Westinghouse

Hematite Decommissioning Project

Technical Basis Document

NUMBER: **HDP-TBD-NC-205**

TITLE: **Assessment of the Adequacy of Lateral Subsurface Soil Sampling in the Burial Pit Area**

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REVISION LOG	
Revision No. Effect. Date	**Change(s)**
0 See Cover Page	This is the initial issuance of this TBD.

1.0 PURPOSE

The purpose of the Technical Basis Document (TBD) is to provide a statistical analysis for the lateral subsurface sampling criteria that accompanied full remediation of the Hematite Decommissioning Project (HDP) Burial Pits. The statistical analysis provides confidence levels associated with the positive lateral identification of all buried debris present at HDP using the subsurface sampling techniques employed over the prior burial pit remediation operations.

2.0 APPLICABILITY

This analysis applies to the lateral dimensions of core sampling and does not incorporate the adequacy of the depth of core sampling.

3.0 ACRONYMS

‘	foot/feet
AEC	Atomic Energy Commission
CFR	Code of Federal Regulations
CSC	Criticality Safety Control
FSS	Final Status Survey
HDP	Hematite Decommissioning Project
NCS	Nuclear Criticality Safety

4.0 BACKGROUND

From the late 1950s to approximately 1970, waste material from operations, including waste contaminated with uranium, was disposed of in unlined pits (Burial Pits) expected to be approximately 20 feet wide by 40 feet long by 12 feet deep that were covered with fill materials.

The technical basis for the selection of the 20 by 40 foot dimension is captured in NSA-TR-09-15 (Ref. 8.1), Section 1.2.1.1, which states "*Based on best available information, it is believed that the burial pits are nominally 20' × 40' and 12' deep. Consignment of waste to the burial pits was reported to be in compliance with AEC regulation 10 CFR 20.304 (1964; Ref. 7). Facility operating procedures (Ref. 8) described the size and spacing requirement for the burial pits, in addition to the required thickness of the overlying soil cover (4'), and the quantity of radioactive material that could be buried in each pit.*"

A maximum distance of 20 feet between core samples was established to ensure that there was appropriate area coverage for isolating an unidentified burial pit. According to D.F. Parkhurst, in an article published in *Environmental Science and Technology* titled "Optimal sampling geometry for hazardous waste sites", (Reference 8.2), the triangular grid is more likely to provide better information than a square grid. The triangular grid effectively reduces the spacing to approximately 17 feet, thus providing additional assurance that a core boring would intercept a burial pit if it existed. In addition, suspect areas of concern received additional confirmatory core samples in closer proximity.

Validation of the complete remediation of the burial pits from buried debris is accomplished via two methods:

- Radiological and soil sample measurements in combination with visual inspection indicate no further presence of buried debris or NCS-related material; and,
- Subsurface core samples indicate no further presence of buried debris or NCS-related material.

Validation provides additional assurance, and is a step in the remediation process that is implemented after it has been determined that the debris/waste in the excavation has been removed and that the subsurface soil is ready to start evaluation for Final Status Survey (FSS). The second step in the validation process includes core samples of the soil. Core boring is an effective method to provide a sample that allows for visual inspection, and radiological and chemical assessment.

NCS requirements govern the depths of the core samples, but not the lateral dimensions. Administrative Criticality Safety Control (CSC) 23 from Reference 8.1 requires core sample depths as follows:

- *Three feet below the deepest identified buried waste item do not identify any further buried waste materials or contaminated soil or*
- *Seven feet below the ground surface (representative of 4 feet of overburden and an additional 3 feet into soil that could have potential burial pit waste) do not identify buried waste materials or contaminated soil.*

5.0 METHODS

By varying unknown input parameters, the probabilities of isolating a "hot spot," or burial pit, can be calculated for each possible scenario. Utilizing a triangular grid, the following input parameters are varied in this analysis:

- Length of the burial pit (L);
- Sample grid spacing (G);
- Acceptable probability of not finding a burial pit (β).

A parameter that was not varied for this analysis is the shape factor, S. This value is fixed at 0.5, which is a ratio of the major and minor axis of an ellipse. The expected size of the burial pits (20' x 40') as discussed in Section 4.0 indicates this shape ratio. In addition, the shape ratio does not alter the end result significantly. See Appendix B for diagrams and notes relating to this selection.

6.0 BURIAL PIT SAMPLING SCENARIOS

The following analyses are based on methodologies presented by Richard O. Gilbert in his book, *Statistical Methods for Environmental Pollution Monitoring*, 1987 (Ref. 8.3).

6.1. Scenario 1

Assume G = 20', and $\beta = 0.05$

From Figure 10.5 (Ref. 8.3), L = 16.8'

» Therefore, there is a 5% chance of missing a burial pit greater than 33.6' long (16.8' wide) with a triangular grid of core samples spaced 20' apart.

6.2. Scenario 2

Assume G = 20', and $\beta = 0.01$

From Figure 10.5 (Ref. 8.3), L = 18'

» Therefore, there is a 1% chance of missing a burial pit greater than 36' long (18' wide) with a triangular grid of core samples spaced 20' apart.

6.3. Scenario 3

Prior to any excavation, assume that the burial pits are 30' long (L = 15') and the probability of a burial pit existing is 100% (P = 1).

Let:

A ≡ event that a burial pit of size L or larger exists;

B ≡ event that a burial pit of size L or larger is hit by a core sample

$P(B|A) = \frac{P(A,B)}{P(A)}$ ≡*probability that a burial pit of size L or larger is hit, given that it exists*

$P(A, B)$ ≡*probability that a burial pit of size L or larger exists and is discovered with core samples*

$P(A)$ ≡*probability that a burial pit of size L or larger exists*

Since it is known that the burial pits exist, $P(A) = 1$.

Whether a burial pit of size L exists: $P(A, B) = P(B|A)\,P(A)$, and $P(B|A) = 1 - \beta$

Assume G = 20', L = 15'

From Fig. 10.5 (Ref. 8.3), $\beta = 0.13$

$$P(B|A) = 1 - 0.13 = 0.87 = \beta$$

» Therefore, there is 87% probability that core samples located 20’ apart on a triangular grid would hit a 30’ long burial pit, which is smaller than the 40’ assumption discussed in Section 4.0.

6.4. **Scenario 4**

Following excavation, assume there exists an undetected burial pit 30’ in length (*L* = 15’).

What is the probability that a burial pit 30’ long exists, despite not being found?

$A \equiv$ *event that a burial pit of size L or larger exists;*

$\bar{A} \equiv$ *event that a burial pit of size L or larger does not exist;*

$B \equiv$ *event that a burial pit of size L or larger is hit;*

$\bar{B} \equiv$ *event that a burial pit of size L or larger is not hit*

$P(A, \bar{B}) \equiv$ *probability that a burial pit of size L or larger exists given that the core sample effort did not find it*

$$P(A|\bar{B}) = \frac{P(A,\bar{B})}{P(\bar{B})} \xrightarrow{yields} \text{Bayes Formula}$$

$$P(A|\bar{B}) = \frac{P(\bar{B}|A)P(A)}{P(\bar{B}|A)P(A) + P(\bar{B}|\bar{A})P(\bar{A})}$$

$$\text{since } P(\bar{B}|\bar{A}) = 1 \text{ and } P(\bar{A}) = 1 - P(A)$$

$$P(A|\bar{B}) = \frac{\beta\, P(A)}{\beta\, P(A) + 1 - P(A)}$$

6.4.1 **Scenario 4A**

Assume β = 0.05, *G* = 20’, and *P(A)* = 0.05 –probability that such a pit exists

From Fig. 10.5 (Ref. 8.3), *L* = 16.6’

If no burial pit 33.2’ long is found with core samples taken on a 20’ triangular grid, the probability that such exists:

$$P(A|\bar{B}) = \frac{0.05 \times 0.05}{0.05 \times 0.05 + 1 - 0.05} = 0.26\%$$

Alternatively, Fig. 10.7 (Ref. 8.3) indicates $P(A|\bar{B}) \cong 0.26\%$

6.4.2 **Scenario 4B**

Assume *P(A)* = 0.1, β = 0.05

$$P(A|\bar{B}) = \frac{0.05 \times 0.1}{0.05 \times 0.1 + 1 - 0.1} = 0.55\%$$

» This scenario assumes a higher probability that a burial pit exists (10%) compared to Section 6.4.1 which used 5%.

6.4.3 **Scenario 4C**

Assume β = 0.01, *G* = 20’

From Fig. 10.5 (Ref. 8.3), *L* = 18’

$$P(A|\bar{B}) = \frac{0.01 \times 0.05}{0.01 \times 0.05 + 1 - 0.05} = 0.053\%$$

» If no burial pit 36’ long is discovered by performing 20’ spaced core samples on a triangular grid, the probability that such exists is 0.053%.

6.4.4 **Scenario 4D**

Assume 20’ long burial pits (*L* = 10’), β = 0.05, *P(A)* = 0.05

From Fig. 10.5 (Ref. 8.3), *G* = 12’

From Fig. 10.7 (Ref. 8.3), $P(A|\bar{B}) \cong 0.3\%$

» If burial pits were 20’ long and core samples were taken at 12’ spacing on a triangular grid, the probability that a burial pit 20’ long or greater exists at the site is approximately 0.3%.

6.4.5 **Scenario 4E**

Assume 20’ long burial pits (*L* = 10’), *G* = 20’

From Fig. 10.5 (Ref. 8.3), β = 0.54

$$P(A|\bar{B}) = \frac{0.54 \times 0.05}{0.54 \times 0.05 + 1 - 0.05} = 2.76\%$$

» If burial pits were 20’ long and core samples were taken at 20’ spacing on a triangular grid, the probability that a 20’ long or greater burial pit exists at the site and wasn’t found is 2.76%.

7.0 CONCLUSION

Based on the analysis provided in this document, it is demonstrated that the likelihood of an existence of a burial pit in the area that has been sampled on a triangular grid is very low. Using a triangular grid with a spacing of 20' and hypothetical elliptical burial pit sizes smaller than those expected, the probability that additional buried debris areas exist today is below 5% in all iterations.

8.0 REFERENCES

8.1. NSA-TR-09-15, Revision 5, "Nuclear Criticality Safety Assessment of Buried Waste Exhumation and Contaminated Soil Remediation", 2013.

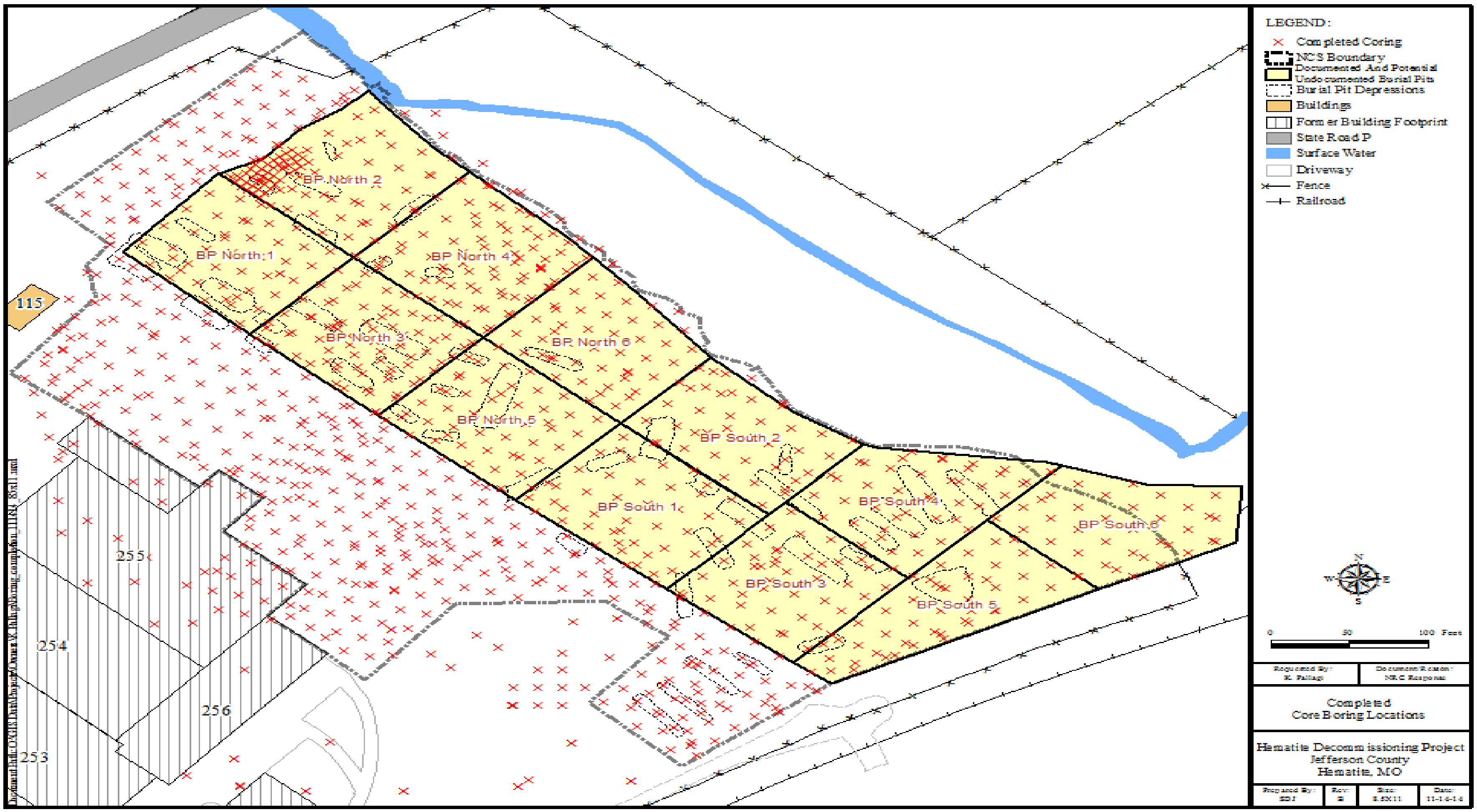
8.2. Parkhurst, D.F. Optimal sampling geometry for hazardous waste sites, *Environmental Science and Technology* 18:521-523.

8.3. Gilbert, Richard O. *Statistical Methods for Environmental Pollution Monitoring*. New York: Van Nostrand Reinhold Company, 1987.

9.0 ATTACHMENTS

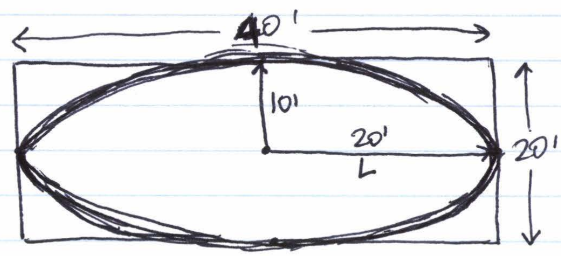
Appendix A: Figure 1, Core Bore Locations
Appendix B: Hand Calculations by Megan Pritchard
Appendix C: Figures 10.5 and 10.7 from Reference 8.3

Figure - 1
Core Bore Locations – Documented and Undocumented Burial Area



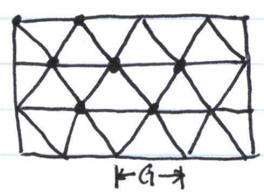
Hand Calculations by Megan Pritchard

Burial pit size assumption is taken from DP Chapter 2 (2.5.1) which was derived from AEC requirements 10CFR20.304 - 20 ft by 40 ft by 12 ft deep.



Assumptions:

- triangular grid spacing for borehole locations
- "hot spot" is a burial pit (item to be detected)



G=20'

L => Length of half the major axis of "hot spot" or burial pit

G => grid spacing

β => acceptable probability of not finding the "hot spot" or burial pit

S => 0 < S ≤ 1; shape of elliptical target

$$S = \frac{\text{length of short axis of ellipse}}{\text{length of long axis of ellipse}}$$

S=1 for circle; for our burial pit S=0.5

Some scenarios:

(1) using $S=0.5$, $G=20'$, $\beta=0.05$

Figure 10.5 $\Rightarrow \frac{L}{G} \approx 0.84$ $L=16.8'$

$\Rightarrow$ there is a 5% chance of missing a burial pit greater than 33.6 ft long (16.8 ft wide) with triangular grid boreholes spaced 20 ft apart.

(2) using $S=0.5$, $G=20'$, $\beta=0.01$

Figure 10.5 $\Rightarrow \frac{L}{G}=0.9$ $L=18'$

$\Rightarrow$ there is a 1% chance of missing a burial pit greater than 36 ft long (18 ft wide) with triangular grid boreholes spaced 20 ft apart.

(3) Prior to any excavation —
Assume burial pits are 30' long ($L=15'$) and the probability of a burial pit existing is 100% ($P=1$)

A ≡ event that a burial pit of size L or larger exists
B ≡ event that a burial pit of size L or larger is hit by taking grid boreholes

$P(B|A) = \frac{P(A,B)}{P(A)}$ = probability that a burial pit of size L or larger is hit, given that it exists

$P(A,B)$ ≡ probability that a burial pit of size L or larger exists and is discovered with boreholes

$P(A) \equiv$ probability that a burial pit of size L or larger exists

Since we know there are burial pits, $P(A) = 1$

whether a burial pit of size L exists:

$$P(A,B) = P(B|A)P(A)$$

$$P(B|A) = 1 - \beta$$

using $G = 20'$, $L = 15'$ use Fig 10.5 $\frac{L}{G} = 0.75$, $\beta = 0.13$

$$P(B|A) = 1 - 0.13 = 0.87 = P(A,B)$$

There is 87% probability that boreholes located 20' apart on a triangular grid would have hit a 30' long burial pit (smaller than 40' regulation).

(4) After excavation —

Assume undetected burial pit is 30' long ($L = 15'$)

What is the probability that a burial pit 30' long exists, even though it was not found?

$A \equiv$ event a burial pit of size L or larger exists
$\bar{A} \equiv$ event a burial pit of size L or larger does not exist
$B \equiv$ event a burial pit of size L or larger is hit
$\bar{B} \equiv$ event a burial pit of size L or larger is not hit

$P(A|\bar{B}) \equiv$ probability that a "hot spot" (burial pit) of size L or larger exists given that the borehole effort did not find it

$$P(A|\bar{B}) = \frac{P(A,\bar{B})}{P(\bar{B})} \Rightarrow \text{Bayes Formula}$$

$$P(A|\bar{B}) = \frac{P(\bar{B}|A)P(A)}{P(\bar{B}|A)P(A) + P(\bar{B}|\bar{A})P(\bar{A})}$$

since $P(\bar{B}|\bar{A}) = 1$ and $P(\bar{A}) = 1 - P(A)$

$$P(A|\bar{B}) = \frac{\beta P(A)}{\beta P(A) + 1 - P(A)}$$

(4a) assume $\beta = 0.05$, $S = 0.5$, $G = 20'$
from Fig 10.5 $L = 16.6'$

assume $P(A) = 0.05$ (probability that such a pit exists)

If no burial pit 33.2' long is found by taking boreholes on a 20' triangular grid, the probability that such exists is:

$$P(A|\bar{B}) = \frac{0.05(0.05)}{0.05(0.05) + 1 - 0.05} = 0.26\%$$

or use Fig. 10.7 when $\beta = 0.05$, $P(A|\bar{B}) \approx 0.26\%$

(4b) assume $P(A) = 0.1$, $\beta = 0.05$, $S = 0.5$

$$P(A|\overline{B}) = \frac{0.05(0.1)}{0.05(0.1)+1-0.1} = 0.55\%$$

This assumes a higher probability that a pit exists (10%), compared to 4a which used 5%.

(4c) assume $S = 0.5$, $\beta = 0.01$, $G = 20'$
from Fig 10.5 $L = 18'$

$$P(A|\overline{B}) = \frac{0.01(0.05)}{0.01(0.05)+1-0.05} = 0.053\%$$

If no burial pit 36' long is found by taking 20' spaced boreholes on a triangular grid, the probability that such exists is 0.053%.

(4d) assume 20' long burial pits ($L = 10'$)
$\beta = 0.05$, $S = 0.5$, $P(A) = 0.05$
from Fig 10.5 $\frac{L}{G} = 0.83$, $G = 12'$

from Fig 10.7 $P(A|\overline{B}) \approx 0.003 = 0.3\%$

If burial pits were 20' long and boreholes were taken at 12' spacing on a triangular grid, the probability that a pit 20' long or greater exists at the site is 0.3%.

(4e) assume 20' long burial pits (L=10')
G=20', S=0.5
using Fig. 10.5 $\frac{L}{G}=0.5$, $\beta=0.54$

$$P(A|\bar{B}) = \frac{0.54(0.05)}{0.54(0.05)+1-0.05} = 2.76\%$$

If burial pits were 20' long and the boreholes were taken at 20' spacing on a triangular grid, the probability that a 20' long or greater pit exists at the site and wasn't found is 2.76%.

Figure 10.5

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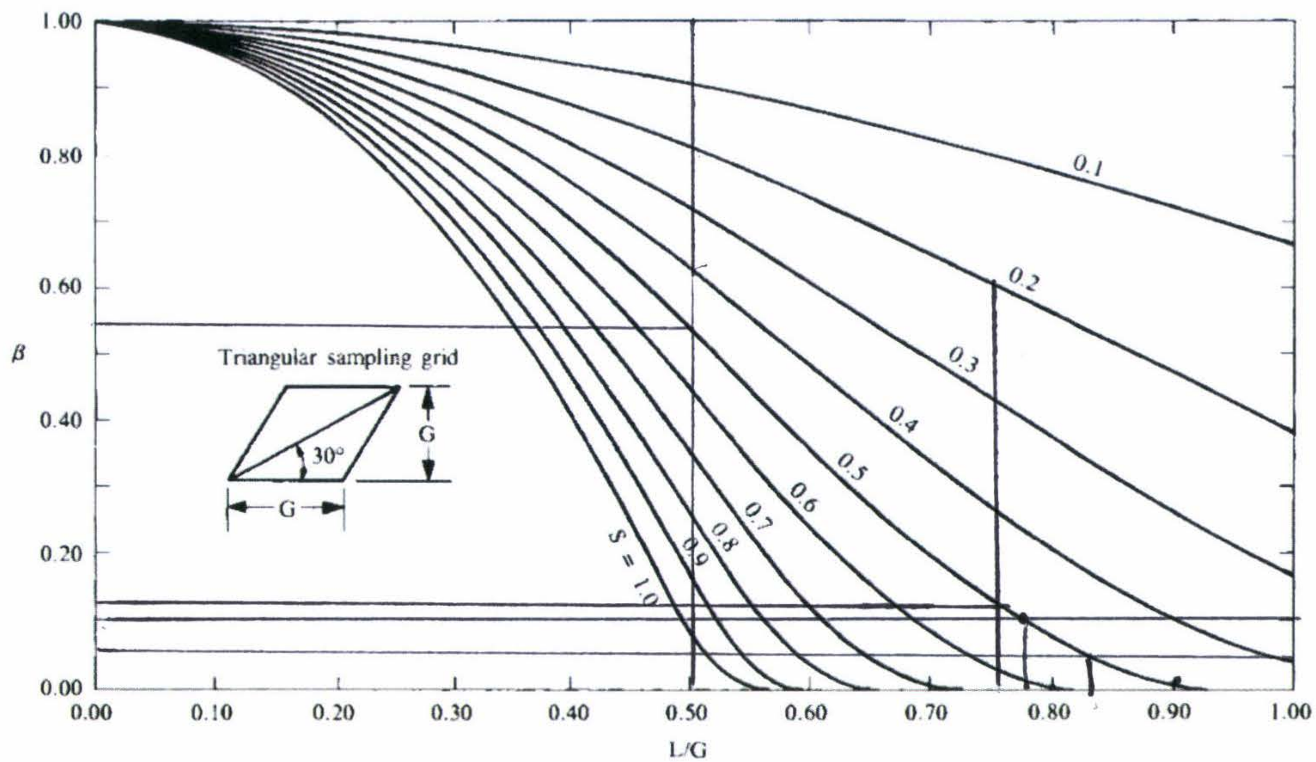

Figure 10.5 Curves relating L/G to consumer's risk, β, for different target shapes when sampling is on a triangular grid pattern (after Zirschky and Gilbert, 1984, Fig. 4).

Figure 10.7

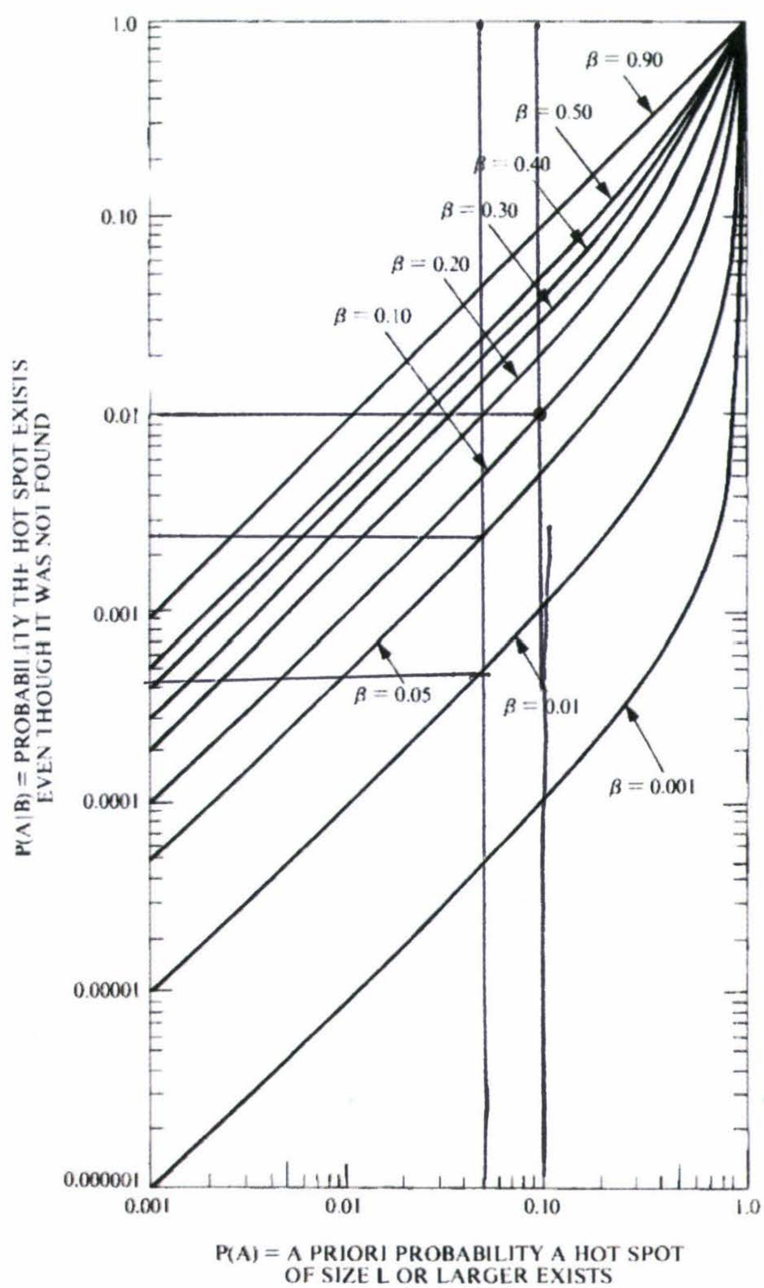

Figure 10.7 Relationship between $P(A|\overline{B})$, $P(A)$ and the consumer's risk β (after Gilbert, 1982, Fig. 5).