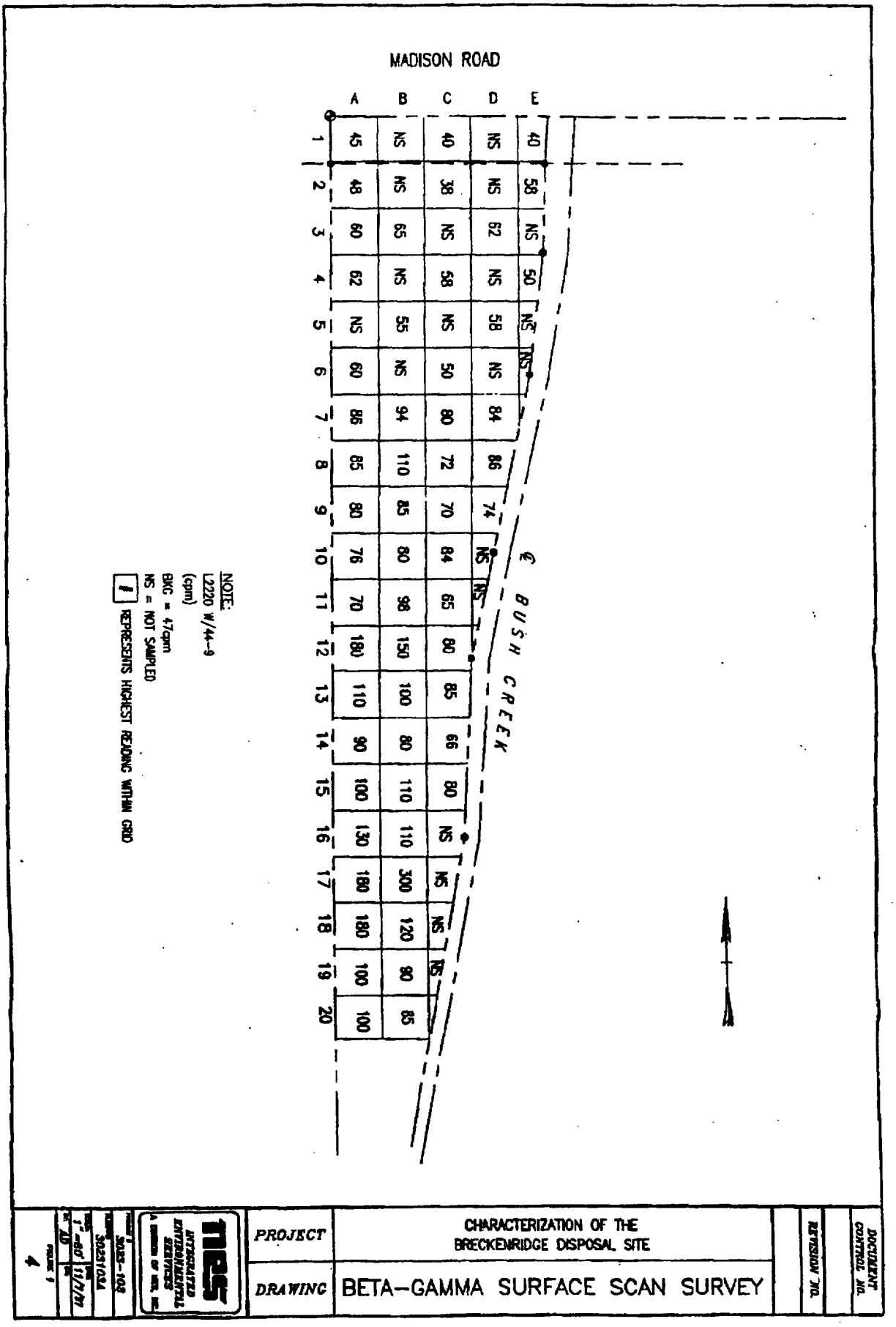


PROJECT	CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE	
DRAWING	GAMMA DOSE RATE SURVEY	

DOCUMENT CONTROL NO. | REVISION NO.

INTEGRATED ENVIRONMENTAL SERVICES

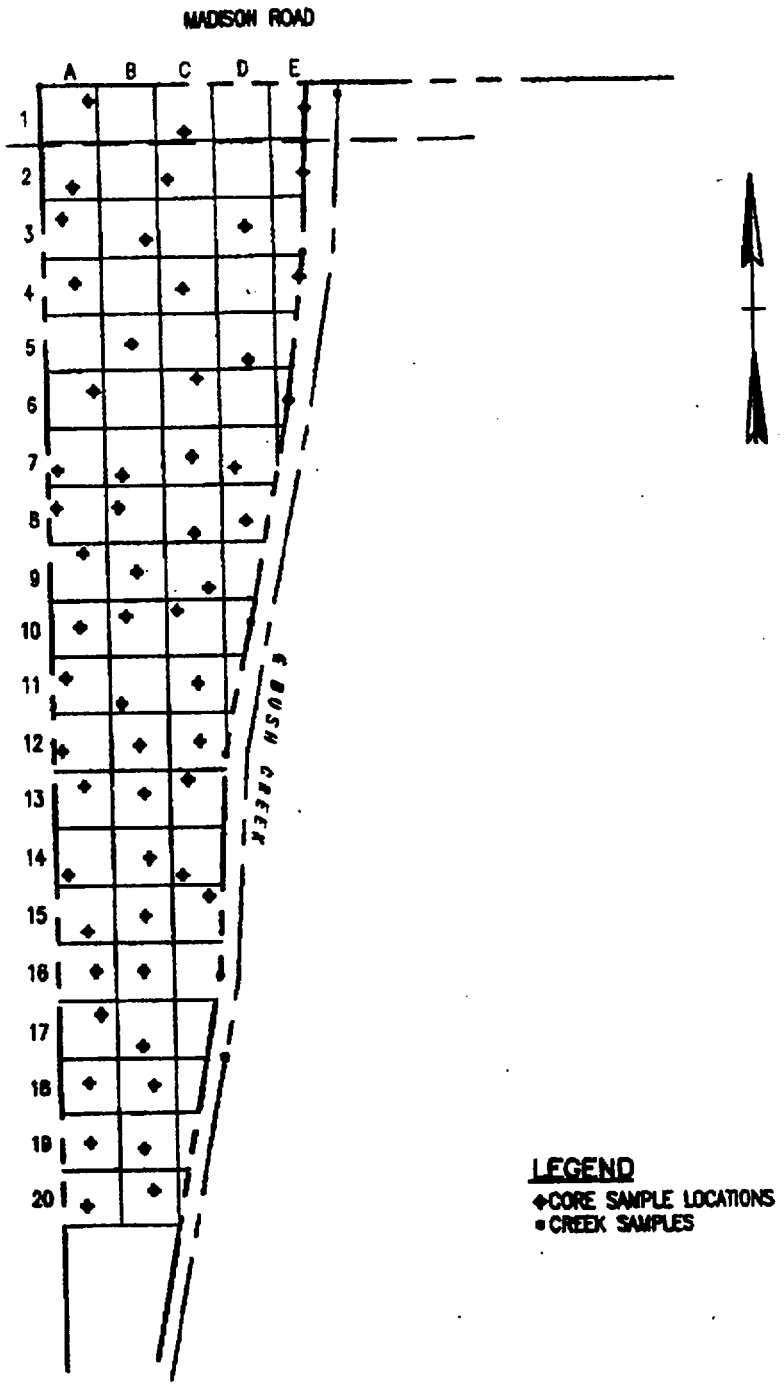
PROJECT 5023-103
DRAWING 50231030
SCALE 1" = 60'
DATE 11/9/87
BY AD
FIGURE 1
SHEET 3



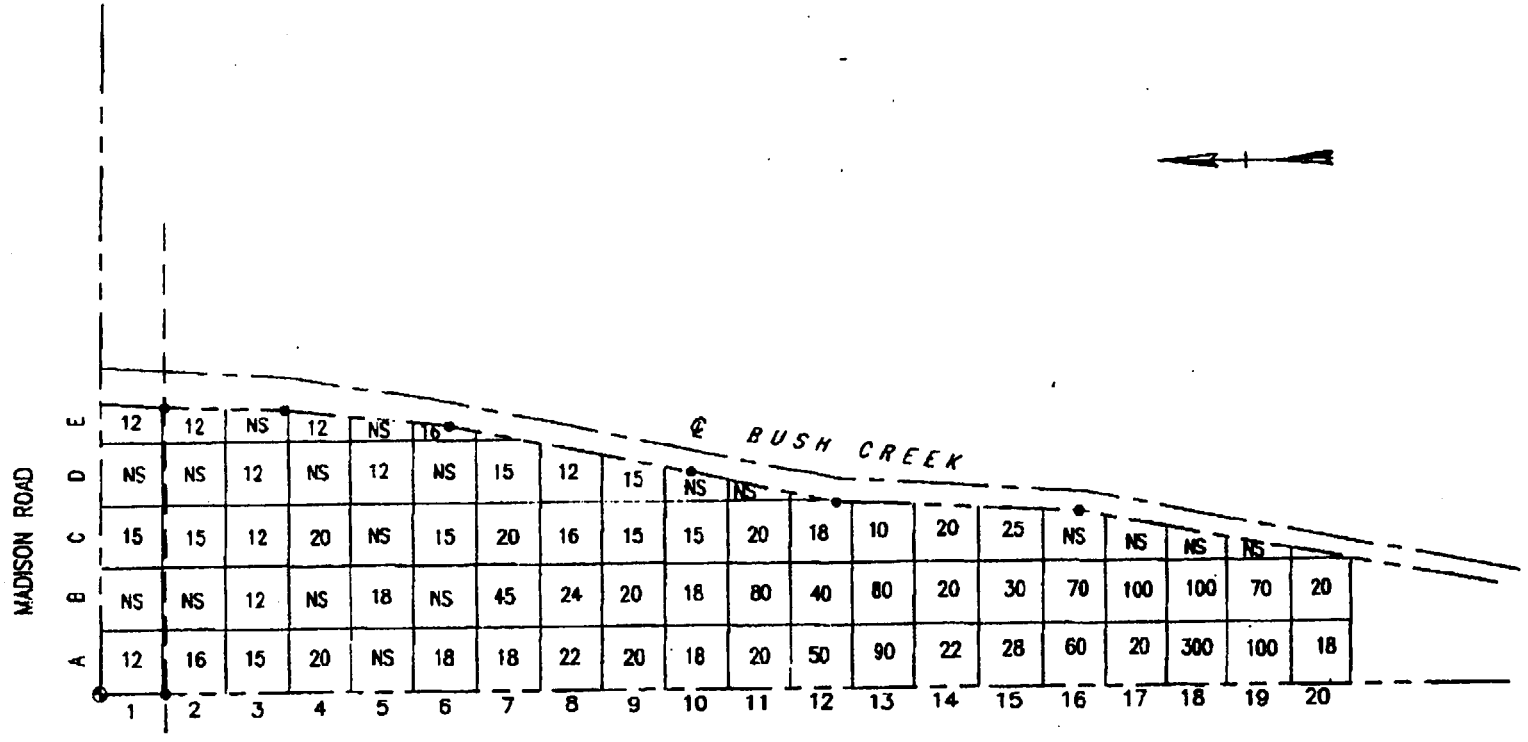
PROJECT	CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE	REVISION NO.	DOCUMENT CONTROL NO.
DRAWING	BETA-GAMMA SURFACE SCAN SURVEY		

MAS INTEGRATED ENVIRONMENTAL SERVICES

PROJECT NO. 30285-1008
DRAWING NO. 30251034
SCALE 1" = 40'
DATE 11/9/99
DRAWN BY
PAGE 1 OF 4



DOCUMENT CONTROL NO.	PROJECT	CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE	NES, Inc.	3023-103
REVISION NO.	DRAWING	CORE SAMPLE LOCATION MAP		3023103A 1"=100' 8/18/99 AD FIGURE 5



NOTE:

ALL NUMBERS LISTED ARE IN HUNDRED cpm
(ie 12=1,200 cpm)

LZ220 W/44-9 (cpm)

BKG = APPROX. 2,000 cpm

NS = NOT SAMPLED

REPRESENTS DOWNHOLE ACTIVITY MEASUREMENTS WITHIN GRID

DOCUMENT CONTROL NO.

REVISION NO.

CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE

DOWNHOLE ACTIVITY MEASUREMENTS

PROJECT

DRAWING

nes

SCIENTECH NES, Inc.
44 Shelter Rock Road
Danbury, CT 06810
(203) 798-3000

3023-103

30231036

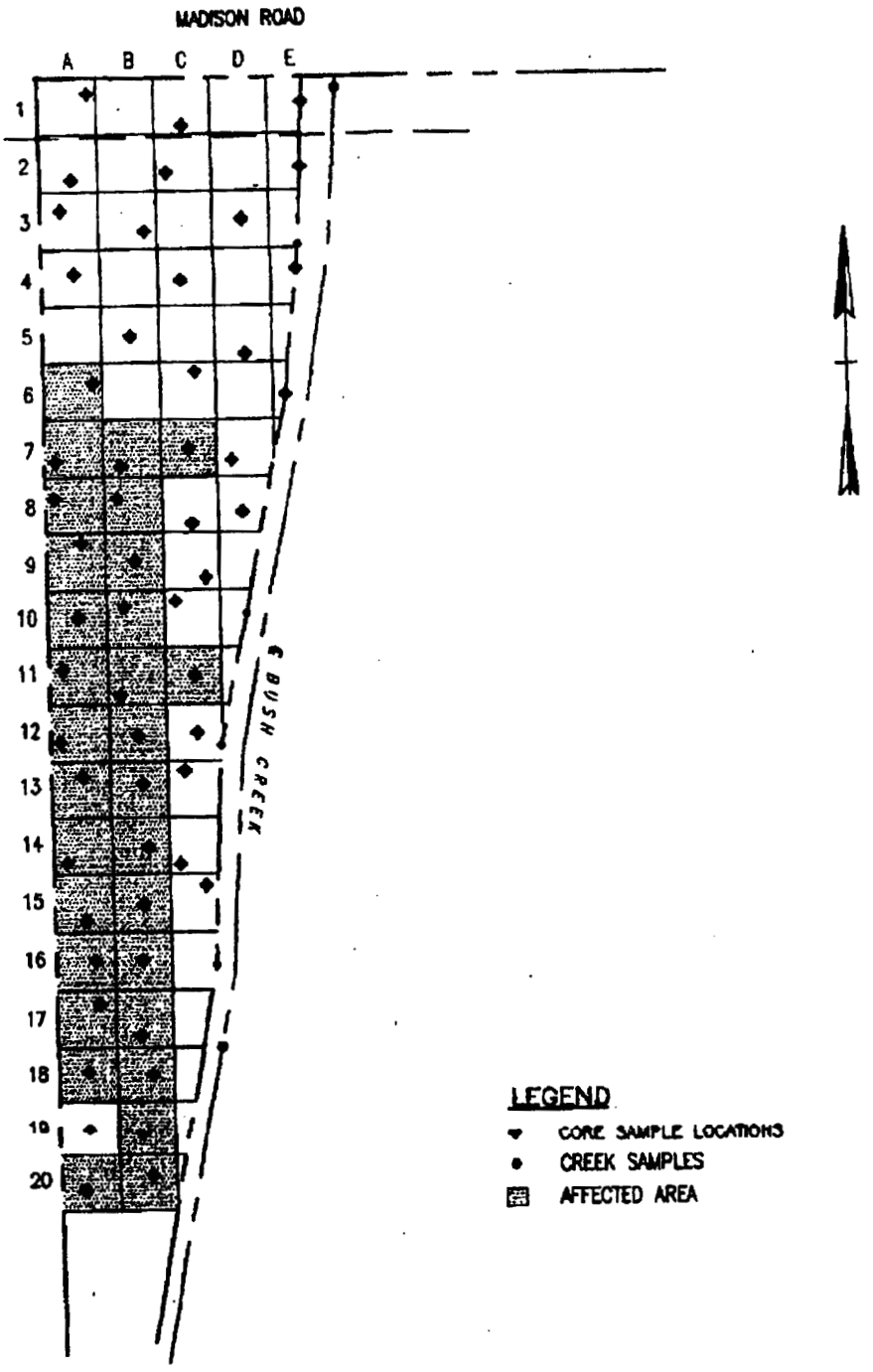
1" =60'

2/24/99

LD

FIGURE 1

6



DOCUMENT CONTROL NO.	PROJECT	CHARACTERIZATION OF THE BRECKENRIDGE DISPOSAL SITE	NES NES, Inc.	PROJECT # 3023-103
				FILENAME 3023103A
REVISION NO.	DRAWING	BOUNDARY OF CONTAMINATION		SCALE 1" =100' DATE 8/18/99
				DR AD CK
				FIGURE # 7