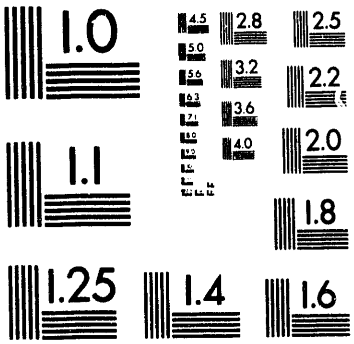

1.0
4.5
2.8
2.5
5.0
3.2
2.2
5.6
6.3
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

1 of 1

WSRC-RP-89-675

ESTIMATES FOR PU-239 LOADINGS IN BURIAL GROUND CULVERTS BASED ON FAST/SLOW NEUTRON MEASUREMENTS (U)

RECEIVED
AUG 11 1993
OSTI

by
W. G. Winn

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

R. C. Hochel
WSRC
K. J. Hofstetter
WSRC
R. A. Sigg
WSRC

A document prepared for:
requested by:
Mary Cunningham
Information Store, San Francisco, CA

DOE Contract No. DE-AC09-89SR18035

This paper was prepared in connection with work done under the above contract number with the U. S. Department of Energy. By acceptance of this paper, the publisher and/or recipient acknowledges the U. S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper, along with the right to reproduce and to authorize others to reproduce all or part of the copyrighted paper.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

SAVANNAH RIVER SITE
TECHNICAL DIVISION

WSRC-RP-89-675

Derivative Classifier
UNCLASSIFIED

KEYWORDS

Criticality
Burial Ground
TRU Waste
Pu-239
Neutron Counters
Estimations
Statistical Models

Lifetime Retention

INFORMATION ONLY

COPY

August 15, 1989

TO: M.A. EBRA

FROM: W.G. WINN, R.C. HOCHEL,
K.J. HOFSTETTER, R.A. SIGG

Estimates for Pu-239 Loadings in Burial Ground Culverts Based on Fast/Slow Neutron Measurements (u)

The above WSRC-RP, which follows this cover sheet, includes a Table of Contents, Main Text, and Appendicies A - C. The data are tabulated to allow easy appraisal of estimated Pu-239 upper limit loadings for comparison with criticality limits.

DISTRIBUTION

SRP

L.M. Papouchado, 703-A
R.G. Garvin, 703-H
J.E. Haywood
S.S. Cathey
W.E. Stewart
J.R. Shappell
H.H. Rowland, 703-F
T.A. Reilly, 707-H
S.J. Mentrup, 724-7G
R.E. Hanvey
C.C. Robbins
D.W. Murdock

SRL

H.D. Harmon, 773-A
A.L. Boni
C.E. Coffey
G.T. Wright
C.W. Jenkins
K.A. Andringa, 773-41A
D.R. Finch
D.A. Orth
M.D. Boersma
R.W. Taylor, 735-A

TABLE OF CONTENTS

SAVANNAH RIVER SITE
TECHNICAL DIVISION

WSRC-RP-89-675

Derivative Classifier
[signature]
UNCLASSIFIED

CC: Distribution
(coversheet)

August 15, 1989

TO: M.A. EBRA

FROM: W.G. WINN, R.C. HOCHEL
K.J. HOFSTETTER, R.A. SIGG

Estimates for Pu-239 Loadings in Burial Ground Culverts Based on Fast/Slow Neutron Measurements

INTRODUCTION

This report provides guideline estimates for Pu-239 mass loadings in selected burial ground culverts. The relatively high recorded Pu-239 contents of these culverts have been appraised as suspect relative to criticality concerns, because they were assayed only with the solid waste monitor (SWM) per gamma-ray counting [ref 1]. After 1985, subsequent waste was also assayed with the neutron coincidence counter (NCC), and a comparison of the assay methods showed that the NCC generally yielded higher assays than the SWM [ref 2]. These higher NCC readings signaled a need to conduct non-destructive/non-intrusive nuclear interrogations of these culverts, and a technical team conducted scoping measurements to illustrate potential assay methods based on neutron and/or gamma counting [ref 3].

A fast/slow neutron method has been developed to estimate the Pu-239 in the culverts [ref 4]. In addition, loading records include the SWM assays of all Pu-239 cuts of some of the culvert drums [ref 5], and these data are useful in estimating the corresponding NCC drum assays from NCC vs SWM data [ref 2]. Togther, these methods yield predictions based on direct measurements and statistical inference.

SUMMARY

Detailed Pu-239 estimates are given for 118 suspect culverts on pads 6, 10, and 13. A total of 9 estimate methods were examined, and one based on direct measurements and one based on statistical inference are adopted as the most appropriate guides. For arbitrary Pu-239 loading limits of 1000 g per drum and 2500 g per culvert, the direct method predicts that 82 culverts comply, and the statistical method predicts that all 118 comply.

Interferences from non-Pu-239 neutron sources cause some of the non-compliance cases in the direct method. Measurements on 36 culverts with better known Pu loadings imply that refinements for the Pu-238 contribution would allow 111 culverts to comply, using the direct method. These measurements also indicate that the SWM provides a better - albeit lower - estimate than the NCC, and thus currently accepted (NCC+SWM)/2 values are conservative on average. Gamma-ray measurements will provide additional information on some of the culverts. Ultimate compliance will depend on criticality loading limits, which are being evaluated and adopted for this work.

There are 93 suspect culverts that were not appraised in this study, because an overburden of soil rendered them inaccessable. However, their recorded SWM assays are much lower than those examined in the present work. Thus, compliance for these culverts may be demonstratable without direct measurements.

MEASUREMENTS AND DATA SOURCES

Measurements were conducted with the fast/slow neutron method, as described in detail earlier [ref 4]. Briefly, a fast and a slow neutron detector were centered atop each culvert and counted for 200 sec. The measured neutron rates were corrected for backgrounds for the adjacent culverts and general area. Each measured neutron rate was compared with a projected neutron rate based on culvert calibrations, which address neutron source location and drum moderator. These rate calibrations were convoluted with the SWM recorded Pu-239 for each drum per location, to yield the projected rate. The ratio of measured to projected neutron rates, designated m/p, reflects the agreement between the actual and recorded Pu-239 loadings. Multiplication of m/p by the recorded mass yields an estimate of the actual Pu-239 in the culvert.

Earlier work [ref 4] had already measured the 71 suspect culverts on pad 13, and the present study measured the 30 suspect culverts on pad 6 and the 17 on pad 10. Thus, results for a total of 118 culverts are presented in this report. There are 93 more culverts that still need to be appraised; however, they were inaccessable in this work due to a soil overburden. Also, it may be possible to cancel measurements on these pending the status of the 118, as the 93 have much lower SWM recorded Pu-239.

The present work also includes measurements on 36 "check" culverts that have better information on their Pu loadings, as both SWM and NCC data were available. These culvert measurements provide further appraisal of the fast/slow neutron method. In particular, they give better information on the effect of Pu-238. These culverts include 33 from pad 10 and 3 from pad 13. A total of 18 have only Pu-239; the other 18 have both Pu-238 and Pu-239.

Further data sources are from records of individual cuts of Pu-239. The cuts are assayed and packaged into the drums, and data on these suggest that most drums are loaded with 10-20 cuts of relatively small amounts of Pu-239 [ref 6]. This further implies that the accumulative percent error in the sum of these SWM assays (per drum loading) will be smaller than the error in a single assay of all these cuts. Given cut data for each drum, NCC vs SWM fluctuation data [ref 2] exist for predicting these errors and thus their upper limit excursions. Unfortunately, cut data for all drums were not available; only data for 68 drums could be examined for these fluctuations [ref 5]. The consistency of these predictions could be tested with the NCC and SWM data for the 36 "check" culverts.

ANALYSES

Two analyses, an m/p measurement method and one based on statistical inference, were considered most appropriate. These evolved from a total of nine different analyses that were examined. Five were described earlier [ref 4] and four new ones have evolved recently. All methods are summarized below, as a framework for discussing the two preferred methods. Each method is given a number and name for easy reference to analysis results, as summarized in Tables in Appendix C. The first five methods are based directly on the measured m/p ratios. The last four utilize statistical models. As will be discussed in further detail in the the RESULTS section, Method #5 is adopted as the preferred m/p-method, and Method #9 is the preferred statistical method. The direct methods and statistical methods leading to the preferred ones are described below.

Direct m/p Methods - Method #5 Preferred

Methods #1 - #5 directly estimate Pu-239 by multiplying each inventory value by its culvert ratio of measured/projected neutron rates. Method #5 is identified as the preferred direct method.

(1) m/p x Inventory Pu-239. [Ref 4 Method #3]. The estimate is defined by its title.

(2) m/p x 3Sig x Inventory Pu-239. [Ref 4 Method #4]. Estimate of Method #1 increased to account for upward 3-sigma fluctuations. The sigma includes all m/p measurements.

(3) **m/p(Pu-239) x Inventory Pu-239.** [Ref 4 Method #5]. Estimate is defined by its title, where m/p(Pu-239) is based on culverts that only have Pu-239 and no other interferring neutron sources. The m/p values for these pure Pu-239 cases were low (average ~1) relative to earlier NCC/SWM values (average 1.40); thus, m/p values were normalized to 1.40 to be conservative. Later measurements with the check culverts showed that this conservative factor was unnecessary.

(4) **m/p(Pu-239) x 3Sig(Pu-239) x Inventory Pu-239.** [Ref 4 Method #6]. Estimate of Method #3 increased to account for upward 3-sigma fluctuations. The sigma includes m/p measurements for culverts having only Pu-239 neutron sources.

(5) **m/p x 3Sig(Pu-239) x Inventory Pu-239....Preferred m/p Method.** [New Method]. Estimate uses measured m/p ratio (as in Methods #1 and #2) increased to account for 3-sigma Pu-239 fluctuations (as in Method #4). The average m/p ratio for the check culverts agrees well with 1.0 for check culverts containing only Pu-239, and the 3-sigma Pu-239 fluctuations are appropriate for upper limit estimates of their Pu-239. The check culverts that contain both Pu-238 and Pu-239 yield m/p values that are biased high; thus, using the 3-sig(Pu-239) for the upper limit Pu-239 estimate for these culverts should yield conservatively high results.

Statistical Methods - Method #9 Preferred

Methods #6 - #9 use statistical inference to estimate the Pu-239 loadings. Method #9 is identified as the preferred statistical method.

(6) **$13/\sqrt{n}$ x Inventory Pu-239.** [Ref 4 Method #2]. This method takes credit for the cut averaging effect in m/p estimates, which lowers the fluctuations by a factor of $\sqrt{n}$. The n is an effective number of recorded Pu-239 cuts of a culvert loading, based on measured log-Normal distribution data. For a single cut (n = 1), a maximum factor of 13 gives the 3-sigma upper limit [ref 4]. The effective n is shown to be proportional to the recorded mass loading. The development is based on culverts having only Pu-239 neutron sources, and uses those with SWM that cluster about 248 g and 926 g, as shown in Figure 1. Appendix A provides further details.

(7) **Refined $13/\sqrt{n}$ x Inventory Pu-239.** [New Method]. This method is the same as Method #6, except that the individual data points of Figure 1 are fitted to the model instead of using two averaged point clusters. This refined approach results in somewhat larger effective n (lower accumulative fluctuations) than afforded by the

point cluster approach. This is expected because the variation in SWM values with the point clusters introduces additional uncertainty in derived NCC values. Mathematical details for this method are discussed in Appendix A.

(8) **Cut Model x Inventory Pu-239.** [New Method]. This method uses the data for the 68 drums with detailed cut information and the NCC vs SWM correlation. Figure 2 reproduces the NCC vs SWM correlation from an earlier study [ref 2]. The correlation shows that ln(NCC) and its error increase linearly with ln(SWM). Using the SWM recorded for each cut, the correlated NCC and error is calculated. The cut NCCs are then summed for each drum and their accumulated error is also determined. The resulting 3-sigma excursion upper limits for the 68 drums are plotted in Figure 3. The figure also includes an envelope curve that is conservatively higher than all measured NCC excursions. This envelope of NCC excursion vs drum SWM is also used to predict the culvert NCC excursion limits. Specifically, the correlated NCCs for the drums and their errors, as determined from the envelope curve, are summed to yield a culvert NCC and its corresponding accumulated error. From this, the 3-sigma excrusion limits for the culverts are determined. The mathematical details for this method are given in Appendix A, where the predictions are shown to be consistent with observations for the 36 check culverts.

(9) **Conservative Cut Model x Inventory Pu-239....Preferred Statistical Method.** [New Method]. This method yields results intermediate to those of Methods #7 and #8. Method #7 is thought to yield a high estimate, because it uses neutron rate fluctuations to infer fluctuations in the Pu-239 loadings. Here, the neutron rate contribution from drums in the bottom of the culvert can be diminished relative to rates from drums in the top; thus, all Pu-239 is not equally represented in the rates and their effective n from rates is lower (larger fluctuations). By contrast, Method #8 can yield low Pu-239 estimates. In Method #8, the cut model only uses 68 drums to predict the NCC (upper limit) vs SWM envelope curve for drums, and all values are accumulated from cuts with SWM less than 30 g. At the same time, Appendix A shows that these predictions are consistent with NCC and SWM measurements for the 36 check culverts, which have SWM cuts of somewhat larger mass. Yet the possibility of very large SWM cuts in the suspect culvert drums cannot be ignored, although they are less likely [ref 6]. Thus, Method #8 should be treated as a possibly low estimate. The Conservative Cut Model increases the drum envelope (Figure 3) by x1.5, to yield the culvert results in Figure 4. The excursion estimates agree with Method #8 for the lowest SWM loadings, where

the lowest probability for a large Pu-239 cut exits; they agree with Method #7 for the largest SWM loadings, where the highest probability for a large Pu-239 cut exists. The estimates increase monotonically with SWM between these limits.

Applicability to Maximum Drum of a Culvert

The above methods were used to estimate both the drum contents and the culvert contents. The m/p methods are not as suitable for the individual drums, because these methods only measure rates for the culvert. However, the projected rates (p-factor of m/p) do depend on the recorded SWM values for the drums, and modeling the projected rates with the drum SWM and distributional data does reduce the fluctuations in the m/p measurements [ref 4]. Also, in most culverts, the SWM of the highest drum is substantially larger than the SWM of the next highest drum, so the m/p of the culvert is heavily influenced by the highest drum. Because the highest drum is appraised relative to a criticality limit, multiplication of its SWM by the culvert m/p yields a useful guideline estimate for examining the drum compliance.

For the statistical methods, which are based on the effect of accumulative errors on the sums of cuts, the estimate for both drums and culverts are based on the same models, and thus the above concern for distinguishing between individual drums is not an issue.

RESULTS

Preferred Methods

Table 1A gives the Pu-239 estimates for the preferred m/p method, which is Method #5. Assuming example loading limits of 1000 g/drum and 2500 g/culvert, Table 1A projects that 82 of the 118 culverts would be in compliance. Table 1B reduces these estimates by including a special Pu-238 correction, which is described in the DISCUSSION section. Table 1B projects that 111 of the culverts would be in compliance with the above example limits.

Table 2 gives the Pu-239 estimates for the preferred statistical method, which is Method #9. Relative to the example limits of 1000 g/drum and 2500 g/culvert, Table 2 projects that all 118 culverts would be in compliance.

These tables are designed to allow rapid appraisal of the estimates against realistic criticality limits, which are yet to be certified. Each table is like a scatter plot, where the culvert estimates are ordered monotonically in the third column (vertical axis), and their corresponding maximum drum estimates are monotonically spaced and printed to the right along respective rows (horizontal axis). The first column gives the table entry number, and the second column identifies the culvert number.

An example of how these tables are used is as follows. Using Table 1A, again suppose Pu-239 limits of 1000 g/drum and 2500 g/culvert. Then Table 1A has 88 culverts with < 2500 g, which is easily determined from columns 1 and 3. Of these, 6 can be easily identified as having maximum drum estimates that are as high as 1000 g. Thus, a total of 88-6 or 82 of these culverts and their drums meet the criteria. Using the table as a scatter plot, one would have drawn a horizontal line under the highest culvert estimate that is less than 2500 g (entry 88) and a vertical line just to the right of the highest drum estimate that is less than 1000 g. Then, the acceptable cases are those having both culvert estimates above the horizontal line and drum estimates to the left of the vertical line.

Other Methods

The results for all nine estimate methods are presented in similar tables in Appendix C, which in addition includes tables that order the data by culvert number for easy reference. Although the preferred methods are recommended at present, the over-conservatism in some of these alternative methods may become attractive, should their estimates be in compliance with the to-be-established criticality limits.

DISCUSSION

Appraisal of Preferred Methods

The preferred analysis methods are considered reasonable and conservative for several reasons. Both methods utilize estimates that are coupled with 3-sigma upper-limit fluctuations. The corresponding 0.1% probability for these limits needs to be appraised in terms of the probability of critical configurations, and preliminary studies [ref 7] indicate that these probabilities should be less than 10^{-5} so that current methods would render these probabilities to be less than 10^{-8}. Other conservative aspects for the preferred methods are discussed below.

Preferred m/p Method (Method #5). The results from the 36 check culverts support Method #5 as the preferred m/p method. The (NCC+SWM)/2 values for the 18 culverts containing only Pu-239 yield a low m/p geometric average of 0.74 ± 0.09. When the SWM values are used, this average is 0.95 ± 0.11, which is consistent with the desired value of 1. Because culvert calibrations in the laboratory used a well-known Pu-239 source [ref 4], the above result implies that the SWM measurements are generally more accurate than the NCC measurements. Appendix B details the analysis for these observations.

For the 18 check culverts containing both Pu-238 and Pu-239, the m/p values tend to be significantly greater than 1, yielding a geometric average of 1.78. Although a correction for Pu-238 contribution was developed [ref 4], the check culvert data show that as Pu-238 becomes a larger fraction of the total Pu, the m/p ratio is biased higher, which makes the correction conservatively high. Appendix B examines this Pu-238 bias trend and develops a bias correction factor R. An R factor was calculated for each of the 118 culverts under study, and each m/p estimate for Pu-239 was divided by its R, to yield the corrected Pu-239 estimates given in Table 1B. With these corrections, 111 of the 118 culverts meet the example criteria of 1000 g/drum and 2500 g/culvert.

The Preferred m/p Method is also conservative due to subcritical multiplication arguments. Measurement of the m/p values assumes that the ratio is entirely related to the ratio m_a/m_r of actual Pu-239 to recorded Pu-239. If a criticality concern exists, noticeable subcritical multiplication M should also be a factor in the m/p ratio r, so that

$$m/p = r = M\ m_a/m_r \qquad (1)$$

An estimate for M is given by

$$M = \frac{1}{1 - k_{eff}} = \frac{r\ m_r}{m_a} \qquad (2)$$

where k_{eff} is the effective criticality constant for the culvert, such that $k_{eff} = 1$ for the critical (infinite multiplication) case. Solving Equation 2 for k_{eff} yields

$$k_{eff} = 1 - m_a/m_r r = 1 - m_a/m_{ao} \qquad (3)$$

where $m_{ao} = m_r r$ is the Pu-239 estimated as the upper excursion (3-sigma limit) value of m/p x SWM in Method #5. From Equation 3, it is clear that for k_{eff} to be near the critical value of 1, the actual Pu-239 or m_a must be small relative to the m/p SWM estimate m_{ao}. However, there has to be a realistic lower limit on m_a because small amounts of Pu-239 cannot produce much multiplication to yield a substantial k_{eff}. For example, suppose the Pu-239 of a drum were estimated as m/p SWM = 1000 g = m_{ao}. Then, if the actual mass were m_a = 500 g, which is the minimum possible critical mass, the k_{eff} would be 0.5. For lower actual masses, criticality would be impossible, and for higher actual masses, k_{eff} would be less than 0.5. Realistic critical configurations for the culverts would involve actual critical masses that are greater than the 500 g minimum considered here, which would render that even greater m/p SWM estimates could be in compliance with criticality concerns. It might be beneficial to examine individual cases using these concepts, to demonstrate compliance when the realistic critical limits become available.

In any event, Method #5 does not take credit for the subcritical multiplication effect, and its estimated masses can only be conservatively high with respect to its assumption of non-multiplication (M=1).

Preferred Statistical Method (Method #9). This method uses statistical modeling to infer the effect of individual cuts, which are summed to give the drum and culvert Pu-239 loadings. As described in the ANALYSES section, this method yields results that are intermediate to Method #7, which can produce overestimates, and Method #8, which can produce underestimates. The possible underestimates of Method #8 are for NCC excursion limits, as predicted from corresponding recorded SWM values. Because these NCC excursion limits exceed the SWM reading, the assay (NCC+SWM)/2 that would have been obtained by current policies would be lower than that of the NCC estimates of Method #8. Thus, although Method #8 may yield a low estimate, it could be even lower if credit for this averaging effect were included. In fact, data for the 36 check culverts indicate that NCC/[(SWM+NCC)/2] = 1.22, as shown in Appendix B. Thus, Method #8 is conservative relative to this effect. Method #9 uses a modification of Method #8, in which the drum NCC estimates are increased by x1.5 to force agreement with the higher loadings that are conservatively estimated by Method #7, as shown in Figure 4. Thus, Method #9 appears to be both a reasonable and conservative statistical method.

Figure 5 compares the preferred statistical method with the current accepted policy of using (NCC+SWM)/2 estimates. Here, the statistical estimates for the 118 suspect culverts and the (NCC+SWM)/2 values for the 36 check culverts are both plotted against their respective SWM values. Because the statistical estimates cluster well above the scatter for the (NCC+SWM)/2 values, the preferred statistical method is quite conservative, implying that probabilities considerably lower than 0.1% really correlate with the above-defined 0.1% upper limit estimates. Actually, Method #8 appears to yield fairly accurate 0.1% upper limit estimates of NCC, as illustrated by a similar plot in Appendix A; however, the data are inadequate for addressing fluctuations of large cuts, which are less likely. Thus, the conservatism of Method #9 makes it more favorable than Method #8.

Preferred m/p Method vs Preferred Statistical Method . The m/p Method generally predicts higher estimates than the Statistical Method. The m/p ratio can be high due to contributions from neutron sources other than Pu-239. Although the analysis includes a correction for some of these neutron sources, the overall results include a conservative bias that is attributed to these sources [ref 4]. Thus, estimates by the m/p Method can be unduly high. The Pu-238 bias factor R provides a correction for this effect. By contrast, the Statistical Method is based on culverts that contain only Pu-239 neutron sources and drum cut data for Pu-239 alone; thus, it is not biased by other neutron sources. Although these considerations favor use of the Statistical Method, it will be prudent to closely examine some of the higher estimate cases of m/p Method, as a guide to their acceptance. Gamma-ray measurements for these can confirm whether the high estimates are caused by sources other than Pu-239.

Applicability to Remaining Culverts

The Statistical Method may be applicable for screening the remaining 93 suspect culverts that were inaccessable due to soil overburden. If so, actual measurements would not be necessary. These remaining culverts have SWM recorded Pu-239 loadings that are much lower than many of those analyzed in the present work. For example, the present study appraised 20 culverts with SWM recorded Pu-239 of 500-1200 g, and the largest loading for the remaining culverts is only 363 g. In addition, their individual drum loadings tend to be smaller. Further detailed data could enhance these appraisals. In particular, additional NCC and SWM data for culvert loadings would be useful to refine the correlations presented in this work. In particular, these data would be transformed to (NCC+SWM)/2 values, which are accepted for current assays.

Need for Realistic Criticality Limits

The results of the present work are presented in a way that acceptable culverts can easily be identified relative to critical loading limits for Pu-239. An effort [ref 8] has been underway to establish realistic limits for these culverts, because the present limits are based on general conditions for a postulated worst possible situation. Thus, the present limits are overly conservative relative to known moderator and geometry conditions of these culverts.

The realistic criticality limits are also needed to guide the completion of these appraisals. In particular, gamma-ray studies are being conducted only for culverts that are considered to be unacceptable from neutron measurements alone, and identification of these culverts is governed by the criticality limits. Because each gamma-ray measurement/analysis of a culvert can involve extensive time and effort, only culverts that absolutely require this appraisal should be studied.

ACKNOWLEDGEMENTS

J.R. Shappell has provided much data from culvert/drum records, including the detailed cut records and updated culvert loading information. S.J. Mentrup has helped assure smooth field measurements, by providing assistance from services in the burial ground.

REFERENCES

(1) O.M. Morris, "Meeting Minutes - Suspect FB-Line TRU Waste", Memorandum to Distribution, December 17, 1987.

(2) E.P. Shine, "Analysis of Large Differences between Neutron Coincident and Gamma Measurements for FB-Line TRU Waste Cuts", Memorandum to W.E. Stewart, October 7, 1988. *

(3) R.C. Hochel, K.J. Hofstetter, R.A. Sigg, and W.G. Winn, "TRU Waste Culvert Monitoring Study",DPST-88-606, June 14, 1988.

(4) W.G. Winn, R.C. Hochel, K.J. Hofstetter, R.A. Sigg, "Fast/Slow Neutron Method for Appraising Pu-239 Waste in Burial Ground Culverts", DPST-89-346, March 6, 1989.

(5) J.R. Shappell, transmittal of culvert data below:

(a) Pu-239 cut data (SWM) for 68 drums from drum waste inventory worksheets.

(b) Data for suspect culverts - Culvert Log Book data on drum contents vs location, appended to COBRA inventory records referenced by:

W.J. Jaegge, "Pu-239 Inventory in Culverts with pre-11/16/85 FB Line Waste", Memorandum to G.H. Street, J.N. Chen, and J.R. Shappell, April 6, 1988.

(c) Data for 36 "check" culverts with NCC and SWM loadings - Culvert Log Book Data on drum contents (NCC & SWM) and location, appended to COBRA inventory records referenced by:

K.S. Weirzbicki, "Burial Slips and Completed Procedures for Culverts Containing FB-Line and TRU Waste", Memorandum to T.H. Fisher, February 28, 1989.

(6) D.W. Murdock, F-Area Separations Department, "FB-Line Solid TRU Waste Analysis", Memorandum to J.K. McKibbin and R.E. Hanvey, August 4, 1988.

---

* Data in this report are consistent with an overall average NCC/SWM bias of 1.40, although recent measurements suggest this may be higher. The overall bias depends on the size distribution of the cuts investigated; thus, the detailed correlated data of this report of ln(NCC) vs ln(SWM) is considered the most reliable.

REFERENCES - continued

(7) R.C. Hochel, K.J. Hofstetter, R.A. Sigg, and W.G. Winn, "Probabilistic Assessment of Culvert Nuclear Safety", DPST-89-383, April 10, 1989.

(8) R.C. Hochel, K.J. Hofstetter, R.A. Sigg, and W.G. Winn, "Nuclear Safety of Plutonium/Polyethylene Waste in TRU Culverts", DPST-88-1014, December 12, 1988.

Table 1. Preferred m/p Analysis - Method #5

A. Base Analysis

i	Cul	Cul-Pu	Max-Drum-Pu	--------------------
1	498	56	37	
2	537	263	187	
3	520	269	220	
4	385	294	92	
5	560	316	37	
6	547	397	271	
7	541	416	264	
8	489	416	182	
9	536	452	347	
10	374	476	187	
11	438	478	108	
12	444	490	154	
13	475	495		433
14	437	521	310	
15	519	589	272	
16	502	550		393
17	539	551		404
18	454	560	209	
19	453	563	219	
20	522	595		437
21	434	631	217	
22	458	682	218	
23	484	709	338	
24	428	716	342	
25	533	733		565
26	367	760		448
27	508	773	203	
28	491	796	319	
29	538	811		571
30	517	813		407
31	354	823	380	
32	400	858	335	
33	461	898	154	
34	557	913	151	
35	433	940	242	
36	278	942		576
37	559	947	214	
38	479	949	266	
39	397	977	243	
40	426	983		451
41	509	986	181	
42	443	993	337	
43	534	996		555
44	548	1015	174	
45	540	1151		799
46	506	1183	290	
47	415	1196	336	
48	358	1199		497
49	401	1206		676
50	550	1276		646
51	531	1308		784
52	538	1373		998
53	532	1377	204	
54	390	1398		838
55	504	1413		731
56	427	1444		482
57	396	1489		766
58	546	1495	169	
59	483	1502	345	
60	439	1507	376	
61	413	1607		756
62	544	1614	203	
63	493	1662		914
64	553	1707	180	
65	554	1732	205	
66	555	1769	261	
67	551	1779	194	
68	405	1824		642
69	404	1829		1819
70	395	1831		935
71	394	1847		920
72	478	1870		545
73	393	1879		944
74	384	1905		988
75	391	1975		1311
76	501	1989		1041
77	514	1998		1055
78	510	2014		391
79	549	2016	218	
80	494	2025		1448
81	543	2025	238	
82	545	2031	378	
83	470	2127		514
84	583	2134		407
85	402	2149		630
86	418	2184		500
87	417	2255		748
88	490	2411		1287
89	480	2542		525
90	381	2571		1444
91	503	2586		1219
92	558	2625	336	
93	492	2648		1507
94	586	2662		1909
95	488	2722		1476
96	409	2816		1412
97	521	2858		2165
98	530	2897		1606
99	552	3101		486
100	505	3298		1938
101	370	3430		1029
102	482	3710		775
103	528	4018		586
104	420	4298		1909
105	412	4301		2419
106	518	4846		2484
107	527	5067		3473
108	513	5069		1066
109	456	5676		1715
110	515	6129		3202
111	516	6383		3346
112	392	6953		3453
113	332	7989		3713
114	529	8581		4317
115	481	7626		2082
116	399	11364		1675
117	324	13744		7134
118	507	36857		18655

B. Analysis with Pu-238 Correction

i	Cul	Cul-Pu	Max-Drum-Pu	--------------------
1	498	69	45	
2	401	109	61	
3	374	121	47	
4	434	122	42	
5	475	136	119	
6	426	141	65	
7	458	145	46	
8	428	157	75	
9	444	153	51	
10	502	167	121	
11	404	170	169	
12	385	183	57	
13	405	186	36	
14	402	189	55	
15	427	195	57	
16	433	197	51	
17	400	208	32	
18	412	215	121	
19	367	216	127	
20	432	225	48	
21	354	233	90	
22	409	235	118	
23	417	238	79	
24	384	253	130	
25	423	257	59	
26	437	265	158	
27	520	283	231	
28	537	286	204	
29	415	300	84	
30	370	308	90	
31	494	306	218	
32	439	308	77	
33	521	311	236	
34	582	318	234	
35	508	344	90	
36	391	347	230	
37	413	368	173	
38	397	375	93	
39	272	385	235	
40	390	388	232	
41	461	393	67	
42	547	397	271	
43	498	397	226	
44	420	398	177	
45	531	403	224	
46	484	415	198	
47	454	416	155	
48	541	416	264	
49	472	417	122	
50	358	423	175	
51	488	424	230	
52	394	425	212	
53	490	430	229	
54	470	431	106	
55	517	431	216	
56	489	432	200	
57	509	436	80	
58	418	437	100	
59	493	437	241	
60	482	439	92	
61	480	442	91	
62	479	444	124	
63	491	450	180	
64	396	451	232	
65	536	452	347	
66	443	453	154	
67	452	467	188	
68	560	473	55	
69	530	475	263	
70	504	479	248	
71	519	529	272	
72	539	551		404
73	381	553	310	
74	527	560	384	
75	503	579	273	
76	586	640		459
77	456	664	201	
78	514	690	364	
79	533	733		565
80	395	738	377	
81	518	738	378	
82	501	739	387	
83	392	768	381	
84	506	782	198	
85	538	811		571
86	559	854	193	
87	557	930	154	
88	523	934	178	
89	534	996		555
90	548	1088	186	
91	540	1151		799
92	505	1210		565
93	550	1276		646
94	510	1288	250	
95	338	1370		637
96	538	1373		995
97	532	1377	204	
98	393	1444		785
99	546	1495	169	
100	481	1589	331	
101	544	1614	203	
102	553	1707	180	
103	545	1714	319	
104	554	1738	205	
105	555	1745	257	
106	551	1779	194	
107	515	1788		734
108	516	2015		1056
109	549	2016	218	
110	543	2085	238	
111	399	2313	343	
112	528	2442	356	
113	558	2599	333	
114	513	3033		638
115	552	3101		486
116	529	3168		[illegible]
117	507	3875		[illegible]
118	324	5224		[illegible]

Table 2. Preferred Statistical Analysis - Method #9

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu	-------------------->
1	498	331	275	
2	374	415	283	
3	434	450	259	
4	401	463	337	
5	550	474	323	
6	426	480	349	
7	458	492	279	
8	444	499	299	
9	475	507		480
10	428	525	382	
11	404	539		538
12	502	589		483
13	385	593	322	
14	400	597		400
15	427	599	322	
16	405	612	352	
17	402	620	315	
18	433	637	297	
19	432	645	286	
20	412	663		467
21	367	664		492
22	437	677		528
23	520	687		573
24	354	699		423
25	533	717		570
26	384	719		497
27	494	722		568
28	417	724		393
29	536	725		572
30	409	727		477
31	423	728	329	
32	535	729		567
33	539	738		567
34	537	741		561
35	521	742		575
36	547	753		561
37	540	758		563
38	522	759		574
39	538	759		566
40	391	762		573
41	526	765		572
42	527	782		575
43	370	802		405
44	439	819	387	
45	541	819		566
46	415	835		407
47	534	840		559
48	272	850		575
49	530	852		572
50	321	857		574
51	492	863		571
52	413	871		542
53	518	876		565
54	529	878		564
55	515	879		569
56	390	881		574
57	516	884		571
58	514	885		572
59	396	901		574
60	395	901		575
61	517	904		567
62	488	906		573
63	332	912		541
64	531	918		571
65	490	919		573
66	508	919		422
67	394	925		565
68	489	927		560
69	393	931		573
70	392	933		571
71	493	935		577
72	503	936		557
73	519	939		570
74	484	940		558
75	504	945		568
76	420	949		545
77	397	955		429
78	505	957		566
79	324	961		572
80	501	963		574
81	507	970		573
82	461	988	357	
83	443	993		524
84	491	995		547
85	454	995		526
86	352	1001		544
87	472	1022		484
88	453	1029		548
89	509	1044		396
90	456	1044		501
91	399	1048	351	
92	479	1059		488
93	480	1063		425
94	560	1066	313	
95	418	1068		444
96	482	1072		426
97	470	1073		452
98	481	1078		434
99	559	1414		532
100	506	1472		555
101	523	1645		538
102	545	1649		533
103	513	1657		551
104	510	1670		542
105	557	1705		524
106	558	1801		489
107	552	1841		531
108	555	1874		524
109	544	1890		497
110	548	1891		551
111	543	1967		496
112	532	2014		543
113	554	2102		516
114	546	2105		506
115	528	2113		549
116	553	2154		500
117	551	2368		530
118	549	2488		539

FIGURE 1. $13/\sqrt{n}$ Analyses

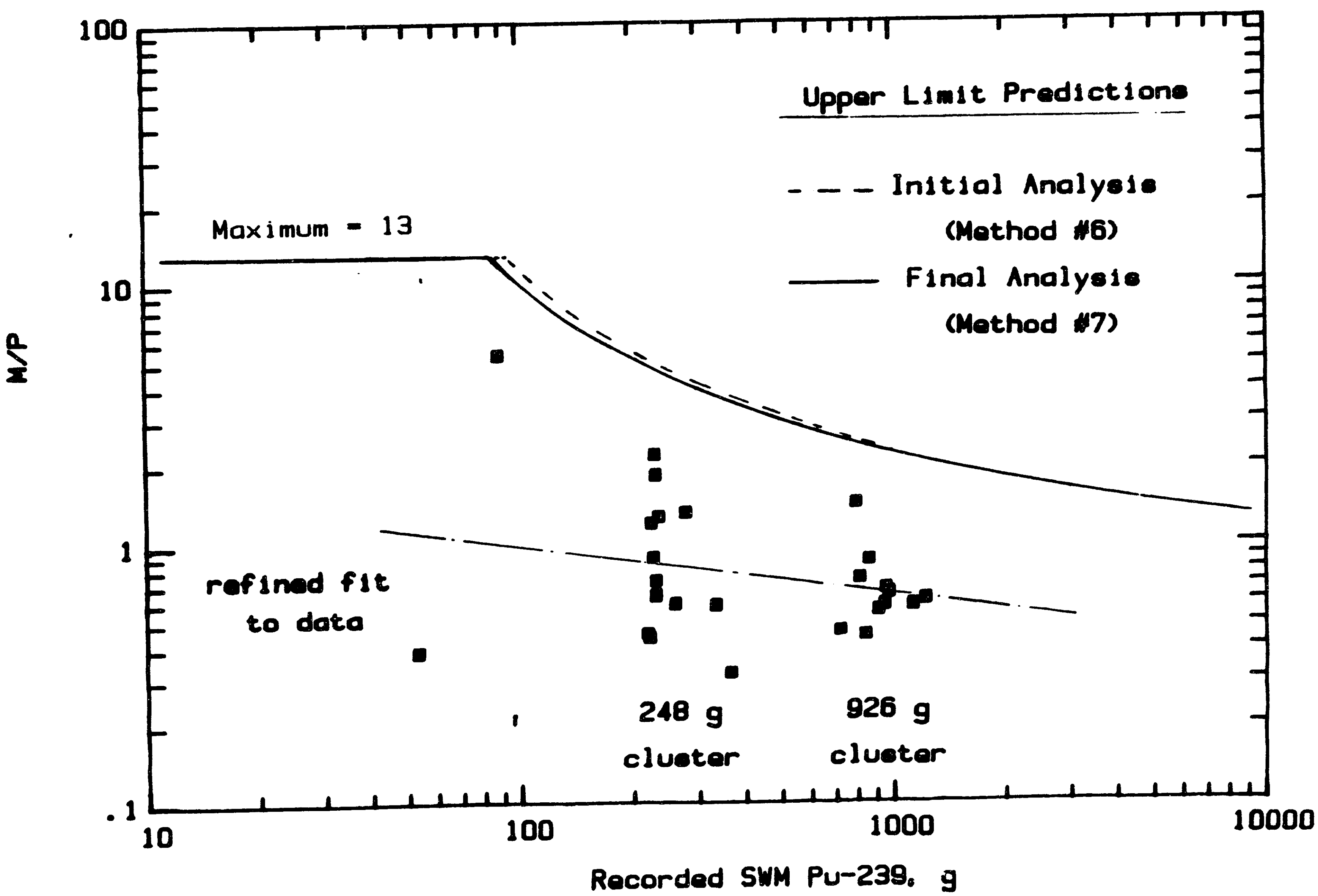
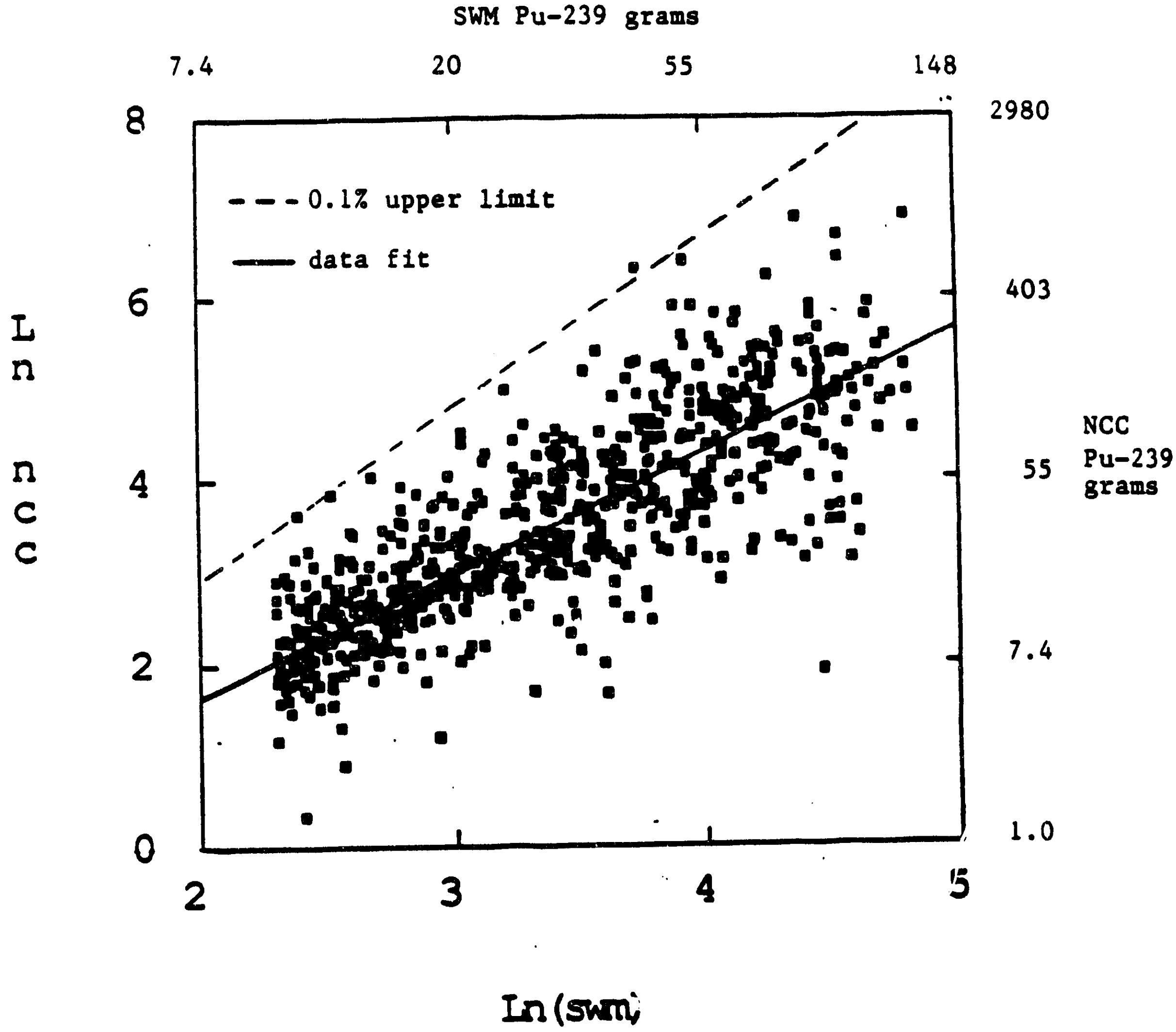


FIGURE 2. NCC vs SWM Measurements of Cuts

(From E.P. Shine, ref 2)



Fit:

$$\ln(NCC) = -0.9019 + 1.309\ \ln(SWM)$$

$$\pm\ (\ln(SWM)/5)(0.9287)$$

FIGURE 3. Predictions with Drum Cut Data

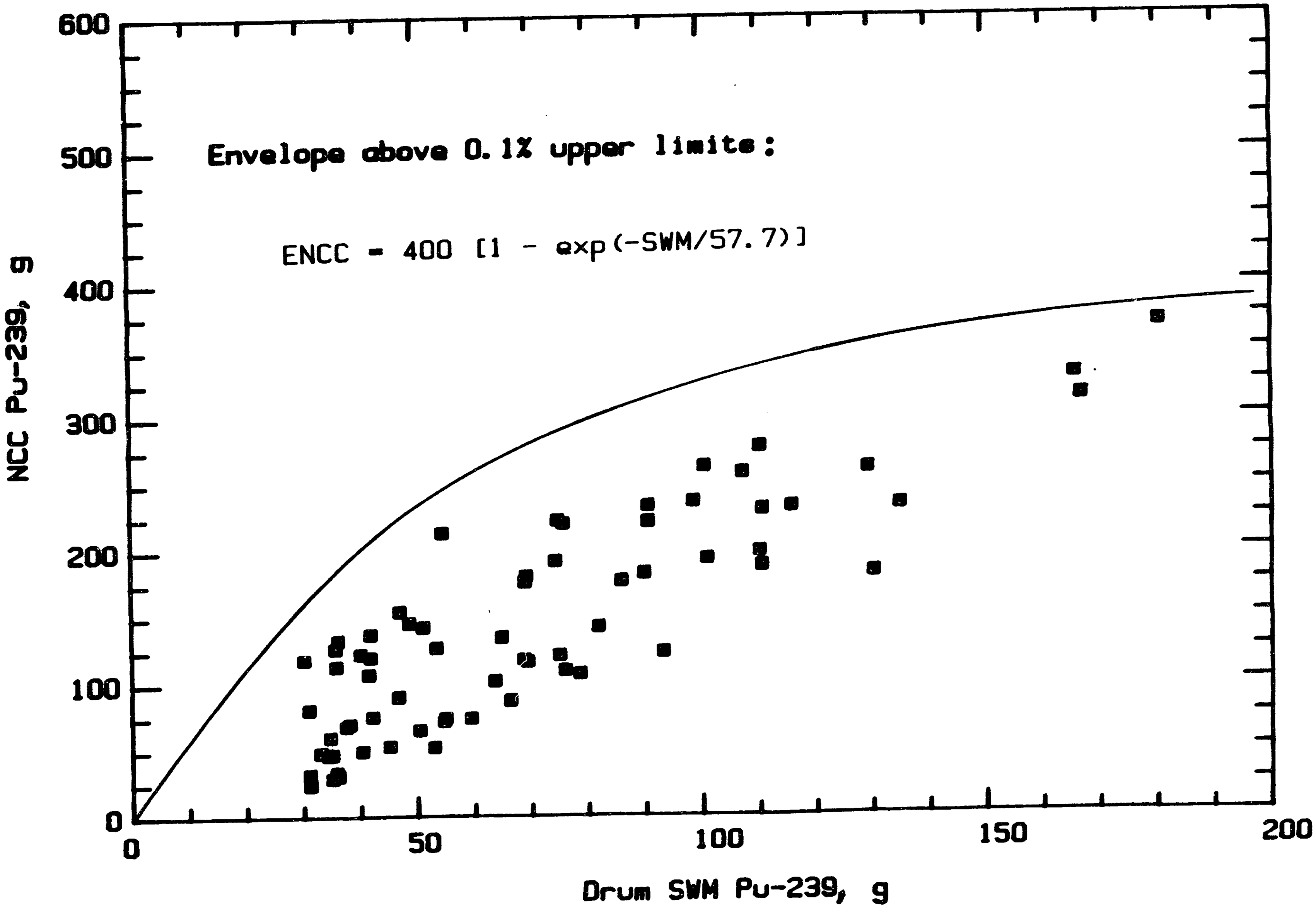


FIGURE 4

3–Sig Upper Limit NCC vs SWM

Culvert Calculations

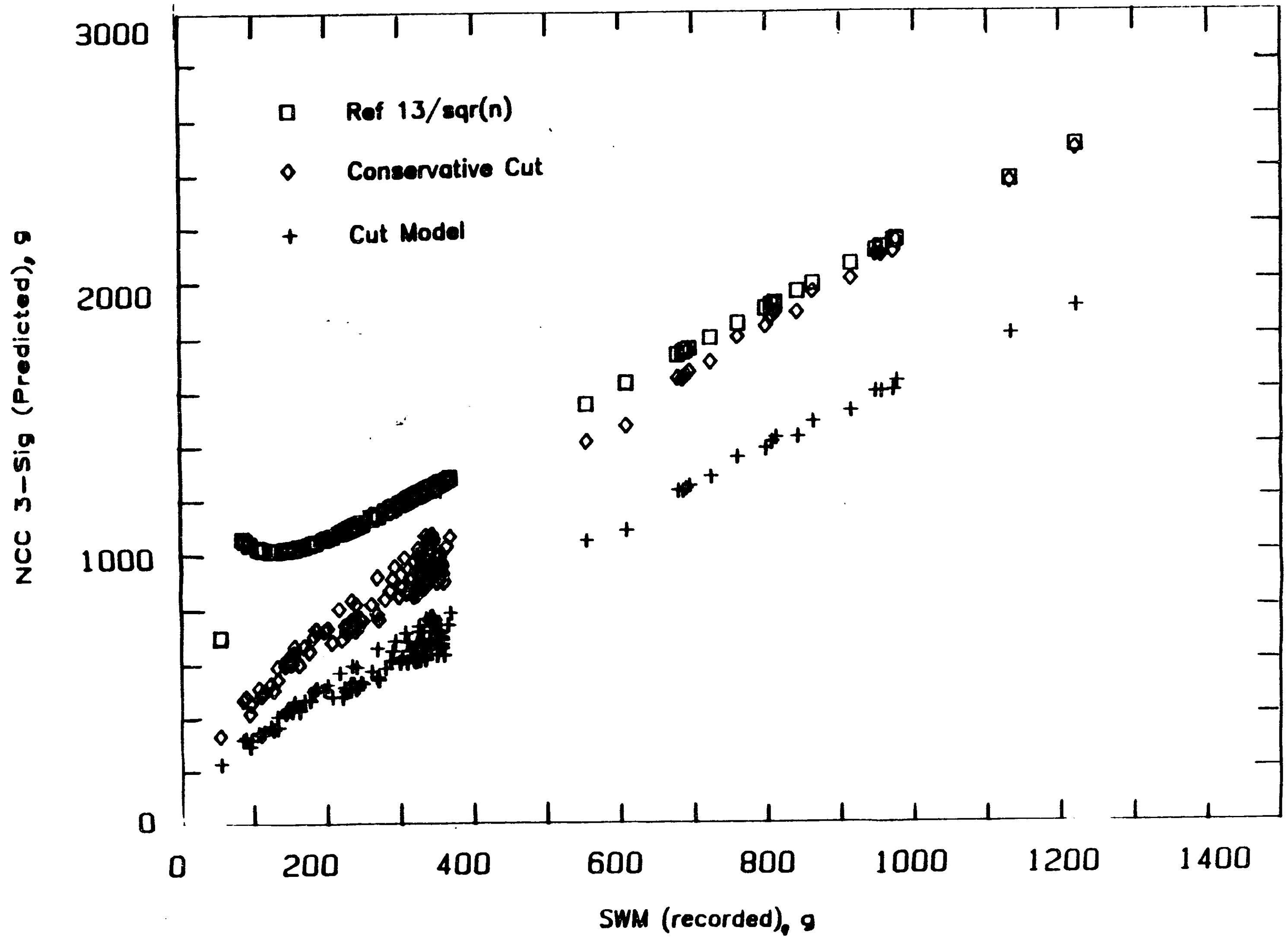
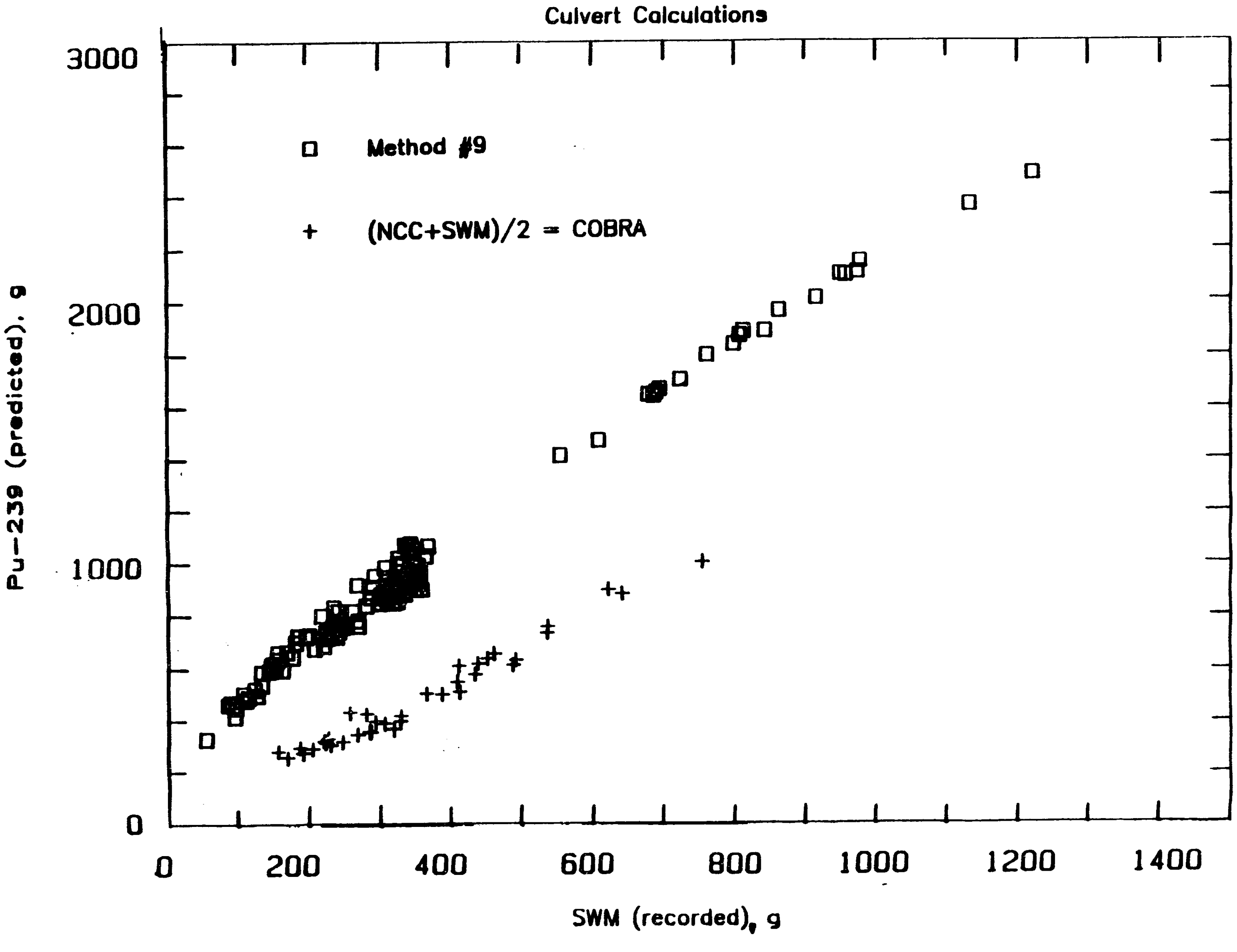


FIGURE 5. Method #9 vs (NCC+SWM)/2



APPENDIX A

Development of New Analysis Methods

This appendix develops the basis of three of the new analysis methods introduced in this report. These are (1) the Refined $13/\sqrt{n}$ Method, (2) the Cut Model Analysis, and (3) the Conservative Cut Model Analysis, which is a combination of the first two. Each method is developed in detail below.

I. Refined $13/\sqrt{n}$ Method (Method #7)

An earlier report [ref 4] showed that the meas/proj values for culverts having only Pu-239 neutron sources were log-normally distributed with distribution sigma of

$$\sigma_D = \sigma_D(1)/\sqrt{n} \qquad \text{(A-1)}$$

where σ_D = constant = log(2.298)
$n = m_r/92.8$
m_r = Pu-239 grams recorded by solid waste monitor (SWM)

The relationship between n (the effective number of Pu-239 components in the recorded total) and m_r was deduced using data that clustered about m_r = 248 g and m_r = 926 g, per data plotted in Figure 1. (Two additional points have been added since the earlier work). Using data from this figure, the n and σ_D of each cluster was determined using the formalism of the earlier work [ref 4], viz:

$$\sigma_T^2 = \sigma_D^2 + \sigma_F^2 + \sigma_A^2 + \sigma_I^2 \qquad \text{(A-2)}$$

where individual sigmas are given by

σ_T = total sigma of meas/proj distribution
σ_F = error in chemical form of Pu-239 = $\sigma_F(1)/\sqrt{n}$ = $\log(1.577)/\sqrt{n}$
σ_A = error in meas/proj analysis model = log(1.158)
σ_I = error in recorded Pu-238 and other neutron sources = 0

In the analysis, σ_D was calculated with Equation A-1, by substituting the value of n deduced from Equation A-2, with its above defined terms:

$$\sigma_T^2 = \sigma_D^2(1)/n + \sigma_F^2(1)/n + \sigma_A^2 \qquad \text{(A-3)}$$

$$n = \frac{\sigma_D^2(1) + \sigma_F^2(1)}{\sigma_T^2 - \sigma_A^2}$$

Upon applying Equation A-3 to Equation A-1, the σ_0 for the two m_r (248 g and 926 g) clusters indicated that $n = m_r/92.8$. This is Method #6 of the main text.

A refinement of this method takes into account that meas/proj decreases slightly with m_r, as seen in Figure 1. The figure shows a log(meas/proj) vs log(m_r) linear least-squares fit, in which calculated $1/\sigma_T^2$ weight each point. The difference between the fitted log(meas/proj) = Y_f and its measured value Y_i is its residual ΔY_i. For a good fit, chi-square considerations yield

$$\sum_{i=1}^{N} \frac{(\Delta Y_i)^2}{(\sigma_T)_i^2} = N - 2 \qquad \text{(A-4)}$$

where there are N-2 degrees of freedom after N points are fitted to a straight line. Calculating the $(\sigma_T)_i$ from Equations A-1 and A-3 with $n = m_r/92.8$ yields fair agreement for Equation A-4. By choosing $n = m_r/82.3$, the agreement is exact; thus, this latter formula for n is used in the Refined $13/\sqrt{n}$ Method. The fitted results of Figure 1 are also consistent with this n.

In summary, the σ_0 for the Refined $13/\sqrt{n}$ Method is defined by the above n and Equation A-1 as

$$\sigma_0 = \frac{\log(2.298)}{\sqrt{m_r/82.3}}$$

which corresponds to error factor $E = 10^{\sigma}$ [or $\exp(\sigma)$ for ln] of

$$E_0 = (2.298)^{\sqrt{82.3/m_r}}$$

The 0.1% probability for an upper-limit excursion corresponds to a level = (geo ave meas/proj) x E_0^3 = (1.071) x E_0^3, as consistent with the earlier treatment [ref 4]. This assures that the excursion is x13 for the lowest (n=1) inferred integral mass (82.3 g). For lower mass loadings, the excursion is conservatively defined as x13. These calculated excursions are also conservatively high relative to the observed meas/proj.

II. Cut Model Analysis (Method #8)

This model uses Pu-239 cut data for individual drums to predict their 0.1%-probability excursion levels of Pu-239. Then these drum results are combined to predict the 0.1%-probability excursion levels for individual culverts. The major development of this approach is discussed first. Then a section supporting the mathematical considerations follows. A final section appraises the reliability of the method.

Major Development

Detailed data for Pu-239 cut loadings of 68 drums were provided [ref 5], and a sample data sheet is given in Figure A-1. These cut values were measured by the solid waste monitor (SWM), which was later determined to read low relative to the neutron coincidence counter (NCC). Because the higher NCC readings are conservatively applied to assure that Pu-239 loadings are safely below criticality levels, the NCC readings are treated as a reliably safe upper-limit indicator of Pu-239. E.P. Shine [Ref 2] has examined NCC vs SWM readings shown in Figure 2, and deduced the correlation

$$\ln(NCC) = -0.9019 + 1.309 \ln(SWM) \pm (\ln(SWM)/5)(0.9287) \quad \text{(A-5)}$$

Thus, given an SWM measurement, the upper-limit excursion ENCC with 0.1%-probability corresponds to a level given by

$$\begin{aligned} \ln(ENCC) &= \ln(NCC) + 3\sigma \\ &= -0.9019 + 1.309 \ln(SWM) + 3\,(\ln(SWM)/5)(0.9287) \end{aligned} \quad \text{(A-6)}$$

These NCC predictions for cuts of a drum are combined to yield a drum ENCC. Each measured SWM = x predicts NCC = y and an excursion $3\sigma = \Delta y$, as deduced by Equations A-5 and A-6. The ln(NCC) with $\pm\ \sigma$ is assumed to be distributed as a Gaussian; thus, the ENCC = Ey = $y \exp(3\sigma)$, and the corresponding y distribution is not Gaussian. If a set of Gaussian variables z_i were added, the excursion of their sum would be

$$Ez_{sum} = \sum z_i + \sqrt{\sum 3\ (\sigma_{i})^2} \quad \text{(A-7)}$$

Although the y are not Gaussian, a formula analogous to this was used for the sum of the cuts in a drum, viz

$$Ey_{sum} = \sum y_i + \sqrt{\sum [y_i \exp(3\sigma_i) - y_i]^2} \quad \text{(A-8)}$$

This formula for Ey_{sum} is shown to be a conservative estimate in the next section, which develops pure mathematical considerations in more detail.

The excursions Ey_{cut} for each drum with cut data were calculated using Equation A-8, as defined by y_i and σ_i values determined from Equations A-5 or A-6. The results are shown in Figure 3, which is a scatter plot of ENCC vs SWM for the 68 drums. It is noted that The ENCC values all lie beneath an envelope curve defined as

$$\begin{aligned} ENCC(drum)_{envelope} &= 400\ [1 - \exp(-SWM/57.7)] \\ ENCC(drum)_{envelope} &= 400\ [1 - \exp(-m_{rd}/57.7)] \end{aligned} \qquad (A\text{-}9)$$

where in this application SWM = m_{rd}, which is the recorded Pu-239 mass of the drum.

A scatter plot of $\sum y_i$ vs $\sum x_i$ (NCC vs SWM) for the drums is given in Figure A-2, and yields the correlation

$$\sum y_i = 0.85 \sum x_i \qquad (A\text{-}10)$$

This NCC/SWM = 0.85 is consistent with the fact that the individual cuts for drums examined are generally small, and Equation A-5 predicts NCC/SWM $\leq$ 1 for SWM $\leq$ 18.8 g. The equation predicts an NCC/SWM of 2.04 for the largest possible cut in this work, which corresponds to a drum loading of 187 g. The available cut distributions and loading data indicate that it is unlikely that a single drum has a cut with this high a SWM value. For example, if the 187 g were composed of ~10 cuts, which is typical, the average cut would have ~20 g Pu-239, which is in the range of the correlation used in this work. Ideally, the cut data for each drum/culvert in question should be analyzed using Equations A-5, A-6, and A-8; however, these data do not appear to be available. Thus, the drum estimates provided by Equations A-9 and A-10 are used in the Cut Model Analysis for the culverts.

The culvert NCC excursions are calculated by summing the drum predictions for each culvert. The individual drum data, EY = $ENCC(drum)_{envelope}$ and Y = $\sum y_i$ are calculated using Equations A-9 and A-10, to yield the corresponding 3σ-deviations of EY-Y. Then the culvert NCC excursions are calculated as

$$ENCC(culvert) = \sum Y_i + \sqrt{\sum (EY_i - Y_i)^2} \qquad (A\text{-}11)$$

$$ENCC(culvert) = 0.85\ SWM + \sqrt{\sum_d \{400[1-\exp(-SWM_d/57.7)] - 0.85\ SWM_d\}^2}$$

$$ENCC(culvert) = 0.85\ m_r + \sqrt{\sum_d \{400[1-\exp(-m_{rd}/57.7)] - 0.85\ m_{rd}\}^2}$$

where SWM = m_r is the total recorded Pu-239 for the culvert and m_{rd} is the Pu-239 per individual drum. The coefficient 0.85 is again used, and it is tempting to increase it to at least 1.0. However, increasing it has little effect on ENCC(culvert), because increases in the first term of Equation A-11 tend to be cancelled by decreases in its second term. Thus, the 0.85 coefficient derived from Figure A-2 was used for Method #8.

Mathematical Considerations

The above development depends on features of the log-Normal distribution and the Central Limit Theorem. First, the moments of the distribution are examined, so that the variance and mean are available. Then the Central Limit Theorem is applied to these parameters. Finally, the application of these concepts to the present work is discussed.

Moments. A variable x, which has a log-Normal distribution, has a Gaussian distribution with variable $z = \log(x)$. Because such a distribution applies for x with its log to any base, the convenient choice of $z = \ln(x)$ is used in the development that follows. Specifically, it is desired to find the moments $\langle x^m \rangle$ as

$$\langle x^m \rangle = \int_{-\infty}^{\infty} x^m f(x)\, dx \qquad \text{(A-12)}$$

where

$$f(x)\, dx = \frac{1}{\sqrt{2\pi}\,\sigma} \exp(\, -[\, \ln(x) - \ln(c)\,]^2/2\sigma^2\,)\, d\ln(x)$$

and ln(c) denotes the maximum of the ln(x) distribution and c is its geometric mean. To derive the moments in detail, note that $x^m = \exp[m\ln(x)]$, and substitute explicitly into Equation (A-12),

$$\langle x^m \rangle = \frac{1}{\sqrt{2\pi}\,\sigma} \int_{-\infty}^{\infty} \exp(\, -[\, \ln(x) - \ln(c)\,]^2/2\sigma^2 + m\ln(x)\,)\, d\ln(x)$$

Upon completing the square in the exp( ) factor,

$$\langle x^m \rangle = \frac{1}{\sqrt{2\pi}\,\sigma} \int_{-\infty}^{\infty} \exp(\, -[\, \ln(x) - \{\ln(c)+m\sigma^2\}\,]^2/2\sigma^2\,)$$

$$* \exp(\, -[\, \ln(c)^2 - \{\ln(c)+m\sigma^2\}^2\,]/2\sigma^2\,)\, d\ln(x)$$

The above integral includes a Gaussian factor which has variable ln(x) and geometric mean $\ln(c)+m\sigma^2$. The other factor is a constant. Thus the integral yields the exp(constant) factor, which is reduced to yield

$$\langle x^m \rangle = \exp(\, [\, m^2\sigma^4 + 2m\sigma^2\ln(c)\,]/2\sigma^2\,) = \exp(\, m^2\sigma^2/2 + m\ln(c)\,)$$

$$\langle x^m \rangle = c^m \exp(\, m^2\sigma^2/2\,) \qquad \text{(A-13)}$$

Variance. The variance s^2 is calculated using the first two moments $\langle x \rangle$ and $\langle x^2 \rangle$ defined by Equation A-13.

$$\langle x \rangle = c \exp(\, \sigma^2/2\,)$$
$$\langle x^2 \rangle = c^2 \exp(\, 2\sigma^2\,)$$

Using these moments, the variance for a single measurement x_i is

$$s^2 = \langle x^2 \rangle - \langle x \rangle^2$$

$$= c^2 [\exp(2\sigma^2) - \exp(\sigma^2)] \qquad \text{(A-14)}$$

Central Limit Theorem. If N values of x_i are summed, the Central Limit Theorem predicts that this sum (or average $= \sum x_i/N$) will have a Gaussian distribution that has a variance composed of the sum of the individual variances (or for the average, the variance $= 1/N \sum [s_i]^2/N = s^2/N$). This can be true even for x_i that have different distributions*. The Gaussian prediction becomes more dependable as N increases.

Present Application. The Central Limit Theorem indicates that the sum of cuts in a drum should be approximately normally distributed. However, the drum excursions defined by Equation A-8 differ from those that are predicted by the log-Normal treatment above. The excursions are compared below for these cases, where the average (sum/N) values are used:

Sum Average	0.1% Probability Excursion Value
General	$\sum x_i/N \quad + \quad 3\, s/\sqrt{N}$
Log-Normal	$c \exp(\sigma^2/2) + 3\, c \sqrt{[\exp(2\sigma^2) - \exp(\sigma^2)]} / \sqrt{N}$
Present Work	$c \quad + \quad [\, c \exp(3\sigma) - c \,] / \sqrt{N}$

By calculating the ratio of the Present Work and Log-Normal cases, it is recognized that the Present Work is conservatively high relative to the Log-Normal one. This is illustrated below for cases ranging up to $\sigma = 1.2$, which corresponds to individual cut excursions of NCC/SWM that exceed the maximum of 13 observed earlier [ref 4].

Cuts N	Data σ	Sum Average Excursion Value: Present Work	Sum Average Excursion Value: Log-Normal	[Present Work / Log-Normal]
	0.4	1.73 c	1.51 c	1.15
10	0.8	4.17 c	2.61 c	1.60
	1.2	12.25 c	5.55 c	2.21
	0.4	1.52 c	1.39 c	1.10
20	0.8	3.24 c	2.25 c	1.44
	1.2	8.96 c	4.53 c	1.98
	0.4	1.42 c	1.33 c	1.07
30	0.8	2.82 c	2.09 c	1.35
	1.2	7.50 c	4.07 c	1.84

---

* K.V. Bury, Statistical Models in Applied Science, John Wiley and Sons, 1974, p. 69.

Thus, in the analysis for the present work, each excursion calculated for the sum of cuts by Equation A-8 and A-11 is an overestimate, even though the excursion for each individual cut is well represented by Equation A-6.

Comparison with Culverts with Known NCC vs SWM Values

Subsequent to the analysis for Method #8, NCC and SWM data from 36 culverts loaded after 1985 were made available, as discussed in Appendix B. These data are plotted in Figure A-3, along with the predictions of the above analysis. The NCC vs SWM data fit the straight line NCC = 1.583 SWM and the scatter about this line is much smaller than Equation A-5 would project for individual cuts with these SWM values; this is expected since each culvert contains many individual cuts and their individual NCC/SWM relative fluctuations statistically average lower when the cuts are summed to yield the culvert inventory. Figure A-3 shows that the upper limits of this scatter barely reach the ENCC(culvert) 3σ upper limit excursions of NCC projected by Method #8 above. Thus, the projections by Method #8 are consistent with measurements on culverts having known NCC and SWM values.

It should be recalled that acceptable current inventories are defined as (NCC+SWM)/2 in post-1985 COBRA listings [ref 5]. Thus, instead of projecting NCC vs SWM values, the COBRA vs SWM values should be examined, viz:

$$\text{COBRA} = (\text{NCC+SWM})/2 = (1.583\ \text{SWM} + \text{SWM})/2 \approx 1.29\ \text{SWM}$$

A plot of COBRA vs SWM in Figure A-3 shows that Method #8 is conservatively high relative to COBRA. Also, the point scatter (not plotted) for COBRA is only 1/2 that for NCC alone.

One concern about the comparison of Method #8 with the culvert data for NCC vs SWM is that Method #8 uses fluctuations about NCC = 0.85 SWM and the culvert data fluctuate about NCC = 1.583 SWM. The discrepancy is probably due to the average size of the cuts involved in the analysis data. For example, Equation A-5 for individual cuts predicts SWM = 11 g Pu-239 for NCC/SWM = 0.85 and SWM = 82 g Pu-239 for NCC/SWM = 1.58. Actually, each case should be evaluated as the sum of cuts to yield an $\langle x \rangle$ value, as developed in Equation A-13. Substituting NCC and its σ from Equations A-5 as the c and σ in Equation A-13 yields SWM = 10 g for $\langle$NCC$\rangle$/SWM = 0.85 and SWM = 39 g for $\langle$NCC$\rangle$/SWM = 1.58. As explained in the preceding section, Method #8 is already mathematically conservative relative to this summing scenario. Fortunately, it is sufficiently conservative to accomodate sums of both the smaller and larger cuts, as evidenced by Figure A-3. Thus, the above discrepancy in NCC/SWM averages has no impact on the overall usefulness of these predictions.

Method Reliability

Overall, the method appears to be reasonable. However, dispite its many conservatisms, the method does not address the possibility that a large cut of Pu-239 is included in a drum. As discussed earlier, the available cut data for developing the drum excursions shown in Figure 3 are relatively low (SWM <30 g). The cuts for the 36 check culverts plotted in Figure A-3 are somewhat larger (average consistent with SWM = 39 g), but quite higher cuts are possible (SWM = 187 g for drum maximum), although very unlikely relative to cut distribution data [ref 6]. Clearly, additional cut data for drums would be useful, particularly for the culvert/drums of the present study. Should these become available, the Cut Model Analysis can be refined.

Dispite the above concern about actual cut sizes, it is worthwhile to appreciate various conservatisms imbedded in this analysis. The analysis does not take credit for the fact that present assays use the average of the SWM and NCC values, which tends to be lower than the NCC value alone. Thus, the present predictions will tend to be high since only the NCC values are used. The fact that the excursions for summed cuts are overestimated has already been elaborated upon in the preceding section, which shows that the present analysis is conservative relative to more realistic predictions for log-Normal combinations using the Central Limit Theorem. Finally, the envelope curve for drum excursions is higher than any excursion actually observed.

III. Conservative Cut Model (Method #9)

A combination analysis intermediate to the Refined $13/\sqrt{n}$ Method and the Cut Model Analysis is developed. The Refined $13/\sqrt{n}$ Model is thought to be conservatively high, because neutrons from drums in the lower half of the culvert are shielded by the upper drums. Thus, the averaging effect for all Pu-239 in the culvert may not be witnessed in the measured neutron rates. The Cut Model Analysis is conservative in general, but an individual large cut in a drum is not addressed with this method. Thus, it is wise to allow that this method can give an underestimate for Pu-239. Clearly, a well-chosen analysis yielding predictions intermediate to the above two cases should be more realistic.

For the intermediate analysis, called the Conservative Cut Model, the drum envelope for cuts is increased by x1.5, and the cut model analysis of Section II is repeated, yielding the plot in Figure 4. This analysis agrees with the Refined $13/\sqrt{n}$ Method for the most heavily loaded culverts, where the chance of large cuts is more likely. It agrees better with the Cut Model Analysis for the culverts with lighter loadings, where the probability for large cuts is smaller. As shown in Figure 4, the predictions gradually increase toward the Refined $13/\sqrt{n}$ Method values, as the SWM loadings increase over the culvert range.

The results for the Conservative Cut Model are also plotted in Figure 5, where the predictions are well above the scatter of (NCC+SWM)/2 values for the 36 check culverts. Thus, the method should be quite conservative relative to presently accepted (NCC+SWM)/2 values in general. Also, the m/p results of the present work indicate that the SWM is more accurate than the (NCC+SWM)/2 value on the average, and the Conservative Cut Model is even more conservative relative to SWM predictions. The 0.1% upper limit excursions of the Cut Model (Method #8) are fairly consistent with the check culvert NCC excursions; therefore, the Conservative Cut Model excursion limits should be associated with a probability significantly lower than 0.1%.

FIGURE A-1. Example Drum Inventory Worksheet

DO NOT REMOVE

SEPARATIONS DEPARTMENT

JB-LINE — Auxiliary Equipment

DPSOL 221-F-JB-1991

UET 1/79 0

132-3

6.23 DRUM WASTE INVENTORY WORKSHEET

Page 1 of 1

Tape on Top of Drum

PURPOSE: To record data for each pail of waste, disposition of pail, and file sequence number of each pail read on PHA (so that each pail is traceable to the drum).

Pail Number	PHA Grams	Cumulative Total, g	File Sequence Number Transferred to DPSOL 221-F-JB-1990 (✓)
1457	6.35	6.85	
1292	8.12	14.97	
866	16.68	31.65	
1448	8.41	40.06	
1094	24.37	64.43	
864	12.88	77.31	
867	15.83	93.14	
865	17.12	110.26	
	110.26	-103.64	

Shipped 3-27-80

Enter file sequence number from OSR 7-375 or OSR 7-375A here: 512078

Completed by [illegible]

Date 2-14-80 Time

FIGURE A-2. Sums of Cuts - NCC vs SWM

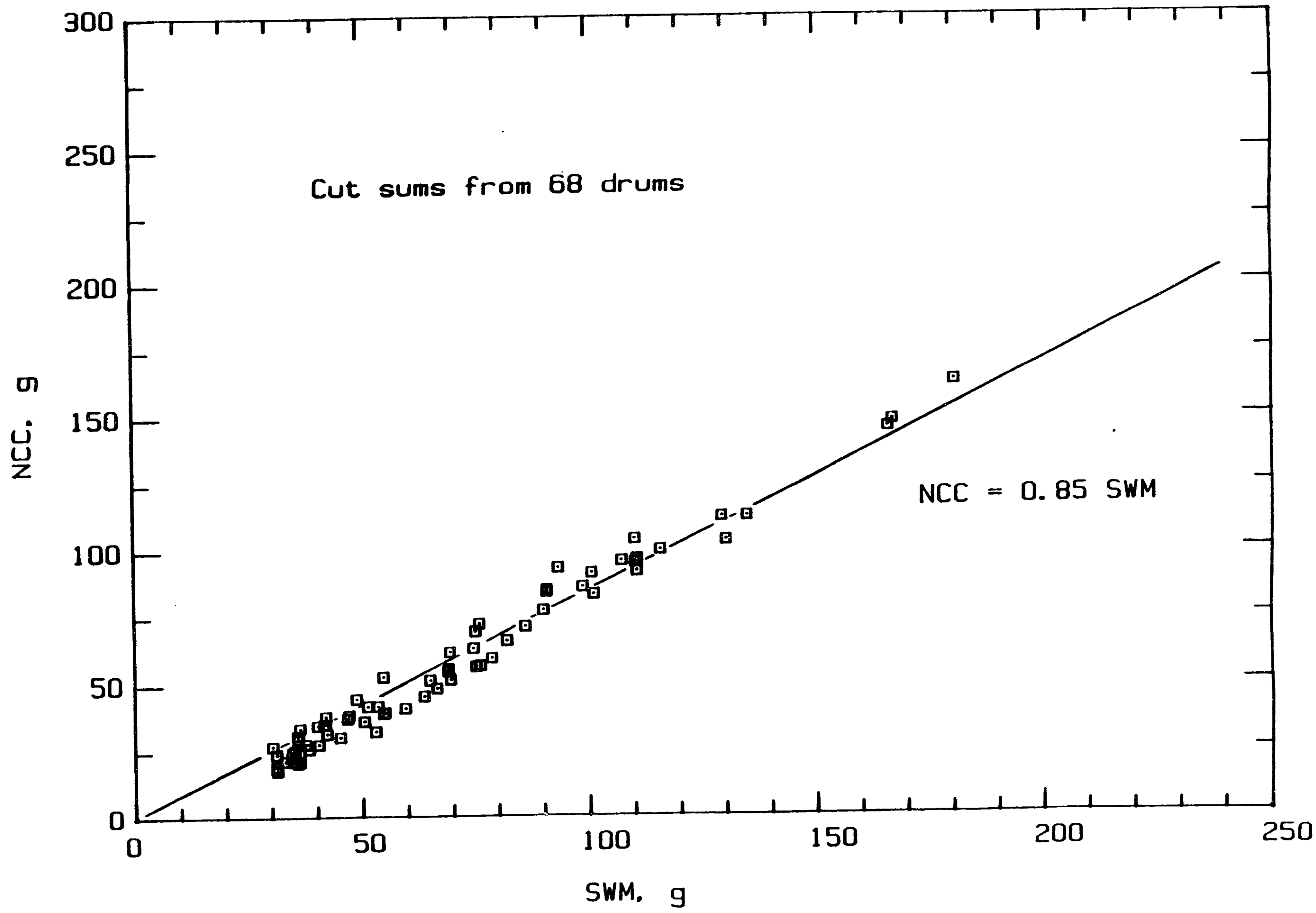
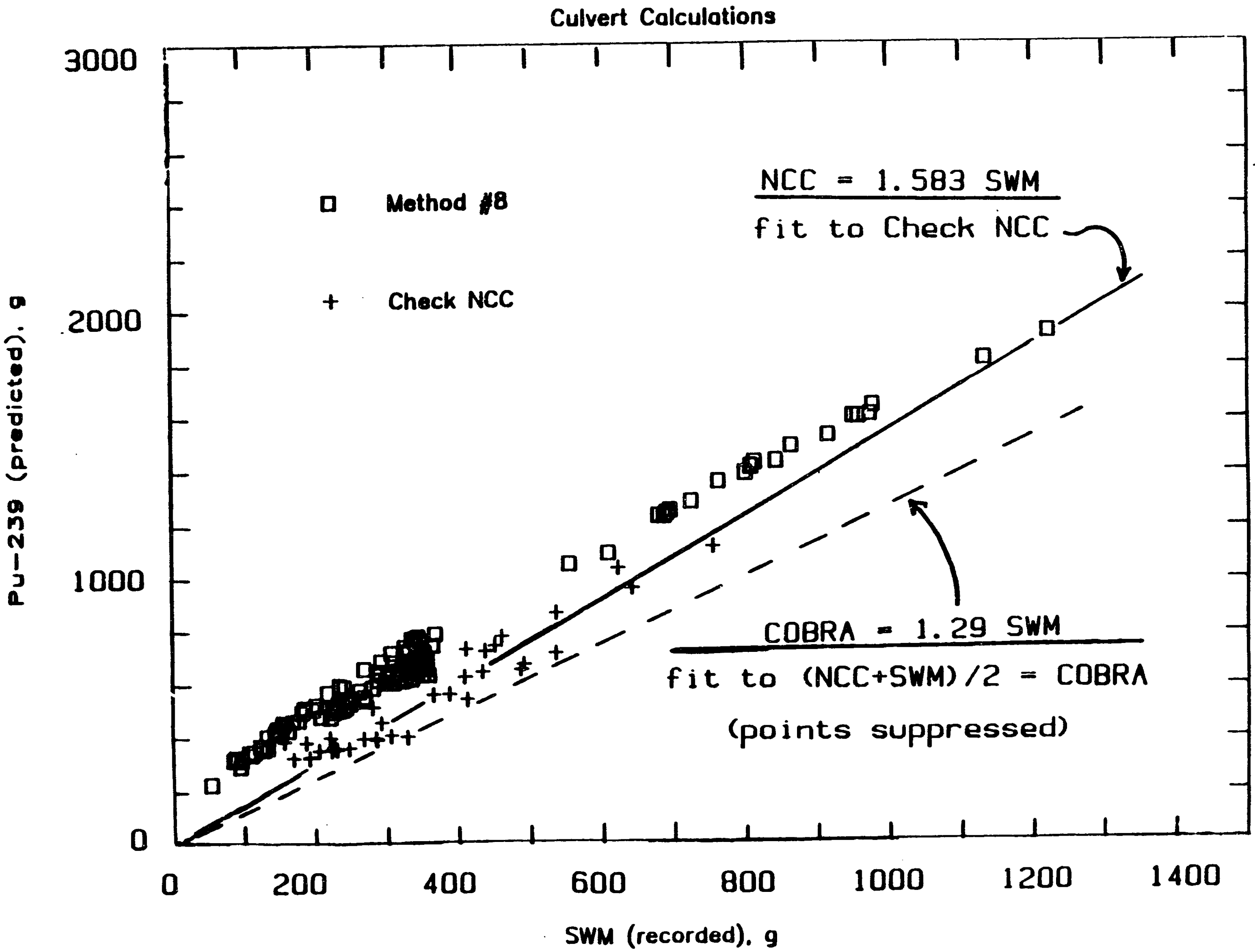


FIGURE A-3. Method #8 vs Check NCC



Appendix B. Comparisons using Better Known Culverts

After 1985, culvert loadings have used values of (NCC+SWM)/2 for Pu inventory in the COBRA files (Ref 5), as these are thought to be better known than the earlier COBRA values, which were based only on SWM measurements. Measurements on 36 culverts inventoried with these later estimates served as a check on the in-the-field measurements program. The results of these check measurements are summarized in Tables B-1 and B-2, and their implications are discussed below. The tables include the raw NCC and COBRA values provided [ref 5]. All check culvert data were transformed to isotopic Pu-239 values for plots in this report, by using the COBRA(isotope) and COBRA(quantity) values of these tables.

Table B-1 includes culverts for which only Pu-239 neutron sources are present. There were 18 of these, and the table illustrates that a representative geometric average of their measured/projected neutron rates m/p is 0.74 ± 0.09. This average should be 1.00 if the projected rates were accurate; thus, the neutron rates projected by (NCC+SWM)/2 estimates are <u>too large</u>. In order to examine the results for rates projected for SWM estimates, the plot in Figure B-1 was used. Here, NCC is plotted against COBRA = (NCC+SWM)/2 for the check culverts, yielding a least squares fit of NCC = 1.2225 COBRA. From this, one can solve for SWM as:

$$SWM = 2\ COBRA - NCC = 2\ COBRA - 1.2225\ COBRA = 0.7775\ COBRA$$

Thus, if the SWM were used instead of the COBRA value, the above average m/p would be divided by 0.7775 to yield 0.95 ± 0.11, which is in good agreement with 1.00. Thus, on average, the SWM values are more accurate, and the later COBRA values of (NCC+SWM)/2 serve as a conservative overestimate.

Table B-2 summarizes 18 check culverts that include neutron sources from both Pu-238 and Pu-239. The m/p ratios for these culverts are calculated using the COBRA = (NCC+SWM)/2 values and the ratio of the tabulated Pu-238/Pu-239 is also recorded. Figure B-2 plots the m/p vs Pu-238/Pu-239 and illustrates that as Pu-238/Pu-239 increases, the m/p is increasingly larger than 1.00. Although the correlation has some scatter, the trend is apparent and implies that the Pu-238 waste may contain PuO_2 that has oxygen non-depleted in O-17, which is a prominent target for (α,n)-production of neutrons. (The Pu-238 oxide standards used in calibrations at the Fab Lab were purportedly depleted in O-17). In any event, the trend gives a basis for correcting some of the high m/p values to lower values, yielding better compliance with critical loading limits. The plotted curve of Figure B-2 is given by:

$$m/p = R(COBRA) = 0.7775 + 0.032\ [100\ Pu238/Pu239(COBRA)]^2$$

where m/p is determined using the Pu239 from COBRA. To transform to SWM units, the substitutions of R(SWM) = R(COBRA)/0.7775 and Pu239(COBRA) = Pu239(SWM)/0.7775 are made to yield:

$$R(SWM) = 1.00 + 0.02488\ [100\ Pu238/Pu239(SWM)]^{2}$$

The R(SWM) for the 118 suspect culverts used this R(SWM) factor to correct for Pu-238. Specifically, the R was calculated for the recorded Pu-238 and Pu-239 for each culvert and then divided into the corresponding estimate for Method #5, yielding the results in Table 1B.

In the present study, R(SWM) corrected the Pu-239 estimates of Method #5 as follows:

Pu-239 (Corrected) = Pu-239 (Method #5) / R(SWM), in general

= Pu-239 (Method #5) / 20, R(SWM) > 20

= 1.29 Pu-239 (SWM) if > above cases

Thus, the general formula applies between limits. If R(SWM) > 20, then R(SWM) = 20 is used to be conservative relative to extrapolated values in Figure B-2. If the correction yields a value less than COBRA = (NCC+SWM)/2 = 1.29 SWM, then it is set equal to 1.29 SWM to yield predicted agreement with currently accepted values.

TABLE B-1. Check Culverts with no Pu-238

Pad	Culvert	Pu-239 Quantity, g NCC	Pu-239 Quantity, g COBRA	Pu-239 Isotope, g COBRA	m/p COBRA
13	565	1202.7	1008.5	933.96	0.763
	567	610.2	504.92	461.60	0.529
	568	668.3	552.36	517.84	1.280
10	570 +	396.4	396.43	372.64	0.462
	571 +	367.7	367.67	318.65	0.417
	582	373.5	295.38	277.66	0.503
	583	408.45	287.21	269.98	1.261
	584	412.5	334.58	294.41	1.424
	585	342.4	261.19	245.51	0.142 *
	586	378.7	311.51	292.82	0.698
	587	405.9	302.14	284.01	0.615
	588	420.79	327.57	307.91	0.747
	589	380.0	321.30	302.02	2.272
	590	417.3	351.05	329.98	0.657
	591	420.0	361.17	339.49	0.415
	592	412.0	358.26	336.77	0.783
	593	350.7	278.78	257.03	0.497
	594	393.3	320.86	287.77	1.027

Analysis of m/p Ratios

Analysis	Geometric Average of Ratios (NCC+SWM)/2	Geometric Average of Ratios SWM
All values	0.68 ± 0.10	0.88 ± 0.13
All less +	0.72 ± 0.11	0.93 ± 0.15
All less *	0.75 ± 0.09	0.96 ± 0.11
All less +,*	0.80 ± 0.10	1.03 ± 0.13
Representative	0.74 ± 0.09	0.95 ± 0.11

Note: SWM = 0.7775 (NCC+SWM)/2 = 0.7775 COBRA (post-1985)

+ Culvert loaded before 1986, SWM values likely.
* Low value not included in some averages above.

TABLE B-2. Check Culverts with Pu-238

(All culverts on Pad 10)

Culvert	Pu-239 Quantity, g NCC	Pu-239 Quantity, g COBRA	Pu-239 Isotope, g COBRA	Pu-238 Isotope, g COBRA	Pu-238* / Pu-239	m/p COBRA
459	735.6	635.646	582.869	4.862	0.83	1.449
562	786.7	613.906	570.745	16.662	2.92	2.015
569	549.9	425.628	395.802	9.141	2.31	0.576
572	796.3	639.701	596.746	2.42	0.41	0.963
573	841.8	736.87	624.490	20.30	3.25	3.095
575	581.7	512.01	476.580	34.20	7.18	0.864
576	443.6	389.979	354.677	22.632	6.38	1.683
577	706.3	616.167	570.295	0.838	0.15	0.169
578	480.1	395.856	371.823	26.356	7.09	0.234
579	695.2	581.338	539.142	0.147	0.03	0.431
580	774.6	621.483	580.392	6.976	1.20	0.396
581	827.7	658.68	619.131	53.42	8.63	7.619
596	589.4	433.12	401.810	83.8	20.86	14.925
597	941.4	761.55	702.020	23.3	3.32	2.008
600	1064.3	887.33	801.582	8.20	1.02	1.136
601	457.7	417.256	363.257	45.673	12.57	7.013
602	598.6	505.215	474.878	49.376	10.40	5.387
604	1127.1	902.12	828.93	8.30	1.00	0.731

Analysis of m/p Ratios

Analysis	Geometric Average of Ratios (NCC+SWM)/2	SWM
All values	1.38 ± 0.40	1.78 ± 0.51

Note: SWM = 0.7775 (NCC+SWM)/2 = 0.7775 COBRA (post-1985)

---

* Values given as Pu-238/Pu-239 x 100%.

FIGURE B-1. NCC vs (NCC+SWM)/2

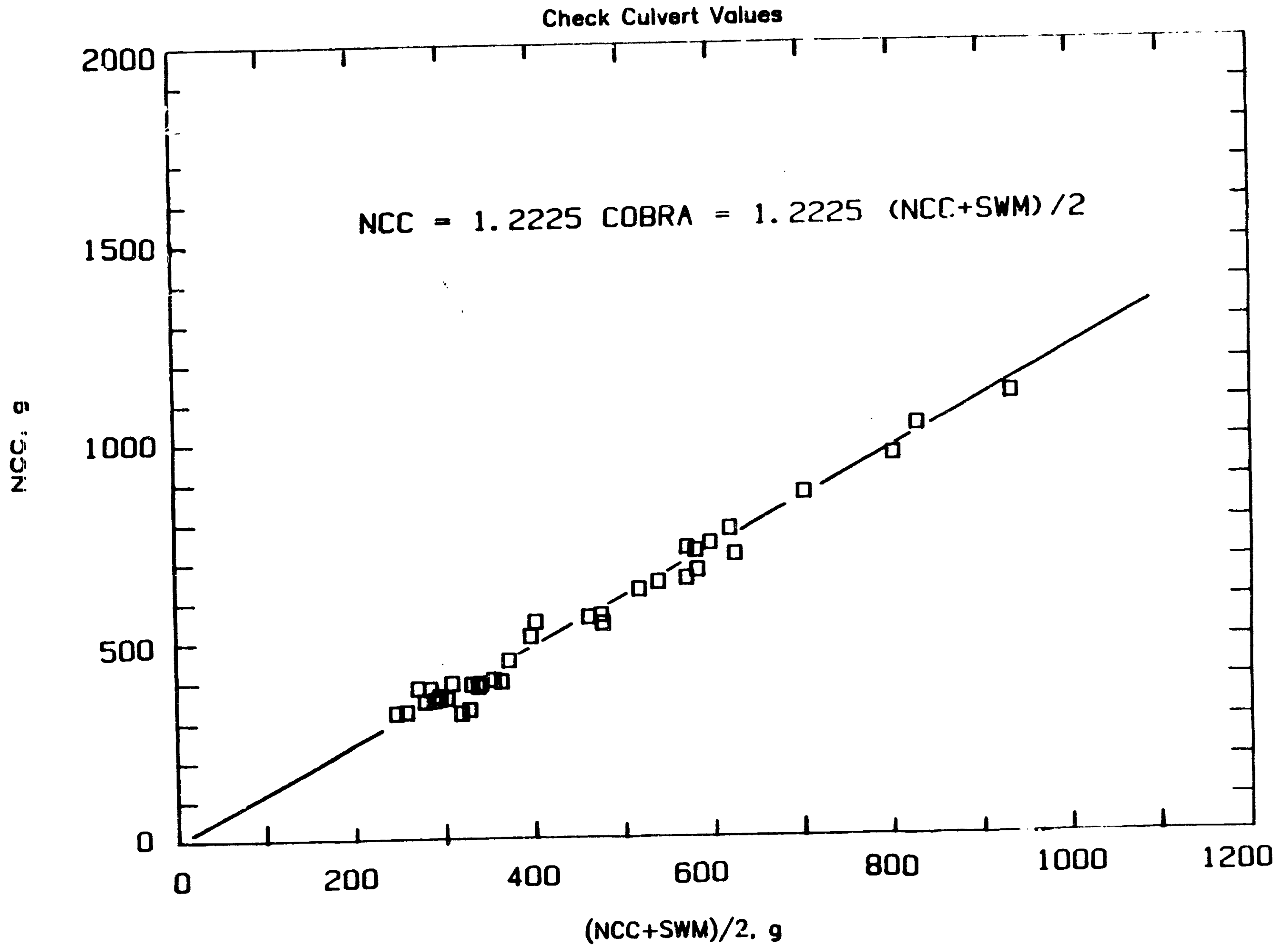
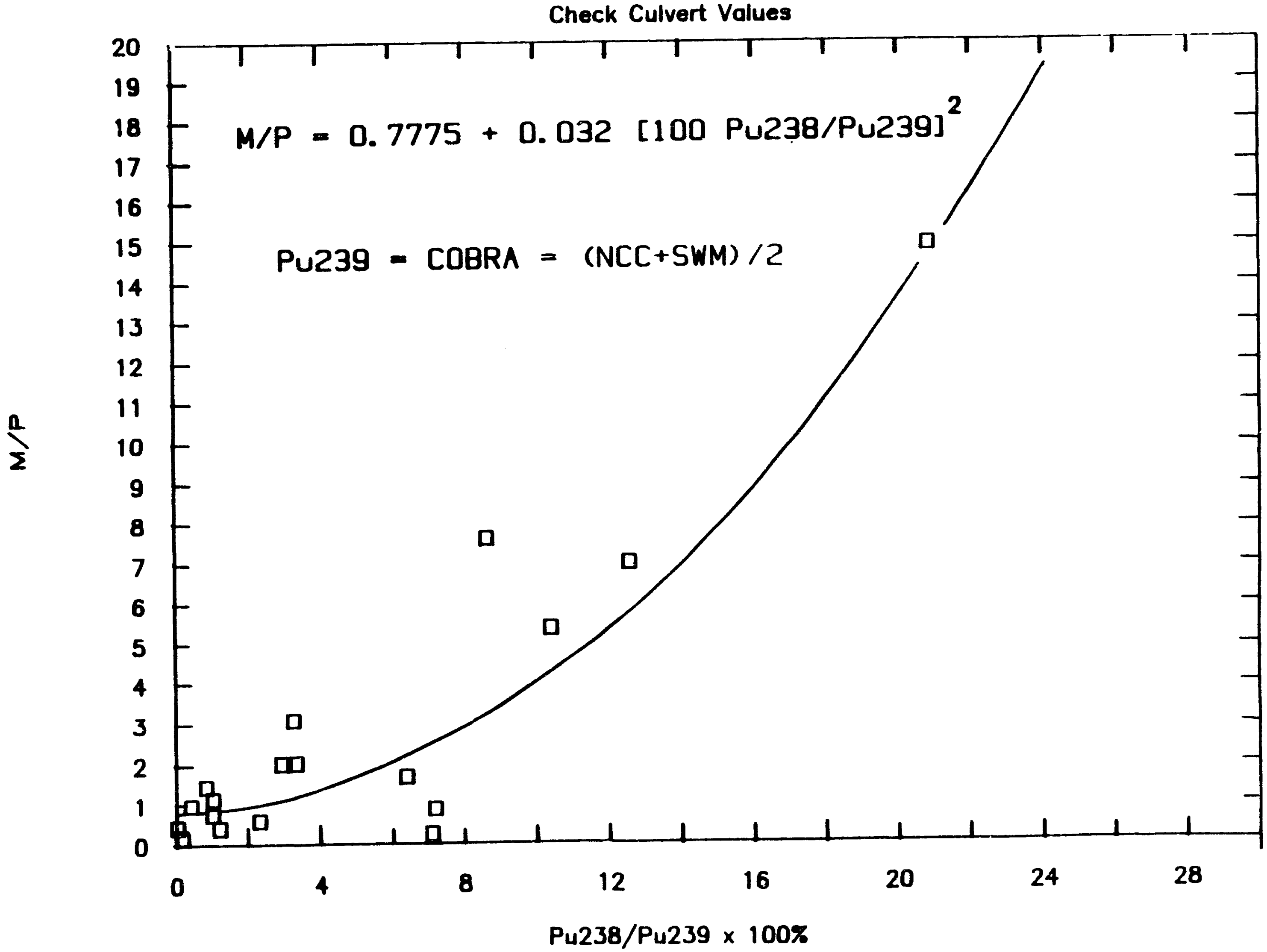


FIGURE B-2. M/P vs Pu238/Pu239



APPENDIX C

Pu-239 Estimates for Each Analysis Method

Table C-1 summarizes the Pu-239 predictions for Method #1 thru Method #9, as defined in the main text. The table format is similar to that of Tables 1 and 2, where the culvert and max drum estimates are monotonically arrayed so that they may be easily appraised against their critcality limits. Table C-2 includes the same data, but here all estimates are ordered according to culvert number.

A summary of the Pu-239 estimation formulae used in the different methods is given below. Some methods yield direct estimates and others are 0.1% upper limit excursions. This distinction is made below and in the tables, to guide proper interpretation by the user. Variables in the formula below are: m/p = measured/projected neutron rates; SWM = solid waste monitor Pu-239, in grams; 3sig factors = E^3, where E is error factor per log-Normal $\sigma = \log(E)$.

m/p Methods

(1) **m/p x Inventory Pu-239**

Direct estimate

Pu-239 = m/p SWM

(2) **m/p x 3Sig x Inventory Pu-239**

0.1% upper limit excursion

Pu-239 = m/p $(1.46)^3$ SWM = 3.12 m/p SWM

(3) **m/p(Pu-239) x Inventory Pu-239**

Direct method

Pu-239 = (1.40/0.989 m/p) SWM = 1.416 m/p SWM

(4) **m/p(Pu-239) x 3Sig(Pu-239) x Inventory Pu-239**

0.1% upper limit excursion

Pu-239 = (1.40/0.989 m/p) $(1.395)^3$ SWM = 3.84 m/p SWM

(5) **m/p x 3Sig(Pu-239) x Inventory Pu-239 ... Preferred m/p**

0.1% upper limit excursion

Pu-239 = m/p $(1.395)^3$ SWM = 2.71 m/p SWM

Statistical Methods

(6) $13/\sqrt{n}$ x Inventory

0.1% upper limit excursion

$$Pu\text{-}239 = 1.071\ (2.298)^{3\sqrt{92.8/SWM}}\ SWM \qquad SWM > 92.8$$

$$= 13\ SWM \qquad SWM \leq 92.8$$

(7) Refined $13/\sqrt{n}$ x Inventory

0.1% upper limit excursion

$$Pu\text{-}239 = 1.071\ (2.298)^{3\sqrt{82.3/SWM}}\ SWM \qquad SWM > 82.3$$

$$= 13\ SWM \qquad SWM \leq 82.3$$

(8) Cut Model x Inventory Pu-239

0.1% upper limit excursion

$$Pu\text{-}239 = 0.85\ SWM + \sqrt{\sum_i \{400[1-\exp(-SWM_i/57.7)] - 0.85\ SWM_i\}^2}$$

(9) Conservative Cut Model x Inventory Pu-239 ... Preferred Statistical Method

0.1% upper limit excursion

$$Pu\text{-}239 = 0.85\ SWM + \sqrt{\sum_i \{600[1-\exp(-SWM_i/57.7)] - 0.85\ SWM_i\}^2}$$

TABLE C-1. Pu-239 Estimates Ordered by Mass

Method #1 m/p x SWM (direct)

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu --------------------->
1	498	21	14
2	537	37	69
3	520	39	81
4	385	109	34
5	560	117	13
6	547	146	130
7	541	154	[illegible]
8	489	154	57
9	536	167	128
10	374	175	69
11	432	176	38
12	444	181	57
13	475	183	160
14	437	192	114
15	519	195	100
16	502	203	145
17	539	203	149
18	454	207	77
19	453	208	81
20	522	220	161
21	434	233	80
22	458	252	80
23	484	262	125
24	428	264	126
25	533	271	209
26	367	281	165
27	508	285	75
28	491	294	118
29	538	299	211
30	517	300	150
31	354	304	118
32	400	315	124
33	461	331	57
34	557	337	56
35	433	347	89
36	272	347	212
37	559	350	79
38	479	350	98
39	397	361	90
40	426	363	167
41	509	364	67
42	443	366	124
43	534	367	205
44	548	374	64
45	540	425	295
46	506	437	107
47	415	441	124
48	352	443	183
49	401	445	249
50	550	471	238
51	531	481	267
52	535	507	367
53	532	508	75
54	390	514	307
55	504	521	270
56	427	533	156
57	396	549	283
58	546	552	62
59	423	554	127
60	439	556	139
61	413	593	279
62	544	596	75
63	493	613	337
64	553	630	67
65	554	639	76
66	555	653	96
67	551	657	72
68	405	673	237
69	404	675	671
70	395	676	345
71	394	682	339
72	472	690	201
73	393	694	348
74	384	703	365
75	391	729	484
76	501	734	384
77	514	737	389
78	510	743	144
79	549	744	80
80	494	747	532
81	543	747	88
82	545	750	140
83	470	785	190
84	523	787	150
85	402	793	232
86	418	806	184
87	417	832	276
88	490	890	475
89	480	938	194
90	321	949	533
91	503	954	450
92	558	968	124
93	492	977	556
94	526	982	704
95	488	1004	545
96	409	1039	521
97	521	1055	799
98	530	1069	592
99	552	1144	179
100	505	1217	568
101	370	1266	380
102	482	1369	286
103	528	1483	216
104	420	1586	704
105	412	1587	892
106	518	1788	916
107	527	1870	1282
108	513	1870	393
109	456	2095	633
110	515	2262	1182
111	516	2355	1235
112	392	2566	1274
113	332	2948	1370
114	529	3167	1593
115	481	3552	768
116	399	4171	618
117	324	5072	2632
118	507	13600	6884

Method #2 m/p x 3Sig x SWM (0.1% upper limit)

I = entry # / Cul = culvert # Cul-Pu = g Pu-239 Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu --------------------->
1	498	54	42
2	537	303	215
3	520	310	253
4	385	339	106
5	560	364	42
6	547	457	312
7	541	479	304
8	489	479	210
9	536	521	400
10	374	548	215
11	432	550	117
12	444	564	177
13	475	570	499
14	337	600	357
15	519	609	313
16	502	633	453
17	539	634	465
18	454	644	241
19	453	649	253
20	522	685	503
21	434	727	250
22	458	785	251
23	484	817	390
24	428	825	394
25	533	844	651
26	367	875	516
27	508	890	234
28	491	917	367
29	538	934	658
30	517	936	468
31	354	948	369
32	400	981	386
33	461	1034	177
34	557	1051	174
35	433	1082	278
36	272	1084	663
37	559	1091	247
38	479	1093	306
39	397	1125	280
40	426	1132	520
41	509	1135	208
42	443	1143	388
43	534	1147	639
44	548	1168	201
45	540	1325	920
46	506	1362	334
47	415	1377	387
48	352	1381	572
49	401	1388	778
50	550	1469	743
1	531	1499	834
2	535	1581	1146
53	532	1585	235
54	390	1603	957
55	504	1626	842
56	427	1662	486
57	396	1714	882
58	546	1722	194
59	423	1729	397
60	439	1735	433
61	413	1850	871
62	544	1858	233
63	493	1913	1052
64	553	1945	208
65	554	1994	236
66	555	2036	301
67	551	2048	224
68	405	2101	739
69	404	2106	2094
70	395	2108	1076
71	394	2126	1059
72	472	2152	628
73	393	2164	1086
74	384	2193	1138
75	391	2274	1510
76	501	2290	1199
77	514	2300	1215
78	510	2319	450
79	549	2321	251
80	494	2331	1660
81	543	2331	274
82	545	2339	435
83	470	2449	591
84	523	2457	468
85	402	2474	725
86	418	2514	575
87	417	2596	861
88	490	2776	1482
89	480	2927	605
90	321	2960	1662
91	503	2977	1403
92	558	3022	387
93	492	3049	1735
94	526	3065	2198
95	488	3133	1700
96	409	3242	1625
97	521	3291	2492
98	530	3335	1849
99	552	3570	560
100	505	3797	1771
101	370	3948	1184
102	482	4271	893
103	528	4625	675
104	420	4949	2138
105	412	4952	[illegible]
106	518	5579	[illegible]
107	527	5834	[illegible]
108	513	5836	1227
109	456	6535	1975
110	515	7056	[illegible]
111	516	7349	[illegible]
112	392	8005	[illegible]
113	332	9197	[illegible]
114	529	9880	[illegible]
115	481	11082	[illegible]
116	399	13015	1928
117	324	15824	[illegible]
118	507	42433	[illegible]

Method #3 m/p(Pu239) x SWM direct.

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu -------------------->
1	498	29	19
2	537	137	98
3	520	141	115
4	385	154	48
5	560	165	19
6	547	207	142
7	541	218	138
8	489	218	35
9	536	236	182
10	374	249	98
11	432	250	51
12	444	256	80
13	475	259	226
14	437	272	162
15	519	276	142
16	502	287	206
17	539	288	211
18	454	292	109
19	453	294	115
20	522	311	228
21	434	330	113
22	458	356	114
23	484	371	177
24	428	374	179
25	533	383	295
26	367	397	234
27	508	404	106
28	491	416	167
29	538	424	298
30	517	425	213
31	354	430	167
32	400	445	175
33	461	469	80
34	557	477	78
35	433	491	126
36	272	492	301
37	559	495	112
38	479	496	139
39	397	511	127
40	426	514	236
41	509	515	94
42	443	519	176
43	534	520	290
44	548	530	91
45	540	601	417
46	506	618	152
47	415	625	175
48	352	627	260
49	401	630	353
50	550	667	337
51	531	681	378
52	535	717	520
53	532	719	107
54	390	727	435
55	504	738	382
56	427	754	221
57	396	778	400
58	546	781	88
59	423	785	180
60	439	787	197
61	413	840	395
62	544	843	106
63	493	868	478
64	553	892	94
65	554	905	107
66	555	924	136
67	551	930	102
68	405	953	335
69	404	956	950
70	395	957	488
71	394	965	481
72	472	977	285
73	393	982	493
74	384	995	516
75	391	1032	685
76	501	1039	544
77	514	1044	551
78	510	1052	204
79	549	1053	114
80	494	1058	754
81	543	1058	124
82	545	1061	198
83	470	1112	268
84	523	1115	213
85	402	1123	329
86	418	1141	261
87	417	1178	391
88	490	1260	672
89	480	1328	274
90	321	1343	754
91	503	1351	637
92	558	1371	176
93	492	1384	788
94	526	1391	997
95	488	1422	771
96	409	1471	738
97	521	1494	1131
98	530	1514	839
99	551	1620	254
100	505	1723	804
101	370	1792	537
102	482	1938	405
103	528	2099	306
104	420	2246	997
105	412	2247	1264
106	518	2532	1297
107	527	2648	1815
108	513	2649	557
109	456	2946	896
110	515	3202	1673
111	516	3335	1748
112	392	3633	1804
113	332	4[illegible]74	1940
114	529	4[illegible]84	2255
115	481	5029	1088
116	399	5907	875
117	324	7182	3728
118	507	19258	9747

Method #4 m/p(Pu239) x (Sig(Pu239) x SWM [illegible] upper limit

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu -------------------->
1	498	79	52
2	537	372	265
3	520	381	311
4	385	416	130
5	560	447	52
6	547	562	384
7	541	590	374
8	489	590	258
9	536	641	492
10	374	673	265
11	432	677	144
12	444	694	218
13	475	701	614
14	437	738	439
15	519	749	385
16	502	779	557
17	539	780	572
18	454	792	296
19	453	798	311
20	522	842	618
21	434	894	307
22	458	966	308
23	484	1005	479
24	428	1014	484
25	533	1038	800
26	367	1076	635
27	508	1094	287
28	491	1128	452
29	538	1149	809
30	517	1152	576
31	354	1166	454
32	400	1207	474
33	461	1272	217
34	557	1292	214
35	433	1330	342
36	272	1333	815
37	559	1341	304
38	479	1344	376
39	397	1384	346
40	426	1392	639
41	509	1395	256
42	443	1406	477
43	534	1410	785
44	548	1437	247
45	540	1629	1131
46	506	1675	411
47	415	1694	475
48	352	1698	704
49	401	1707	957
50	550	1807	914
51	531	1844	1026
52	535	1944	1409
53	532	1950	289
54	390	1971	1178
55	504	2000	1035
56	427	2044	598
57	396	2108	1084
58	546	2117	239
59	423	2127	488
60	439	2134	533
61	413	2276	1071
62	544	2285	287
63	493	2353	1294
64	553	2417	255
65	554	2452	291
66	555	2504	370
67	551	2519	275
68	405	2583	909
69	404	2590	2576
70	395	2593	1324
71	394	2615	1302
72	472	2647	772
73	393	2661	1336
74	384	2697	1400
75	391	2797	1857
76	501	2816	1474
77	514	2829	1494
78	510	2852	553
79	549	2855	308
80	494	2867	2042
81	543	2867	337
82	545	2877	536
83	470	3012	727
84	523	3021	576
85	402	3042	892
86	418	3092	708
87	417	3193	1059
88	490	3414	1822
89	480	3600	744
90	321	3641	2045
91	503	3662	1726
92	558	3716	476
93	492	3750	2134
94	526	3770	2701
95	488	3854	2090
96	409	3987	1999
97	521	4047	3065
98	530	4102	2274
99	552	4390	689
100	505	4670	2178
101	370	4856	1456
102	482	5253	1098
103	528	5689	830
104	420	6086	[illegible]
105	412	6091	1425
106	518	6861	[illegible]
107	527	7175	[illegible]
108	513	7178	1509
109	456	8038	2429
110	515	8679	[illegible]
111	516	9038	[illegible]
112	392	9845	4990
113	382	11312	5257
114	529	12151	6112
115	461	13630	3948
116	399	16007	2171
117	324	19462	[illegible]
118	507	52190	[illegible]

Method #5 m/p x (3.g.Pu239) x SWM (0.1% upper limit)

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu -------------------->
1	498	56	37
2	537	263	187
3	520	269	220
4	385	294	92
5	560	316	37
6	547	397	271
7	541	416	264
8	489	416	182
9	536	452	347
10	374	476	187
11	432	478	102
12	444	490	154
13	475	495	433
14	437	521	310
15	519	529	272
16	502	550	393
17	539	551	404
18	454	560	209
19	453	563	219
20	522	595	437
21	434	631	217
22	458	682	218
23	484	709	338
24	428	716	342
25	533	733	565
26	367	760	448
27	508	773	203
28	491	796	319
29	538	811	571
30	517	813	407
31	354	823	320
32	400	852	335
33	461	898	154
34	557	913	151
35	433	940	242
36	272	962	576
37	559	947	214
38	479	949	266
39	397	977	243
40	426	983	451
41	509	986	181
42	443	993	337
43	534	996	555
44	548	1015	174
45	540	1151	799
46	506	1183	290
47	415	1196	336
48	352	1199	497
49	401	1206	676
50	550	1276	646
51	531	1302	724
52	535	1373	995
53	532	1377	204
54	390	1392	832
55	504	1413	731
56	427	1444	422
57	396	1489	766
58	546	1495	169
59	423	1502	345
60	439	1507	376
61	413	1607	756
62	544	1614	203
63	493	1662	914
64	553	1707	180
65	554	1732	205
66	555	1769	261
67	551	1779	194
68	405	1824	642
69	404	1829	1819
70	395	1831	935
71	394	1847	920
72	472	1870	545
73	393	1879	944
74	384	1905	988
75	391	1975	1311
76	501	1989	1041
77	514	1998	1055
78	510	2014	391
79	549	2016	218
80	494	2025	1442
81	543	2025	238
82	545	2031	378
83	470	2127	514
84	523	2134	407
85	402	2149	630
86	418	2184	500
87	417	2255	768
88	490	2411	1287
89	480	2542	525
90	321	2571	1444
91	503	2586	1219
92	558	2625	336
93	492	2648	1507
94	526	2662	1909
95	488	2722	1476
96	409	2816	1412
97	521	2858	2165
98	530	2897	1606
99	552	3101	486
100	505	3298	1538
101	370	3430	1029
102	482	3710	775
103	528	4018	586
104	420	4298	1909
105	412	4301	2419
106	518	4846	2483
107	527	5067	3473
108	513	5069	1066
109	456	5676	1715
110	515	6129	3202
111	516	6383	3341
112	392	6953	3453
113	332	7989	[illegible]
114	529	8581	4317
115	481	9626	2082
116	399	11304	1675
117	324	13744	7134
118	507	36857	18655

Method #6 13/π SWM (0.1% upper limit)

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu -------------------->
1	498	694	459
2	401	1102	618
3	405	1144	663
4	402	1144	559
5	385	1144	578
6	427	1145	576
7	433	1145	513
8	412	1145	1129
9	404	1146	1147
10	502	1146	1202
11	400	1147	825
12	550	1148	581
13	444	1149	516
14	367	1150	1188
15	428	1152	758
16	432	1154	485
17	354	1158	915
18	409	1159	1191
19	417	1161	797
20	458	1162	469
21	426	1168	652
22	384	1169	1183
23	423	1173	596
24	475	1173	1206
25	437	1179	1152
26	370	1188	842
27	520	1192	1157
28	537	1195	1146
29	533	1197	1153
30	434	1199	424
31	539	1201	1150
32	374	1203	479
33	535	1203	1150
34	547	1204	1146
35	536	1204	1156
36	540	1204	1147
37	415	1206	852
38	538	1209	1149
39	494	1212	1151
40	439	1213	778
41	521	1216	1160
42	526	1220	1155
43	522	1222	1158
44	541	1238	1149
45	527	1246	1160
46	508	1246	913
47	391	1249	1157
48	534	1261	1145
49	413	1270	1145
50	332	1272	1146
51	397	1277	942
52	272	1286	1159
53	390	12[illegible]	1157
54	461	1295	640
55	492	1299	1155
56	420	1300	1145
57	531	1306	1154
58	530	1312	1155
59	518	1314	1148
60	503	1317	1145
61	529	1317	1148
62	484	1318	1145
63	454	1319	1153
64	321	1320	1159
65	472	1320	1200
66	515	1322	1151
67	504	1326	1151
68	352	1327	1145
69	488	1328	1157
70	394	1329	1149
71	516	1332	1154
72	514	1333	1155
73	490	1333	1156
74	470	1335	1051
75	519	1335	1153
76	517	1335	1150
77	509	1341	808
78	324	1341	1155
79	418	1342	1012
80	493	1342	1162
81	482	1343	927
82	399	1344	659
83	481	1346	966
84	480	1347	923
85	456	1348	1177
86	479	1349	1194
87	501	1351	1158
88	491	1355	1144
89	396	1356	1157
90	392	1357	1154
91	443	1359	1155
92	507	1362	1157
93	505	1363	1149
94	489	1363	1146
95	393	1364	1156
96	395	1367	1159
97	453	1374	1144
98	560	1380	553
99	559	1648	1150
100	506	1727	1144
101	545	1828	1149
102	523	1839	1147
103	513	1844	1144
104	510	1852	1145
105	557	1893	1155
106	558	1947	1193
107	552	2002	1150
108	555	2013	1155
109	544	2021	1182
110	548	2064	1144
111	543	2094	1183
112	532	2168	1145
113	546	2217	1172
114	554	2227	1162
115	528	2251	1144
116	553	2257	1179
117	551	2478	1151
118	549	2603	1146

Method #7 Refined 13/$\sqrt{n}$ SWM (0.1% upper limit)

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu -------------------->
1	498	594	459
2	444	1015	516
3	502	1015	1040
4	404	1015	1015
5	428	1015	758
6	385	1017	578
7	405	1018	563
8	458	1019	469
9	402	1019	559
10	426	1021	552
11	427	1021	576
12	433	1022	513
13	412	1023	1056
14	475	1024	1043
15	400	1028	925
16	367	1032	1032
17	432	1038	485
18	434	1039	424
19	374	1041	479
20	354	1043	915
21	409	1045	1045
22	417	1047	797
23	550	1053	581
24	384	1057	1029
25	423	1062	596
26	401	1062	618
27	437	1069	1015
28	370	1080	842
29	520	1084	1042
30	537	1088	1026
31	533	1091	1037
32	539	1095	1032
33	535	1097	1032
34	547	1098	1025
35	536	1098	1041
36	540	1098	1027
37	415	1101	852
38	538	1104	1031
39	494	1107	1034
40	439	1108	778
41	521	1111	1045
42	526	1115	1039
43	522	1118	1044
44	541	1135	1030
45	527	1144	1046
46	508	1144	913
47	391	1147	1042
48	534	1159	1024
49	413	1169	1015
50	332	1172	1015
51	397	1176	942
52	272	1186	1045
53	390	1190	1043
54	461	1196	680
55	492	1200	1039
56	420	1201	1016
57	531	1207	1038
58	530	1213	1039
59	518	1215	1029
60	503	1218	1021
61	529	1218	1028
62	484	1219	1023
63	454	1220	1015
64	321	1221	1044
65	472	1222	1039
66	515	1223	1034
67	504	1227	1034
68	352	1228	1015
69	488	1229	1042
70	394	1230	1030
71	516	1234	1038
72	514	1235	1039
73	490	1235	1041
74	470	1236	1051
75	519	1237	1036
76	517	1237	1032
77	509	1242	808
78	324	1243	1035
79	418	1243	1012
80	493	1244	1049
81	482	1245	927
82	399	1246	659
83	481	1248	966
84	480	1249	923
85	456	1250	1026
86	479	1251	1036
87	501	1253	1044
88	491	1257	1016
89	396	1258	1043
90	392	1259	1038
91	443	1261	1016
92	507	1265	1042
93	505	1265	1031
94	489	1266	1024
95	393	1266	1041
96	395	1270	1045
97	453	1277	1017
98	560	1283	553
99	559	1553	1015
100	506	1631	1020
101	545	1732	1015
102	523	1743	1015
103	513	1748	1018
104	510	1756	1015
105	557	1797	1016
106	558	1851	1035
107	552	1905	1015
108	555	1916	1016
109	544	1924	1028
110	548	1967	1018
111	543	1996	1029
112	532	2070	1015
113	546	2119	1023
114	554	2129	1018
115	528	2152	1017
116	553	2158	1027
117	551	2376	1015
118	549	2501	1015

Method #8 Cut Model x SWM (0.1% upper limit)

I = entry # / Cul = culvert # / Cul-Pu = g Pu-239 / Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu -------------------->
1	498	225	183
2	374	291	189
3	434	313	173
4	401	316	225
5	550	324	216
6	426	335	232
7	475	342	320
8	458	345	186
9	444	354	199
10	404	360	359
11	428	366	254
12	502	402	322
13	385	417	215
14	427	423	214
15	400	424	267
16	405	428	235
17	402	434	210
18	433	447	198
19	412	455	311
20	367	460	328
21	432	461	190
22	520	472	382
23	437	476	352
24	354	492	282
25	533	495	380
26	536	500	382
27	494	503	379
28	384	504	331
29	409	505	318
30	535	506	378
31	417	510	262
32	539	510	378
33	537	511	374
34	521	513	383
35	423	520	219
36	540	524	375
37	547	525	374
38	538	525	378
39	522	525	383
40	526	530	381
41	391	538	382
42	527	549	383
43	370	566	270
44	541	574	377
45	534	583	373
46	439	588	258
47	415	594	271
48	492	603	381
49	272	603	383
50	518	611	377
51	529	612	376
52	530	612	381
3	413	[illegible]	361
4	515		379
55	321	617	383
56	516	617	381
57	514	618	381
58	390	624	382
59	395	632	383
60	396	632	382
61	488	639	382
62	332	643	361
63	531	647	381
64	394	652	377
65	517	653	378
66	508	654	282
67	393	658	382
68	503	659	371
69	392	660	381
70	490	661	382
71	519	663	380
72	504	667	379
73	493	671	384
74	489	671	373
75	484	673	372
76	420	677	363
77	397	683	286
78	324	689	381
79	505	690	377
80	501	691	383
81	507	694	382
82	461	713	238
83	454	715	351
84	443	715	350
85	352	718	362
86	491	721	365
87	472	735	322
88	453	744	366
89	456	750	334
90	509	757	264
91	479	762	325
92	399	764	234
93	470	767	301
94	480	768	283
95	418	770	296
96	482	773	284
97	481	778	290
98	560	785	209
99	559	1048	354
100	506	1086	370
101	523	1228	358
102	545	1229	355
103	513	1239	367
104	510	1248	361
105	557	1281	350
106	558	1354	326
107	552	1385	354
108	555	1410	349
109	544	1425	332
110	548	1428	367
111	543	1486	331
112	532	1526	362
113	554	[illegible]	344
114	546	[illegible]	337
115	528	1604	366
116	553	1636	333
117	551	1812	353
118	549	1911	359

Method #9 Conservative Cut Model x SWM (0.1% upper limit)

I = entry # Cul = culvert # Cul-Pu = g Pu-239 Max-Drum-Pu = g Pu-239

I	Cul	Cul-Pu	Max-Drum-Pu --------------------->
1	498	331	275
2	374	415	283
3	434	450	259
4	401	463	337
5	550	474	323
6	426	480	349
7	458	492	279
8	444	499	299
9	475	507	480
10	428	525	382
11	404	539	538
12	502	589	483
13	385	593	322
14	400	597	400
15	427	599	322
16	405	612	352
17	402	620	315
18	433	637	297
19	432	645	286
20	412	663	467
21	367	664	492
22	437	677	528
23	520	687	573
24	354	699	423
25	533	717	570
26	384	719	497
27	494	722	568
28	417	724	393
29	536	725	572
30	409	727	477
31	423	728	329
32	535	729	567
33	539	738	567
34	537	741	561
35	521	742	575
36	547	753	561
37	540	758	563
38	522	759	574
39	538	759	566
40	391	762	573
41	526	765	572
42	527	782	575
43	370	802	405
44	439	819	387
45	541	819	566
46	415	835	407
47	534	840	559
48	272	850	575
49	530	852	572
50	321	857	574
51	492	863	571
52	413	871	542
53	518	876	565
54	529	878	564
55	515	879	569
56	390	881	574
57	516	884	571
58	514	885	572
59	396	901	574
60	395	901	575
61	517	904	567
62	488	906	573
63	332	912	541
64	531	918	571
65	490	919	573
66	508	919	422
67	394	925	565
68	489	927	560
69	393	931	573
70	392	933	571
71	493	935	577
72	503	936	557
73	519	939	570
74	484	940	558
75	504	945	568
76	420	949	545
77	397	955	429
78	505	957	566
79	324	961	572
80	501	963	574
81	507	970	573
82	461	988	357
83	443	993	524
84	491	995	547
85	454	995	526
86	352	1001	544
87	472	1022	484
88	453	1029	548
89	509	1044	396
90	456	1044	501
91	399	1048	351
92	479	1059	488
93	480	1063	425
94	560	1066	313
95	418	1068	444
96	462	1072	426
97	470	1073	452
98	481	1078	434
99	559	1414	532
100	506	1472	555
101	523	1645	538
102	545	1649	533
103	513	1657	551
104	510	1670	542
105	557	1705	524
106	558	1801	489
107	552	1841	531
108	555	1874	524
109	544	1890	497
110	548	1891	552
111	543	1967	496
112	532	2014	543
113	554	2102	516
114	546	2105	506
115	528	2113	549
116	553	2154	500
117	551	2368	530
118	549	2488	539

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #1,#2

		Recorded Mass			Method #1 m/p x SWM		Method #2 m/p x 3Sig x SWM	
Culvert #	Pad #	Culvert g	Max Drum g	Meas/Proj #	Culvert g	Max Drum g	Culvert g	Max Drum g
272	13	299.027	182.810	1.162	347.469	212.425	1084.104	662.767
321	10	323.805	181.850	2.930	948.749	532.821	2960.096	1662.400
324	13	339.472	176.200	14.940	5071.712	2632.428	15823.740	8213.175
332	13	288.188	133.940	10.229	2947.875	1370.072	9197.370	4274.625
352	6	329.263	136.420	1.344	442.529	183.348	1380.692	572.047
354	6	180.841	70.360	1.680	303.813	118.205	947.896	368.799
367	6	167.871	99.010	1.671	280.512	165.446	875.199	516.191
370	6	216.070	64.800	5.857	1265.522	379.534	3948.429	1184.145
374	6	93.848	36.880	1.870	175.496	68.966	547.547	215.173
384	6	195.460	101.420	3.596	702.874	364.706	2192.967	1137.884
385	6	142.240	44.460	0.763	108.529	33.923	338.611	105.840
390	6	301.462	180.100	1.704	513.691	306.890	1602.717	957.498
391	6	269.640	179.010	2.703	728.837	483.864	2273.971	1509.656
392	6	351.124	174.380	7.307	2565.663	1274.195	8004.869	3975.487
393	6	356.008	178.760	1.948	693.504	348.224	2163.731	1086.460
394	6	330.690	164.650	2.061	681.552	339.344	2126.443	1058.752
395	6	358.680	183.100	1.884	675.753	344.960	2108.350	1076.276
396	6	350.357	180.210	1.568	549.360	282.569	1714.003	881.616
397	6	291.585	72.480	1.237	360.691	89.658	1125.355	279.732
399	6	342.056	50.670	12.195	4171.373	617.921	13014.684	1927.912
400	6	161.460	63.460	1.948	314.524	123.620	981.315	385.695
401	6	84.780	47.540	5.248	444.925	249.490	1388.167	778.409
402	6	146.709	43.020	5.404	792.815	232.480	2473.584	725.338
404	6	131.873	131.150	5.118	674.926	671.226	2105.769	2094.224
405	6	144.970	50.990	4.644	673.241	236.798	2100.511	738.808
409	6	182.690	91.590	5.687	1038.958	520.872	3241.549	1625.122
412	6	154.470	86.860	10.275	1587.179	892.487	4951.999	2784.558
413	6	286.100	134.610	2.073	593.085	279.047	1850.426	870.625
415	6	233.380	65.510	1.891	441.322	123.879	1376.923	386.504
417	6	184.890	61.320	4.500	832.005	275.940	2595.856	860.933
418	6	340.000	77.820	2.370	805.800	184.433	2514.096	575.432
420	6	309.360	137.390	5.127	1586.089	704.399	4948.597	2197.723
423	6	199.780	45.830	2.774	554.190	127.132	1729.072	396.653
426	6	109.327	50.190	3.319	362.856	166.581	1132.112	519.732
427	13	151.346	44.290	3.520	532.738	155.901	1662.142	486.410
428	13	122.034	58.290	2.166	264.326	126.256	824.696	393.919
432	13	175.290	37.290	1.006	176.342	37.514	550.186	117.043
433	13	153.204	39.430	2.263	346.701	89.230	1081.706	278.398
434	13	94.980	32.600	2.453	232.986	79.968	726.916	249.500
437	13	206.270	122.620	0.932	192.244	114.282	599.800	356.559
439	13	239.610	59.840	2.321	556.135	138.889	1735.141	433.333
443	13	352.340	119.450	1.040	366.434	124.228	1143.273	387.591
444	13	126.380	39.710	1.431	180.850	56.825	564.251	177.294
453	13	363.432	141.570	0.572	207.883	80.978	648.595	252.651
454	13	323.667	120.880	0.638	206.500	77.121	644.279	240.619
456	13	344.396	104.080	6.082	2094.616	633.015	6535.203	1975.005
458	13	113.037	36.090	2.226	251.620	80.336	785.056	250.649
461	13	305.770	52.270	1.084	331.455	56.661	1034.139	176.781

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #1,#2

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #1 m/p x SWM Culvert g	Method #1 m/p x SWM Max Drum g	Method #2 m/p x 3Sig x SWM Culvert g	Method #2 m/p x 3Sig x SWM Max Drum g
470	13	334.901	80.860	2.344	785.008	189.536	2449.225	591.352
472	13	324.490	94.620	2.126	689.866	201.162	2152.381	627.626
475	13	105.977	92.740	1.724	182.704	159.884	570.038	498.837
479	13	345.430	96.750	1.014	350.266	98.105	1092.830	306.086
480	13	343.640	70.990	2.730	938.137	193.803	2926.988	604.664
481	13	343.477	74.280	10.341	3551.896	768.129	11081.914	2396.564
482	13	341.354	71.346	4.010	1368.830	286.097	4270.748	892.624
484	13	322.785	154.000	0.811	261.779	124.894	816.749	389.669
488	13	329.822	178.900	3.045	1004.308	544.751	3133.441	1699.622
489	13	355.619	155.860	0.432	153.627	67.332	479.318	210.074
490	13	333.991	178.260	2.664	889.752	474.885	2776.026	1481.640
491	13	349.800	140.180	0.840	293.832	117.751	916.756	367.384
492	10	308.824	175.780	3.164	977.119	556.168	3048.612	1735.244
493	13	340.105	187.040	1.803	613.209	337.233	1913.213	1052.167
494	13	238.244	169.690	3.136	747.133	532.148	2331.056	1660.301
498	13	53.400	35.300	0.385	20.559	13.590	64.144	42.402
501	10	346.830	181.540	2.116	733.892	384.139	2289.744	1198.513
502	13	131.580	94.130	1.542	202.896	145.148	633.037	452.863
503	10	321.610	151.570	2.967	954.217	449.708	2977.157	1403.090
504	10	328.440	169.960	1.587	521.234	269.727	1626.251	841.547
505	13	355.340	165.750	3.425	1217.039	567.694	3797.163	1771.205
506	10	608.096	149.180	0.718	436.613	107.111	1362.232	334.187
507	13	355.056	179.710	38.305	13600.420	6883.792	42433.311	21477.430
508	13	267.526	70.240	1.066	285.183	74.876	889.770	233.613
509	13	339.232	62.190	1.072	363.657	66.668	1134.609	208.003
510	13	694.000	134.590	1.071	743.274	144.146	2319.015	449.735
513	13	688.950	144.820	2.715	1870.499	393.186	5835.958	1226.741
514	10	333.900	176.300	2.208	737.251	389.270	2300.224	1214.524
515	10	325.730	170.180	6.943	2261.543	1181.560	7056.015	3686.466
516	10	333.290	174.700	7.067	2355.360	1234.605	7348.725	3851.967
517	13	335.320	167.710	0.895	300.111	150.100	936.348	468.313
518	10	320.040	163.990	5.587	1788.063	916.212	5578.758	2858.582
519	13	335.320	172.310	0.582	195.156	100.284	608.887	312.887
520	13	219.900	179.270	0.452	99.395	81.030	310.112	252.814
521	13	241.970	183.260	4.359	1054.747	798.830	3290.811	2492.351
522	10	247.510	181.610	0.887	219.541	161.088	684.969	502.595
523	10	685.250	130.660	1.149	787.352	150.128	2456.539	468.400
526	13	245.400	175.980	4.003	982.336	704.448	3064.889	2197.878
527	13	267.410	183.290	6.992	1869.731	1281.564	5833.560	3998.479
528	10	972.150	141.810	1.525	1482.529	216.260	4625.490	674.732
529	13	322.100	162.020	9.831	3166.565	1592.819	9879.683	4969.594
530	13	318.510	176.540	3.356	1068.920	592.468	3335.029	1848.501
531	13	313.710	174.470	1.532	480.604	267.288	1499.484	833.939
532	13	913.870	135.450	0.556	508.112	75.310	1585.309	234.968
533	13	225.070	173.530	1.202	270.534	208.583	844.067	650.779
534	10	279.040	155.390	1.317	367.496	204.649	1146.587	638.504
535	13	230.510	167.090	2.198	506.661	367.264	1580.782	1145.863
536	13	231.510	177.780	0.721	166.919	128.179	520.786	399.920

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #1,#2

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #1 m/p x SWM Culvert g	Method #1 m/p x SWM Max Drum g	Method #2 m/p x 3Sig x SWM Culvert g	Method #2 m/p x 3Sig x SWM Max Drum g
537	13	222.630	158.400	0.436	97.067	69.062	302.848	215.475
538	13	235.960	166.080	1.269	299.433	210.756	934.232	657.557
539	13	228.490	167.570	0.890	203.356	149.137	634.471	465.308
540	13	231.650	160.810	1.833	424.614	294.765	1324.797	919.666
541	13	260.820	165.420	0.589	153.623	97.432	479.304	303.989
543	13	861.775	101.150	0.867	747.159	87.697	2331.136	273.615
544	10	811.310	101.910	0.734	595.502	74.802	1857.965	233.382
545	10	677.780	126.200	1.106	749.625	139.577	2338.829	435.481
546	13	948.097	106.970	0.582	551.792	62.257	1721.592	194.240
547	13	231.350	157.900	0.633	146.445	99.951	456.907	311.846
548	13	841.400	144.570	0.445	374.423	64.334	1168.200	200.721
549	13	1221.550	131.950	0.609	743.924	80.358	2321.043	250.716
550	13	88.345	44.697	5.330	470.879	238.235	1469.142	743.293
551	13	1131.993	123.600	0.580	656.556	71.688	2048.455	223.667
552	13	797.840	125.150	1.434	1144.103	179.465	3569.600	559.931
553	13	976.340	103.120	0.645	629.739	66.512	1964.787	207.519
554	13	955.320	113.250	0.669	639.109	75.764	1994.020	236.384
555	13	805.730	118.920	0.810	652.641	96.325	2036.241	300.535
557	13	722.698	119.570	0.466	336.777	55.720	1050.745	173.845
558	10	760.166	97.350	1.274	968.451	124.024	3021.569	386.955
559	13	554.018	125.390	0.631	349.585	79.121	1090.706	246.858
560	13	367.785	42.510	0.317	116.588	13.476	363.754	42.044

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #3,#4

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Recorded Mass Meas/Proj #	Method #3 m/p(Pu239) x SWM Culvert g	Method #3 m/p(Pu239) x SWM Max Drum g	Method #4 m/p(Pu239) x 3Sig(Pu239) x SW Culvert g	Method #4 m/p(Pu239) x 3Sig(Pu239) x SW Max Drum g
272	13	299.027	182.810	1.162	492.017	300.794	1333.365	815.152
321	10	323.805	181.850	2.930	1343.428	754.474	3640.690	2044.624
324	13	339.472	176.200	14.940	7181.544	3727.518	19461.984	10101.574
332	13	288.188	133.940	10.229	4174.191	1940.022	11312.058	5257.460
352	6	329.263	136.420	1.344	626.622	259.621	1698.145	703.574
354	6	180.841	70.360	1.680	430.199	167.378	1165.839	453.594
367	6	167.871	99.010	1.671	397.206	234.271	1076.427	634.875
370	6	216.070	64.800	5.857	1791.979	537.420	4856.263	1456.407
374	6	93.848	36.880	1.870	248.502	97.655	673.440	264.646
384	6	195.460	101.420	3.596	995.270	516.424	2697.181	1399.509
385	6	142.240	44.460	0.763	153.677	48.035	416.465	130.175
390	6	301.462	180.100	1.704	727.387	434.557	1971.218	1177.649
391	6	269.640	179.010	2.703	1032.033	685.151	2796.810	1856.760
392	6	351.124	174.380	7.307	3632.979	1804.260	9845.373	4889.544
393	6	356.008	178.760	1.948	982.001	493.086	2661.223	1336.263
394	6	330.690	164.650	2.061	965.078	480.511	2615.361	1302.184
395	6	358.680	183.100	1.884	956.866	488.464	2593.108	1323.737
396	6	350.357	180.210	1.568	777.893	400.118	2108.091	1084.320
397	6	291.585	72.480	1.237	510.738	126.955	1384.100	344.049
399	6	342.056	50.670	12.195	5906.664	874.976	16007.060	2371.184
400	6	161.460	63.460	1.948	445.366	175.046	1206.942	474.375
401	6	84.780	47.540	5.248	630.014	353.278	1707.339	957.383
402	6	146.709	43.020	5.404	1122.627	329.192	3042.318	892.110
404	6	131.873	131.150	5.118	955.695	950.456	2589.934	2575.735
405	6	144.970	50.990	4.644	953.309	335.305	2583.467	908.677
409	6	182.690	91.590	5.687	1471.165	737.555	3986.856	1998.775
412	6	154.470	86.860	10.275	2247.446	1263.761	6090.578	3424.792
413	6	286.100	134.610	2.073	839.809	395.130	2275.882	1070.802
415	6	233.380	65.510	1.891	624.911	175.413	1693.510	475.370
417	6	184.890	61.320	4.500	1178.119	390.731	3192.703	1058.881
418	6	340.000	77.820	2.370	1141.013	261.158	3092.145	707.737
420	6	309.360	137.390	5.127	2245.902	997.428	6086.393	2703.031
423	6	199.780	45.830	2.774	784.733	180.020	2126.625	487.853
426	6	109.327	50.190	3.319	513.805	235.878	1392.410	639.230
427	13	151.346	44.290	3.520	754.357	220.756	2044.307	598.247
428	13	122.034	58.290	2.166	374.285	178.779	1014.313	484.490
432	13	175.290	37.290	1.006	249.700	53.119	676.687	143.954
433	13	153.204	39.430	2.263	490.928	126.350	1330.415	342.408
434	13	94.980	32.600	2.453	329.908	113.234	894.051	306.865
437	13	206.270	122.620	0.932	272.217	161.823	737.708	438.541
439	13	239.610	59.840	2.321	787.487	196.666	2134.089	532.966
443	13	352.340	119.450	1.040	518.870	175.907	1406.138	476.708
444	13	126.380	39.710	1.431	256.083	80.464	693.986	218.058
453	13	363.432	141.570	0.572	294.362	114.665	797.722	310.742
454	13	323.667	120.880	0.638	292.403	109.204	792.413	295.943
456	13	344.396	104.080	6.082	2965.977	896.349	8037.797	2429.105
458	13	113.037	36.090	2.226	356.294	113.756	965.558	308.279
461	13	305.770	52.270	1.084	469.340	80.232	1271.911	217.427

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #3,#4

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #3 m/p(Pu239) x SWM Culvert g	Method #3 m/p(Pu239) x SWM Max Drum g	Method #4 m/p(Pu239) x 3Sig(Pu239) x SW Culvert g	Method #4 m/p(Pu239) x 3Sig(Pu239) x SW Max Drum g
470	13	334.901	80.860	2.344	1111.571	268.383	3012.358	727.317
472	13	324.490	94.620	2.126	976.850	284.846	2647.263	771.931
475	13	105.977	92.740	1.724	258.709	226.395	701.102	613.532
479	13	345.430	96.750	1.014	495.977	138.916	1344.097	376.462
480	13	343.640	70.990	2.730	1328.402	274.425	3599.970	743.691
481	13	343.477	74.280	10.341	5029.484	1087.671	13629.902	2947.589
482	13	341.354	71.346	4.010	1938.263	405.114	5252.692	1097.859
484	13	322.785	154.000	0.811	370.679	176.850	1004.539	479.263
488	13	329.822	178.900	3.045	1422.100	771.367	3853.891	2090.404
489	13	355.619	155.860	0.432	217.536	95.341	589.524	258.375
490	13	333.991	178.260	2.664	1259.889	672.437	3414.299	1822.303
491	13	349.800	140.180	0.840	416.066	166.736	1127.539	451.854
492	10	308.824	175.780	3.164	1383.601	787.534	3749.558	2134.217
493	13	340.105	187.040	1.803	868.304	477.522	2353.105	1294.085
494	13	238.244	169.690	3.136	1057.941	753.521	2867.019	2042.043
498	13	53.400	35.300	0.385	29.112	19.244	78.892	52.152
501	10	346.830	181.540	2.116	1039.191	543.940	2816.209	1474.078
502	13	131.580	94.130	1.542	287.301	205.530	778.586	556.987
503	10	321.610	151.570	2.967	1351.171	636.787	3661.674	1725.692
504	10	328.440	169.960	1.587	738.068	381.933	2000.164	1035.038
505	13	355.340	165.750	3.425	1723.328	803.854	4670.219	2178.445
506	10	608.096	149.180	0.718	618.244	151.670	1675.441	411.024
507	13	355.056	179.710	38.305	19258.195	9747.449	52189.708	26415.586
508	13	267.526	70.240	1.066	403.819	106.024	1094.349	287.326
509	13	339.232	62.190	1.072	514.938	94.401	1395.482	255.828
510	13	694.000	134.590	1.071	1052.476	204.111	2852.210	553.140
513	13	688.950	144.820	2.715	2648.627	556.752	7177.779	1508.797
514	10	333.900	176.300	2.208	1043.948	551.207	2829.098	1493.771
515	10	325.730	170.180	6.943	3202.345	1673.089	8678.356	4534.070
516	10	333.290	174.700	7.067	3335.190	1748.201	9038.366	4737.623
517	13	336.320	167.710	0.895	424.958	212.542	1151.635	575.989
518	10	320.040	163.990	5.587	2531.898	1297.356	6861.443	3515.836
519	13	335.320	172.310	0.582	276.341	142.003	748.885	384.827
520	13	219.900	179.270	0.452	140.743	114.739	381.414	310.941
521	13	241.970	183.260	4.359	1493.522	1131.144	4047.445	3065.400
522	10	247.510	181.610	0.887	310.871	228.101	842.459	618.133
523	10	685.250	130.660	1.149	1114.891	212.582	3021.354	576.096
526	13	245.400	175.980	4.003	1390.988	997.498	3769.578	2703.220
527	13	267.410	183.290	6.992	2647.539	1814.694	7174.830	4917.821
528	10	972.150	141.810	1.525	2099.261	306.225	5688.997	829.868
529	13	322.100	162.020	9.831	4483.856	2255.431	12151.250	6112.218
530	13	318.510	176.540	3.356	1513.590	838.935	4101.829	2273.514
531	13	313.710	174.470	1.532	680.535	378.480	1844.249	1025.680
532	13	913.870	135.450	0.556	719.486	106.639	1949.808	288.992
533	13	225.070	173.530	1.202	383.076	295.354	1038.137	800.408
534	10	279.040	155.390	1.317	520.374	289.782	1410.213	785.310
535	13	230.510	167.090	2.198	717.432	520.046	1944.241	1409.323
536	13	231.510	177.780	0.721	236.357	181.502	640.527	491.870

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #3,#4

Culvert	Pad	Recorded Mass Culvert	Recorded Mass Max Drum	Meas/Proj	Method #3 m/p(Pu239) x SWM Culvert	Method #3 m/p(Pu239) x SWM Max Drum	Method #4 m/p(Pu239) x 3Sig(Pu239) x SW Culvert	Method #4 m/p(Pu239) x 3Sig(Pu239) x SW Max Drum
#	#	g	g	#	g	g	g	g
537	13	222.630	158.400	0.436	137.446	97.792	372.480	265.017
538	13	235.960	166.080	1.269	423.997	298.430	1149.033	808.745
539	13	2[illegible].490	167.570	0.890	287.952	211.178	780.351	572.294
540	13	231.650	160.810	1.833	601.254	417.387	1629.399	1131.118
541	13	260.820	165.420	0.589	217.530	137.964	589.507	373.883
543	13	861.775	101.150	0.867	1057.977	124.179	2867.118	336.525
544	10	811.310	101.910	0.734	843.230	105.920	2285.154	287.042
545	10	677.780	126.200	1.106	1061.469	197.641	2876.580	535.608
546	13	948.097	106.970	0.582	781.338	88.155	2117.426	238.901
547	13	231.350	157.900	0.633	207.365	141.530	561.960	383.547
548	13	841.400	144.570	0.445	530.183	91.096	1436.796	246.871
549	13	1221.550	131.950	0.609	1053.396	113.786	2854.704	308.361
550	13	88.345	44.697	5.330	666.764	337.341	1806.932	914.193
551	13	1131.993	123.600	0.580	929.683	101.510	2519.442	275.093
552	13	797.840	125.150	1.434	1620.049	254.123	4390.333	688.672
553	13	976.340	103.120	0.645	891.711	94.182	2416.536	255.232
554	13	955.320	113.250	0.669	904.978	107.282	2452.492	290.735
555	13	805.730	118.920	0.810	924.140	136.396	2504.420	369.634
557	13	722.698	119.570	0.466	476.877	78.899	1292.336	213.816
558	10	760.166	97.350	1.274	1371.327	175.618	3716.297	475.924
559	13	554.018	125.390	0.631	495.013	112.035	1341.485	303.616
560	13	367.785	42.510	0.317	165.088	19.082	447.390	51.711

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #5,#6

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #5 m/p x 3Sig(Pu239) x SWM Culvert g	Method #5 Max Drum g	Method #6 13/√n SWM Culvert g	Method #6 Max Drum g
272	13	299.027	182.810	1.162	941.642	575.672	1286.483	1159.193
321	10	323.805	181.850	2.930	2571.109	1443.944	1319.507	1158.524
324	13	339.472	176.200	14.940	13744.339	7133.880	1340.857	1154.824
332	13	288.188	133.940	10.229	7988.741	3712.896	1272.394	1145.607
352	6	329.263	136.420	1.344	1199.255	496.874	1326.909	1144.890
354	6	180.841	70.360	1.680	823.333	320.335	1157.834	914.680
367	6	167.871	99.010	1.671	760.189	448.358	1150.180	1188.425
370	6	216.070	64.800	5.857	3429.565	1028.536	1188.015	842.400
374	6	93.848	36.880	1.870	475.594	186.897	1202.804	479.440
384	6	195.460	101.420	3.596	1904.789	988.354	1168.967	1182.693
385	6	142.240	44.460	0.763	294.114	91.931	1143.997	577.980
390	6	301.462	180.100	1.704	1392.103	831.673	1289.681	1157.334
391	6	269.640	179.010	2.703	1975.148	1311.272	1248.923	1156.613
392	6	351.124	174.380	7.307	6952.947	3453.068	1356.923	1153.722
393	6	356.008	178.760	1.948	1879.395	943.688	1363.699	1156.449
394	6	330.690	164.650	2.061	1847.006	919.621	1328.851	1148.676
395	6	358.680	183.100	1.884	1831.291	934.843	1367.415	1159.397
396	6	350.357	180.210	1.568	1488.765	765.763	1355.861	1157.408
397	6	291.585	72.480	1.237	977.472	242.973	1276.783	942.240
399	6	342.056	50.670	12.195	11304.421	1674.565	1344.407	658.710
400	6	161.460	63.460	1.948	852.360	335.010	1147.364	824.980
401	6	84.780	47.540	5.248	1205.748	676.118	1102.140	618.020
402	6	146.709	43.020	5.404	2148.530	630.021	1143.985	559.260
404	6	131.873	131.150	5.118	1829.049	1819.022	1146.371	1146.676
405	6	144.970	50.990	4.644	1824.482	641.721	1143.925	662.870
409	6	182.690	91.590	5.687	2815.576	1411.564	1159.109	1190.670
412	6	154.470	86.860	10.275	4301.256	2418.638	1145.169	1129.180
413	6	286.100	134.610	2.073	1607.261	756.216	1269.709	1145.392
415	6	233.380	65.510	1.891	1195.981	335.713	1206.248	851.630
417	6	184.890	61.320	4.500	2254.734	747.797	1160.680	797.160
418	6	340.000	77.820	2.370	2183.718	499.815	1341.581	1011.660
420	6	309.360	137.390	5.127	4298.300	1908.920	1300.130	1144.667
423	6	199.780	45.830	2.774	1501.854	344.529	1172.671	595.790
426	6	109.327	50.190	3.319	983.341	451.433	1167.544	652.470
427	13	151.346	44.290	3.520	1443.720	422.491	1144.521	575.770
428	13	122.034	58.290	2.166	716.322	342.154	1152.389	757.770
432	13	175.290	37.290	1.006	477.886	101.662	1154.267	484.770
433	13	153.204	39.430	2.263	939.559	241.814	1144.880	512.590
434	13	94.980	32.600	2.453	631.392	216.713	1199.386	423.800
437	13	206.270	122.620	0.932	520.980	309.704	1178.540	1151.909
439	13	239.610	59.840	2.321	1507.125	376.388	1213.200	777.920
443	13	352.340	119.450	1.040	993.035	336.658	1358.608	1154.715
444	13	126.380	39.710	1.431	490.103	153.996	1149.212	516.230
453	13	363.432	141.570	0.572	563.363	219.450	1374.041	1144.047
454	13	323.667	120.880	0.638	559.614	208.999	1319.321	1153.385
456	13	344.396	104.080	6.082	5676.411	1715.469	1347.628	1177.007
458	13	113.037	36.090	2.226	681.891	217.711	1162.090	469.170
461	13	305.770	52.270	1.084	898.242	153.550	1295.367	679.510

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #5,#6

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #5 m/p x 3Sig(Pu239) x SWM Culvert g	Method #5 Max Drum g	Method #6 13/√n SWM Culvert g	Method #6 Max Drum g
470	13	334.901	80.860	2.344	2127.372	513.642	1334.596	1051.180
472	13	324.490	94.620	2.126	1869.536	545.149	1320.434	1200.456
475	13	105.977	92.740	1.724	495.129	433.285	1173.331	1205.620
479	13	345.430	96.750	1.014	949.221	265.863	1349.054	1194.348
480	13	343.640	70.990	2.730	2542.352	525.205	1346.587	922.870
481	13	343.477	74.280	10.341	9625.637	2081.631	1346.362	965.640
482	13	341.354	71.346	4.010	3709.528	775.324	1343.442	927.498
484	13	322.785	154.000	0.811	709.420	338.463	1318.129	1145.058
488	13	329.822	178.900	3.045	2721.675	1476.274	1327.669	1156.541
489	13	355.619	155.860	0.432	416.330	182.468	1363.158	1145.526
490	13	333.991	178.260	2.664	2411.228	1286.937	1333.352	1156.125
491	13	349.800	140.180	0.840	796.285	319.106	1355.090	1144.193
492	10	308.824	175.780	3.164	2647.993	1507.215	1299.417	1154.566
493	13	340.105	187.040	1.803	1661.797	913.902	1341.726	1162.269
494	13	238.244	169.690	3.136	2024.731	1442.121	1211.660	1151.105
498	13	53.400	35.300	0.385	55.715	36.830	694.200	458.900
501	10	346.830	181.540	2.116	1988.848	1041.016	1350.985	1158.311
502	13	131.580	94.130	1.542	549.849	393.352	1146.493	1201.937
503	10	321.610	151.570	2.967	2585.928	1218.709	1316.542	1144.560
504	10	328.440	169.960	1.587	1412.545	730.959	1325.790	1151.247
505	13	355.340	165.750	3.425	3298.177	1538.450	1362.771	1149.170
506	10	608.096	149.180	0.718	1183.221	290.271	1726.815	1144.205
507	13	355.056	179.710	38.305	36857.138	18655.075	1362.376	1157.074
508	13	267.526	70.240	1.066	772.845	202.914	1246.308	913.120
509	13	339.232	62.190	1.072	985.510	180.669	1340.527	808.470
510	13	694.000	134.590	1.071	2014.273	390.635	1851.646	1145.398
513	13	688.950	144.820	2.715	5069.053	1065.535	1844.321	1143.923
514	10	333.900	176.300	2.208	1997.951	1054.923	1333.228	1154.886
515	10	325.730	170.180	6.943	6128.783	3202.027	1322.113	1151.363
516	10	333.290	174.700	7.067	6383.027	3345.779	1332.395	1153.913
517	13	335.320	167.710	0.895	813.302	406.772	1335.169	1150.101
518	10	320.040	163.990	5.587	4845.652	2482.935	1314.426	1148.390
519	13	335.320	172.310	0.582	528.873	271.771	1335.169	1152.527
520	13	219.900	179.270	0.452	269.360	219.591	1191.896	1156.783
521	13	241.970	183.260	4.359	2858.365	2164.830	1215.881	1159.510
522	10	247.510	181.610	0.887	594.957	436.549	1222.268	1158.359
523	10	685.250	130.660	1.149	2133.725	406.848	1838.952	1146.895
526	13	245.400	175.980	4.003	2662.131	1909.054	1219.820	1154.688
527	13	267.410	183.290	6.992	5066.970	3473.038	1246.164	1159.532
528	10	972.150	141.810	1.525	4017.653	586.065	2251.411	1144.027
529	13	322.100	162.020	9.831	8581.391	4316.538	1317.204	1147.581
530	13	318.510	176.540	3.356	2896.772	1605.589	1312.367	1155.035
531	13	313.710	174.470	1.532	1302.436	724.351	1305.931	1153.776
532	13	913.870	135.450	0.556	1376.983	204.091	2168.306	1145.145
533	13	225.070	173.530	1.202	733.148	565.260	1197.280	1153.224
534	10	279.040	155.390	1.317	995.913	554.598	1260.708	1145.401
535	13	230.510	167.090	2.198	1373.051	995.285	1203.109	1149.800
536	13	231.510	177.780	0.721	452.350	347.366	1204.198	1155.817

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #5,#6

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #5 m/p x 3Sig(Pu239) x SWM Culvert g	Method #5 m/p x 3Sig(Pu239) x SWM Max Drum g	Method #6 13/√n SWM Culvert g	Method #6 13/√n SWM Max Drum g
537	13	222.630	158.400	0.436	263.051	187.159	1194.719	1146.283
538	13	235.960	166.080	1.269	[illegible].464	571.147	1209.104	1149.323
539	13	228.490	167.570	0.890	551.095	404.162	1200.926	1150.033
540	13	231.650	160.810	1.833	1150.705	798.812	1204.351	1147.119
541	13	260.820	165.420	0.589	416.318	264.042	1238.101	1149.020
543	13	861.775	101.150	0.867	2024.801	237.659	2093.718	1183.307
544	10	811.310	101.910	0.734	1613.809	202.713	2021.194	1181.597
545	10	677.780	126.200	1.106	2031.483	378.254	1828.111	1149.327
546	13	948.097	106.970	0.582	1495.358	168.715	2217.156	1171.525
547	13	231.350	157.900	0.633	396.865	270.866	1204.023	1146.123
548	13	841.400	144.570	0.445	1014.686	174.344	2064.468	1143.922
549	13	1221.550	131.950	0.609	2016.034	217.769	2603.106	1146.340
550	13	88.345	44.697	5.330	1276.082	645.617	1148.485	581.061
551	13	1131.993	123.600	0.580	1779.267	194.274	2477.529	1151.142
552	13	797.840	125.150	1.434	3100.518	486.350	2001.792	1150.023
553	13	976.340	103.120	0.645	1706.594	180.249	2257.372	1178.985
554	13	955.320	113.250	0.669	1731.986	205.321	2227.449	1161.805
555	13	805.730	118.920	0.810	1768.658	261.041	2013.158	1155.235
557	13	722.698	119.570	0.466	912.666	151.000	1893.237	1154.599
558	10	760.166	97.350	1.274	2624.504	336.105	1947.432	1192.721
559	13	554.018	125.390	0.631	947.376	214.418	1648.104	1149.860
560	13	367.785	42.510	0.317	315.953	36.519	1380.127	552.630

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #7,#8

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Recorded Mass Meas/Proj #	Method #7 Refined 13/$\sqrt{n}$ SWM Culvert g	Method #7 Refined 13/$\sqrt{n}$ SWM Max Drum g	Method #8 Cut Model x SWM Culvert g	Method #8 Cut Model x SWM Max Drum g
272	13	299.027	182.810	1.162	1186.353	1045.079	602.942	383.170
321	10	323.805	181.850	2.930	1220.660	1044.191	616.807	382.887
324	13	339.472	176.200	14.940	1242.668	1039.137	689.352	381.127
332	13	288.188	133.940	10.229	1171.590	1014.975	643.308	360.742
352	6	329.263	136.420	1.344	1228.303	1015.463	718.039	362.394
354	6	180.841	70.360	1.680	1043.266	914.680	491.553	281.838
367	6	167.871	99.010	1.671	1032.285	1032.324	459.798	328.082
370	6	216.070	64.800	5.857	1080.000	842.400	566.283	269.886
374	6	93.848	36.880	1.870	1040.830	479.440	290.580	188.907
384	6	195.460	101.420	3.596	1057.490	1029.076	504.380	331.024
385	6	142.240	44.460	0.763	1017.189	577.980	416.732	214.894
390	6	301.462	180.100	1.704	1189.693	1042.593	623.831	382.360
391	6	269.640	179.010	2.703	1146.773	1041.612	537.985	382.024
392	6	351.124	174.380	7.307	1259.159	1037.575	660.011	380.522
393	6	356.008	178.760	1.948	1266.098	1041.389	658.146	381.946
394	6	330.690	164.650	2.061	1230.306	1029.850	652.409	376.944
395	6	358.680	183.100	1.884	1269.900	1045.349	631.601	383.254
396	6	350.357	180.210	1.568	1258.070	1042.693	631.894	382.394
397	6	291.585	72.480	1.237	1176.199	942.240	683.206	286.101
399	6	342.056	50.670	12.195	1246.316	658.710	764.294	233.782
400	6	161.460	63.460	1.948	1027.570	824.980	423.813	266.828
401	6	84.780	47.540	5.248	1062.084	618.020	315.631	224.516
402	6	146.709	43.020	5.404	1019.015	559.260	433.726	210.216
404	6	131.873	131.150	5.118	1014.693	1014.623	360.045	358.797
405	6	144.970	50.990	4.644	1018.257	662.870	427.882	234.701
409	6	182.690	91.590	5.687	1044.968	1045.298	505.077	318.213
412	6	154.470	86.860	10.275	1023.077	1056.381	454.553	311.226
413	6	286.100	134.610	2.073	1168.767	1015.091	612.583	361.196
415	6	233.380	65.510	1.891	1100.534	851.630	594.029	271.477
417	6	184.890	61.320	4.500	1047.031	797.160	509.641	261.797
418	6	340.000	77.820	2.370	1243.413	1011.660	769.893	296.169
420	6	309.360	137.390	5.127	1200.575	1015.695	676.768	363.021
423	6	199.780	45.830	2.774	1061.998	595.790	519.761	219.238
426	6	109.327	50.190	3.319	1021.115	652.470	335.192	232.393
427	13	151.346	44.290	3.520	1021.315	575.770	423.446	214.348
428	13	122.034	58.290	2.166	1015.112	757.770	365.721	254.345
432	13	175.290	37.290	1.006	1038.352	484.770	460.997	190.402
433	13	153.204	39.430	2.263	1022.343	512.590	447.460	198.033
434	13	94.980	32.600	2.453	1038.770	423.800	312.946	172.654
437	13	206.270	122.620	0.932	1068.992	1014.997	475.766	352.233
439	13	239.610	59.840	2.321	1108.206	777.920	588.247	258.206
443	13	352.340	119.450	1.040	1260.885	1015.773	715.361	349.535
444	13	126.380	39.710	1.431	1014.543	516.230	353.672	199.011
453	13	363.432	141.570	0.572	1276.673	1016.952	743.760	365.605
454	13	323.667	120.880	0.638	1220.467	1015.376	715.339	350.771
456	13	344.396	104.080	6.082	1249.625	1025.962	750.438	334.132
458	13	113.037	36.090	2.226	1018.601	469.170	344.841	185.997
461	13	305.770	52.270	1.084	1195.619	679.510	713.229	238.328

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #7,#8

Culvert	Pad	Recorded Mass			Method #7 Refined 13/√n SWM		Method #8 Cut Model x SWM	
		Culvert	Max Drum	Meas/Proj	Culvert	Max Drum	Culvert	Max Drum
#	#	g	g	#	g	g	g	g
470	13	334.901	80.860	2.344	1236.226	1051.180	767.257	301.498
472	13	324.490	94.620	2.126	1221.618	1039.412	734.762	322.397
475	13	105.977	92.740	1.724	1024.022	1042.961	341.922	319.827
479	13	345.430	96.750	1.014	1251.088	1035.774	762.060	325.210
480	13	343.640	70.990	2.730	1248.556	922.870	768.340	283.121
481	13	343.477	74.280	10.341	1248.325	965.640	777.547	289.599
482	13	341.354	71.346	4.010	1245.325	927.498	772.984	283.840
484	13	322.785	154.000	0.811	1219.235	1022.801	672.874	372.271
488	13	329.822	178.900	3.045	1229.087	1041.514	638.536	381.990
489	13	355.619	155.860	0.432	1265.544	1023.911	671.374	373.150
490	13	333.991	178.260	2.664	1234.945	1040.944	661.080	381.789
491	13	349.800	140.180	0.840	1257.280	1016.489	720.960	364.766
492	10	308.824	175.780	3.164	1199.834	1038.773	602.856	380.989
493	13	340.105	187.040	1.803	1243.561	1049.088	670.942	384.359
494	13	238.244	169.690	3.136	1106.513	1033.715	503.134	378.873
498	13	53.400	35.300	0.385	694.200	458.900	224.959	183.047
501	10	346.830	181.540	2.116	1253.070	1043.906	690.512	382.795
502	13	131.580	94.130	1.542	1014.663	1040.306	401.938	321.735
503	10	321.610	151.570	2.967	1217.594	1021.436	659.416	371.078
504	10	328.440	169.960	1.587	1227.149	1033.931	667.293	378.971
505	13	355.340	165.750	3.425	1265.148	1030.667	689.907	377.380
506	10	608.096	149.180	0.718	1631.432	1020.192	1088.174	369.855
507	13	355.056	179.710	38.305	1264.744	1042.241	694.445	382.241
508	13	267.526	70.240	1.066	1143.987	913.120	653.717	281.592
509	13	339.232	62.190	1.072	1242.329	808.470	756.584	263.865
510	13	694.000	134.590	1.071	1755.735	1015.088	1248.087	361.182
513	13	688.950	144.820	2.715	1748.448	1018.194	1238.544	367.489
514	10	333.900	176.300	2.208	1234.817	1039.224	618.104	381.160
515	10	325.730	170.180	6.943	1223.353	1034.107	613.406	379.051
516	10	333.290	174.700	7.067	1233.959	1037.848	617.402	380.630
517	13	335.320	167.710	0.895	1236.815	1032.160	652.610	378.135
518	10	320.040	163.990	5.587	1215.404	1029.367	610.500	376.679
519	13	335.320	172.310	0.582	1236.815	1035.842	662.690	379.811
520	13	219.900	179.270	0.452	1084.433	1041.845	471.976	382.105
521	13	241.970	183.260	4.359	1111.147	1045.498	512.732	383.300
522	10	247.510	181.610	0.887	1118.117	1043.970	525.491	382.816
523	10	685.250	130.660	1.149	1743.108	1014.583	1228.065	358.446
526	13	245.400	175.980	4.003	1115.451	1038.946	529.553	381.055
527	13	267.410	183.290	6.992	1143.834	1045.526	549.223	383.309
528	10	972.150	141.810	1.525	2152.474	1017.036	1602.383	365.748
529	13	322.100	162.020	9.831	1218.278	1027.960	612.314	375.869
530	13	318.510	176.540	3.356	1213.273	1039.432	612.442	381.238
531	13	313.710	174.470	1.532	1206.600	1037.652	647.173	380.552
532	13	913.870	135.450	0.556	2070.099	1015.253	1525.882	361.756
533	13	225.070	173.530	1.202	1090.521	1036.858	494.550	380.233
534	10	279.040	155.390	1.317	1159.273	1023.626	583.311	372.931
535	13	230.510	167.090	2.198	1097.046	1031.683	506.473	377.899
536	13	231.510	177.780	0.721	1098.258	1040.519	500.331	381.637

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Methods #7,#8

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #7 Refined 13/√R SWM Culvert g	Method #7 Refined 13/√R SWM Max Drum g	Method #8 Cut Model x SWM Culvert g	Method #8 Cut Model x SWM Max Drum g
537	13	222.630	158.400	0.436	1087.633	1025.514	511.010	374.307
538	13	235.960	166.080	1.269	1103.695	1030.915	524.943	377.509
539	13	228.490	167.570	0.890	1094.609	1032.052	509.744	378.082
540	13	231.650	160.810	1.833	1098.428	1027.122	523.752	375.358
541	13	260.820	165.420	0.589	1135.211	1030.420	573.800	377.250
543	13	861.775	101.150	0.867	1996.132	1029.419	1485.595	330.701
544	10	811.310	101.910	0.734	1924.172	1028.466	1424.606	331.608
545	10	677.780	126.200	1.106	1732.322	1014.554	1229.215	355.107
546	13	948.097	106.970	0.582	2118.524	1023.093	1597.867	337.350
547	13	231.350	157.900	0.633	1098.063	1025.191	524.706	374.083
548	13	841.400	144.570	0.445	1967.115	1018.091	1428.424	367.348
549	13	1221.550	131.950	0.609	2500.812	1014.702	1911.045	359.365
550	13	88.345	44.697	5.330	1052.632	581.061	324.005	215.653
551	13	1131.993	123.600	0.580	2376.470	1014.831	1811.928	353.037
552	13	797.840	125.150	1.434	1904.914	1014.638	1385.422	354.282
553	13	976.340	103.120	0.645	2158.382	1027.031	1636.326	333.027
554	13	955.320	113.250	0.669	2128.726	1018.478	1595.637	343.811
555	13	805.730	118.920	0.810	1916.197	1015.941	1409.753	349.070
557	13	722.698	119.570	0.466	1797.087	1015.737	1280.645	349.640
558	10	760.166	97.350	1.274	1850.935	1034.818	1354.301	325.983
559	13	554.018	125.390	0.631	1552.857	1014.616	1048.328	354.472
560	13	367.785	42.510	0.317	1282.887	552.630	784.770	208.532

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Method #9

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #9 Conservative Cut Model x SWM Culvert g	Method #9 Conservative Cut Model x SWM Max Drum g
272	13	299.027	182.810	1.162	850.101	574.755
321	10	323.805	181.850	2.930	856.962	574.331
324	13	339.472	176.200	14.940	961.124	571.690
332	13	288.188	133.940	10.229	911.529	541.113
352	6	329.263	136.420	1.344	1000.590	543.591
354	6	180.841	70.360	1.680	698.891	422.757
367	6	167.871	99.010	1.671	664.427	492.124
370	6	216.070	64.800	5.857	802.336	404.828
374	6	93.848	36.880	1.870	414.529	283.361
384	6	195.460	101.420	3.596	718.907	496.537
385	6	142.240	44.460	0.763	592.980	322.341
390	6	301.462	180.100	1.704	881.497	573.541
391	6	269.640	179.010	2.703	762.085	573.036
392	6	351.124	174.380	7.307	933.466	570.783
393	6	356.008	178.760	1.948	931.237	572.919
394	6	330.690	164.650	2.061	925.486	565.416
395	6	358.680	183.100	1.884	901.477	574.881
396	6	350.357	180.210	1.568	900.945	573.591
397	6	291.585	72.480	1.237	954.912	429.152
399	6	342.056	50.670	12.195	1048.213	350.673
400	6	161.460	63.460	1.948	596.991	400.243
401	6	84.780	47.540	5.248	462.760	336.774
402	6	146.709	43.020	5.404	619.647	315.325
404	6	131.873	131.150	5.118	539.403	538.196
405	6	144.970	50.990	4.644	611.903	352.052
409	6	182.690	91.590	5.687	726.591	477.320
412	6	154.470	86.860	10.275	662.540	466.839
413	6	286.100	134.610	2.073	871.491	541.793
415	6	233.380	65.510	1.891	834.806	407.215
417	6	184.890	61.320	4.500	723.729	392.695
418	6	340.000	77.820	2.370	1067.627	444.254
420	6	309.360	137.390	5.127	948.992	544.531
423	6	199.780	45.830	2.774	728.403	328.856
426	6	109.327	50.190	3.319	480.261	348.590
427	13	151.346	44.290	3.520	599.265	321.522
428	13	122.034	58.290	2.166	524.501	381.518
432	13	175.290	37.290	1.006	645.226	285.603
433	13	153.204	39.430	2.263	637.333	297.050
434	13	94.980	32.600	2.453	449.620	258.981
437	13	206.270	122.620	0.932	676.717	528.350
439	13	239.610	59.840	2.321	818.945	387.309
443	13	352.340	119.450	1.040	992.569	524.303
444	13	126.380	39.710	1.431	498.601	298.517
453	13	363.432	141.570	0.572	1029.237	548.407
454	13	323.667	120.880	0.638	995.280	526.156
456	13	344.396	104.080	6.082	1044.188	501.198
458	13	113.037	36.090	2.226	492.174	278.996
461	13	305.770	52.270	1.084	987.535	357.491

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Method #9

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #9 Conservative Cut Model x SWM Culvert g	Method #9 Conservative Cut Model x SWM Max Drum g
470	13	334.901	80.860	2.344	1072.553	452.247
472	13	324.490	94.620	2.126	1021.796	483.596
475	13	105.977	92.740	1.724	506.809	479.741
479	13	345.430	96.730	1.014	1058.784	487.815
480	13	343.640	70.990	2.730	1062.686	424.682
481	13	343.477	74.280	10.341	1077.715	434.399
482	13	341.354	71.346	4.010	1071.971	425.761
484	13	322.785	154.000	0.811	940.018	558.406
488	13	329.822	178.900	3.045	905.932	572.985
489	13	355.619	155.860	0.432	926.722	559.726
490	13	333.991	178.260	2.664	919.352	572.683
491	13	349.800	140.180	0.840	994.719	547.150
492	10	308.824	175.780	3.164	863.262	571.484
493	13	340.105	187.040	1.803	934.984	576.539
494	13	238.244	169.690	3.136	721.977	568.309
498	13	53.400	35.300	0.385	331.217	274.571
501	10	346.830	181.540	2.116	962.520	574.193
502	13	131.580	94.130	1.542	588.908	482.603
503	10	321.610	151.570	2.967	935.922	556.617
504	10	328.440	169.960	1.587	945.148	568.457
505	13	355.340	165.750	3.425	957.317	566.070
506	10	608.096	149.180	0.718	1472.119	554.782
507	13	355.056	179.710	38.305	969.829	573.361
508	13	267.526	70.240	1.066	919.381	422.388
509	13	339.232	62.190	1.072	1044.107	395.797
510	13	694.000	134.590	1.071	1670.261	541.773
513	13	688.950	144.820	2.715	1656.612	551.233
514	10	333.900	176.300	2.208	884.942	571.739
515	10	325.730	170.180	6.943	879.274	568.577
516	10	333.290	174.700	7.067	884.306	570.945
517	13	335.320	167.710	0.895	904.371	567.203
518	10	320.040	163.990	5.587	875.599	565.019
519	13	335.320	172.310	0.582	939.068	569.716
520	13	219.900	179.270	0.452	686.850	573.157
521	13	241.970	183.260	4.359	741.616	574.951
522	10	247.510	181.610	0.887	759.082	574.224
523	10	685.250	130.660	1.149	1645.121	537.669
526	13	245.400	175.980	4.003	764.783	571.582
527	13	267.410	183.290	6.992	781.891	574.964
528	10	972.150	141.810	1.525	2112.883	548.622
529	13	322.100	162.020	9.831	877.720	563.804
530	13	318.510	176.540	3.356	851.943	571.857
531	13	313.710	174.470	1.532	917.813	570.829
532	13	913.870	135.450	0.556	2013.777	542.635
533	13	225.070	173.530	1.202	717.149	570.350
534	10	279.040	155.390	1.317	839.958	559.396
535	13	230.510	167.090	2.198	729.162	566.848
536	13	231.510	177.780	0.721	725.092	572.455

TABLE C-2. Pu-239 Estimates Ordered by Culvert/ Method #9

Culvert #	Pad #	Recorded Mass Culvert g	Recorded Mass Max Drum g	Meas/Proj #	Method #9 Conservative Cut Model x SWM Culvert g	Method #9 Conservative Cut Model x SWM Max Drum g
537	13	222.630	158.400	0.436	740.609	561.460
538	13	235.960	166.080	1.269	759.327	566.263
539	13	228.490	167.570	0.890	738.422	567.123
540	13	231.650	160.810	1.833	757.992	563.037
541	13	260.820	165.420	0.589	819.189	565.875
543	13	861.775	101.150	0.867	1967.029	496.051
544	10	811.310	101.910	0.734	1889.883	497.412
545	10	677.780	126.200	1.106	1649.039	532.660
546	13	948.097	106.970	0.582	2105.327	506.025
547	13	231.350	157.900	0.633	753.206	561.125
548	13	841.400	144.570	0.445	1891.461	551.021
549	13	1221.550	131.950	0.609	2487.807	539.047
550	13	88.345	44.697	5.330	473.781	323.480
551	13	1131.993	123.600	0.580	2367.773	529.556
552	13	797.840	125.150	1.434	1840.592	531.423
553	13	976.340	103.120	0.645	2153.907	499.541
554	13	955.320	113.250	0.669	2102.160	515.716
555	13	805.730	118.920	0.810	1873.650	523.604
557	13	722.698	119.570	0.466	1705.279	524.460
558	10	760.166	97.350	1.274	1800.505	488.975
559	13	554.018	125.390	0.631	1414.037	531.708
560	13	367.785	42.510	0.317	1066.422	312.797

DATE FILMED

10 / 6 / 93

END