CORRES CONTROL
INCOMING LTR NO

01375 RF 94

DUE
DATE

ACTION

DIST.	LTR	ENC
BERMAN, H S		
CARNIVAL, G J		
COPP R D		
CORDOVA, R.C.		
DAVIS J G		
FERRERA D W		
FRANZ W A		
HANNI, B J		
HEALY T J		
HEDAHL T G		
HILBIG J G		
HUTCHINS N M		
KELL R E		
KIRBY W A		
KUESTER A W		
MAHAFFEY J W		
MANN H P		
MARX G E		
McKENNA F G		
MORGAN R V		
PIZZUTO V M		
POTTER G L		
SANDLIN N B		
SATTERWHITE D G		
SCHUBERT A L		
SETLOCK G H		
STIGER S G	X	
SULLIVAN M T		
SWANSON, E R		
WILKINSON R B		
WILSON J M		

CORRES CONTROL	x	x
ADMN RECORD/080		
PATS/ T130G		

Reviewed for Addressee
Corres Control RFP

4/7/94 CM
DATE BY

Ref Ltr #

DOE ORDER # 5400.1

RF 46522 (Rev 01/94)

041194-3

Department of Energy

ROCKY FLATS OFFICE
P.O BOX 928
GOLDEN COLORADO 80402-0928

000024254

APR 05 1994

94-DOE-03468

APR 1994

Mr LeRoy Carlson
U S Fish & Wildlife Service
Colorado State Office
Golden Field Office
730 Simms Street
Golden, Colorado 80401

Dear Mr Carlson

Please find enclosed one (1) copy of the final document entitled "Guide for Conducting Statistical Comparisons of RCRA Facility Investigation/Remedial Investigation (RFI/RI) Data and Background Data At the Rocky Flats Plant" This document was prepared in response to (1) the U S Environmental Protection Agency, Region VIII, (EPA) letter to the U S Department of Energy, Rocky Flats Office (DOE/RFO) dated May 20, 1993, and the August 12, 1993 EPA/Colorado Department of Health Stop Work letter to DOE/RFO

The enclosed statistical methodology will be used for comparing RFI/RI data and background data for Operable Units (OUs) 3 and up at the Rocky Flats Plant As stated in the EPA's May 20, 1993 letter, both OUs 1 and 2 are exempt from this methodology

Any questions or concerns regarding this letter and enclosure should be addressed to Bruce Thatcher of my staff at 966-3532

Stiger

Sincerely,

Jessie Roberson
Acting Assistant Manager for
Environmental Restoration

Enclosure

ADMIN RECORD
A-SW-002597

cc w/o Enclosure
A Rampertaap, EM-453
F Lockhart, ER, RFO
B Thatcher, ER, RFO
R Birk, ER, RFO
J Pepe, ER, RFO
S Slaten, ER, RFO
S Olinger, ER, RFO
G Hill, ER, RFO
S Stiger, EG&G
R Stewart, DOI
R Cattany, CDNR
B McIntyre, CDWR
G Van Slyke, CDWR
D Parker, CSCB
J Brush, CDH
E Kay, CDH

Identical letters sent to the following, dated APR 5 1994

Dave Weber
Colorado Division of Wildlife
6060 Broadway
Denver, CO 80206

Pat Rogers
Colorado Geological Survey
1313 Sherman, Room 715
Denver, CO 80203

Steve Arnold
Colorado Department of Health
4300 Cherry Creek Drive South
Denver, CO 80222-1530

Jeb Love
Colorado Department of Health
4300 Cherry Creek Drive South
Denver, CO 80222-1530

ORRPS CONTROL
INCOMING LTR NO
1271 RF 94

DUE
DATE

ACTION

DIST.	LTR	ENC
RMAN H S		
RNIVAL G J		
OPP R D		
ORDOVA R C		
AVIS J G		
RRERA D W		
ANZ W A		
NNI B J		
ALY, T J		
DAHL T G		
LBIG J G		
UTCHINS N M		
LL R E		
RBY W A		
ESTER A W		
HAFFEY J N		
NN H P		
RX G E		
KENNA F G		
ORGAN R V		
ZUTO V M		
TTER G L		
NDLIN N B		
TTERWHITE D G		
HUBERT A L		
TLOCK G H		
GER S G	X	X
LLIVAN M T		
ANSON E R		
KINSON R B		
SON J M		
Hopkins J	X	
Roberts R	X	

RRES CONTROL	x	x
MN RECORD/080	X	3
ATS/T130G		

Reviewed for Addressee
Corres Control RFP

4/94 CM
DATE BY

ef Ltr #

E ORDER # 54841

6522 (Rev 01 94)

1A700

Department of Energy

ROCKY FLATS OFFICE
P O BOX 928
GOLDEN COLORADO 80402 0928

MAR 3 0 1994

94-DOE-03457

Mr Martin Hestmark
U S Environmental Protection Agency, Region VIII
ATTN Rocky Flats Project Manager, 8HWM-RI
999 18th Street, Suite 500, 8WM-C
Denver, Colorado 80202-2405

0113023642

Mr Gary Baughman
Hazardous Waste Facilities Unit Leader
Colorado Department of Health
4300 Cherry Creek Drive South
Denver, Colorado 80222-1530

Gentlemen

Please find enclosed two (2) copies of the final document entitled "Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data At the Rocky Flats Plant" This document was prepared in response to (1) the U S Environmental Protection Agency, Region VIII, (EPA) letter to the U S Department of Energy, Rocky Flats Office (DOE/RFO) dated May 20, 1993, and the August 12, 1993 EPA/Colorado Department of Health (CDH) Stop Work letter to DOE/RFO In addition please find enclosed responses to EPA comments dated September 21 and October 25, 1993 and CDH comments dated September 13 and October 13, 1993 These comments, along with the discussion from the September 29, 1993 meeting between EPA, CDH and DOE/RFO are reflected in the final methodology

The enclosed statistical methodology will be used for comparing Resource Conservation and Recovery Act Facility Investigation/Remedial Investigation (RFI/RI) data and background data for Operable Units (OUs) 3 and up at the Rocky Flats Plant As stated in the EPA May 20, 1993 letter, both OUs 1 and 2 are exempt from this methodology

Any questions or concerns regarding this letter and enclosure should be addressed to Bruce Thatcher of my staff at 966-3532

Sincerely,

Jessie Roberson
Acting Assistant Manager for
Environmental Restoration

Enclosure

APR 1994
RECEIVED
RECORDS CENTER

cc w/Enclosure
A Rampertaap, EM-453
F Lockhart, ER, RFO
R Birk, ER, RFO
J Pepe, ER, RFO
S Slaten, ER, RFO
S Olinger, AMESH, RFO
G Hill, ESH, RFO
S Stiger, EG&G
R Gilbert, PNL
B Ramsey, SMS

cc w/o Enclosure
M Silverman, OOM, RFO
L Smith, OOM, RFO
B Thatcher, ER, RFO
J Hopkins, EG&G
R Roberts, EG&G

Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data At the Rocky Flats Plant

General

This document is intended to provide guidelines for OU-to-background comparisons of data, and to explicitly discuss approaches to the issue of determining OU-specific contamination. The OU-to-background comparison will be applied for inorganics and radionuclides In addition, the comparison may occasionally be performed for organics on a limited, case-by-case basis, subject to EPA and CDH approval

It is important to establish a common approach leading to a common list of possible contaminants for each OU To this end, Figure 1, **GENERAL APPROACH TO DETERMINING "CONTAMINANTS"** was developed. In this general technique, a "Tool-Box" approach is employed to arrive at one common list of contaminants for each OU (or subdivision), for all functional aspects of the RFI/RI and CMS/FS.

As indicated, several disciplines such as the Human Health or Ecological Risk Assessors and Regulatory specialists may pare the list of contaminants to "Contaminants of Concern" (COCs) based on factors germane to their application (e g , toxicity)

The text below follows Figure 2, **FLOWCHART FOR COMPARING OU DATA TO BACKGROUND.**

Start

Determine Background and OU Target Populations

Appropriate geographical, geological, and temporal data sets will be defined for comparison This is essentially a matching exercise so that Site (OU) data sets are comparable to background sets Consideration will be given to issues such as

Geologic materials
Hydrostratigraphic unit
Temporal comparability
Sample size for statistical tests
Confidence in geo/hydrologic regime determination

The background data sets will be taken from the 1993 Background Geochemistry Characterization Report (EG&G, September, 1993), except for surficial soils Rock Creek surficial soil samples were used as background for OUs 1 and 2, and will be used until the FY94 surficial soil sampling data is available Surficial soils are scheduled to be sampled in FY94 to supplement the Rock Creek data and the FY94 samples will be used subsequently as background surficial soil data The following media have defined backgrounds groundwater (Rocky Flats Alluvium, valley fill alluvium, colluvium, weathered sandstone, and unweathered Arapahoe/Laramie formation rocks), surface water (Rock Creek and Woman Creek), seeps, stream sediments (Rock Creek and Woman Creek), seep sediments, and soils (Rocky Flats Alluvium, colluvium, surficial, weathered claystone, and weathered Arapahoe, Laramie sandstone) Site media will be cross-referenced to one or more background media

Set DQOs

DQOs are established to define data needs for each of the RFI/RI tasks, coordinate that collection activities support those needs, and ensure the quality and quantity of resultant data Three stages are used in the development of DQOs

Identify Decision Types:

Identify and involve data users,
Evaluate available data,
Develop a conceptual model of the study site, and
Specify RFI/RI objectives, and anticipate the decisions necessary to achieve the objectives

Identify Data Uses and Needs:

Identify data uses,
Identify data types,
Identify data-quality needs,
Identify data-quantity needs,
Evaluate sampling and analysis options, and
Review data precision, accuracy, representativeness, completeness, and comparability (PARCC)

Design Data Collection Program:

Assemble data-collection components, and
Develop data-collection documentation

Data Collection and Validation

Under current IAG schedule conditions, analytical data may not be 100% "validated" when the background comparisons are made in each draft report However, non-validated data will be used only for draft RFI/RIs Final RFI/RI reports will use only data that have undergone

validation. Data that have been rejected will not be used. The potential impacts of using non-validated data will be discussed on a case-by-case basis in the final reports

Data Presentation

A "preliminary" exploratory data appraisal will be performed to obtain a "feel" for the data This will involve techniques and identification of issues such as

Gross summary statistics
Spatial arrays
Temporal plots
Sampling strategy comparability evaluation
Affected media matrix
Hit ratios
Non-detect rates
Detection limit/quantitation limit issues
Extent of data qualifications "J", "B", etc.
Histograms/boxplots/other visuals
DQO adequacy/completeness assessment

This step will help guide the need for, and evaluate the appropriateness and applicability of further analysis, evaluate assumptions, and ascertain the impacts and limitations in light of the actual data as collected Information generated during the exploratory data appraisal will be used in evaluating the appropriateness of the scope of the formal RFI/RI proposal Results will be informationally discussed in a meeting with EPA, CDH, and DOE/RFO

Several data-presentation techniques were identified by Dr. Gilbert as appropriate for different conditions. To perform them all for all compounds in a standard full suite is not necessary when it is clear from a preliminary review that the vast majority of data points for some compounds are entirely or almost entirely on-detects

Accordingly, we have refined the methodology as follows·

Box plots will be used when the percentage of non-detects is 50% or less

Histograms will also be used when the percentage of non-detects is 50% or less Bars in the histogram will be shaded to indicate the percentage of detects and non-detects within each bar interval

Probability plots, ordered listings, and other graphics will be used as appropriate

As indicated by the OU1 process, visual presentation of the data is important Interpretable graphics will be produced to the extent that they facilitate analysis In general, graphics will be a central feature of analysis

BACKGROUND COMPARISON METHODOLOGY TOOL BOX APPROACH

Employ ng Bounding-Benchmark Comparison (Hot Measurement), Inferential Statistics, and Profess nal Judgement

General

The tool-box approach employs a bounding-benchmark comparison, inferential statistics, and professional judgement This approach was forwarded in the OU1 comment-resolution process, endorsed by Dr Gilbert, and is widely applied in the hazardous waste industry and environmental business across America It employs a "weight-of-evidence" framework wherein all three aspects are factored into the determination of what is a Site (OU) contaminant Statisticians will be used to verify that the methods used are correct

Bounding-Benchmark Comparison ("Hot-Measurement Test" Component)

- o A hot-measurement test will be performed that will compare each analyte concentration to an upper-limit value for that analyte

- o The upper-limit value will be the value at which there is a 99% probability that 99% of the background distribution will be below this value ($UTL_{99/99}$). If the $UTL_{99/99}$ cannot be calculated or reasonably estimated, then background values from technical literature and professional judgement will be used The resulting geochemical interpretation of data will be subject to Agency review and approval

- o The $UTL_{99/99}$ is required instead of a toxicity-based value because a single list of potential contaminants must be used by many disciplines (Human Health, Ecological, Regulatory, etc ,) to ensure consistency across the RFI/RI and CMS/FS Reports The subjective nature of what is "hot", as well as toxicity and ARAR considerations, will be dealt with by the specialists who determine COC's specific to their discipline

- o In addition to ensuring that high concentrations do not get overlooked, the $UTL_{99/99}$ is an important tool for identifying locations of suspected elevated concentration in the "nature and extent" section

Background Comparison Using Inferential Statistical Methods

Based on Dr Gilbert's work, the following inferential statistical tests will be used to compare background data sets to data sets compiled at the Operable Units (OUs) These data sets will be compiled and compared by analyte, and by the correct background data set (i e , colluvium, alluvium, alluvium + colluvium, surface soils, etc [See Determine Background and OU Target Populations]).

It should be noted that Dr Gilbert's recommendations establish a framework that emphasizes using the most appropriate test available Thus professional judgement will be necessary both in application of inferential tests, as well as their interpretation Additionally, within the framework of a battery of tests drawn from a "tool box" of methods, it is requested that EPA and CDH remain open to consultation on the use of other tests as appropriate

The results of all tests (hot-measurement, inferential) will then be evaluated in light of professional judgement This process is depicted on Figure 3, **BACKGROUND COMPARISONS METHODOLOGY**

If hot-measurement or inferential statistical tests show that the concentration of a given analyte in the OU data set is not greater than the concentration in the background data set, and if considerations in the professional-judgement arena do not override, then the analyte is considered not to be a contaminant

If either the hot-measurement test or at least one inferential statistical test shows that the concentration of a given analyte in the OU data set may be greater than the concentration in the background data set, then professional judgement (using temporal and spatial analysis, as well as pattern-recognition concepts) is again applied to see if the analyte concentrations in the two data sets are actually different

After the hot-measurement test and prior to the use of inferential statistical testing, the issue of non-detects must be dealt with for all tests except the Gehan test, which can be applied with non-detects present. For all other tests, non-detects should be replaced with a value of 0 5 times the applicable reported detection limit, following EPA guidance (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, July 1992), but realizing the performance of simple substitution decreases with an increasing proportion of non-detects

The handling of non-detects, and the presence of multiple detection limits in the RFEDS data base, requires the use of good professional judgement along with the general guidance offered here The use of graphical displays of data will assist in the handling of high-value non-detects

Detection limits will be discussed in the RI report

Gehan Test or Nonparametric ANOVA Test

- The Gehan test is a nonparametric test and can be used when multiple detection limits are present The Gehan test will be applied without replacing non-detects These are the principal favorable attributes of the Gehan test

- Standard nonparametric ANOVA tests (Wilcoxon Rank Sum and Kruskal-Wallis) are widely used in environmental assessment, and are discussed in EPA guidance (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, July 1992) These tests require replacement of non-detect values, either by simple substitution or maximum-likelihood methods

- For the Gehan or nonparametric ANOVA test, a p-value will be generated and p-values that are equal to or less than 0 05 will normally be considered indicative of a significant difference from background Statements of the test and null hypotheses will be given, in both statistical and narrative terms

Quantile Test

- The quantile test is also a nonparametric test and can be considered as a rapid screening test

- Due to limitations in the quantile test, the test will only be used if the largest 20% of the combined background and site data are detects

- A p-value will be generated and p-values that are equal to or less than 0 05 will indicate a significant difference from background Statements of the test and null hypotheses will be given, in both statistical and narrative terms

Slippage Test

- The slippage test is a nonparametric test and can be considered as a rapid screening test

- Due to limitations in the slippage test, the test will possibly not be used if the largest background value is a non-detect If the largest background value is a non-detect, then professional judgement will be applied to determine whether or not the slippage test is applicable For example, if the second largest background value is a detect and is similar in value to the largest background value, it could be used in place of the largest value (although the replacement must be taken into account when interpreting the test results)

- A p-value will be generated and p-values that are equal to or less than 0 05 will indicate a significant difference from background Statements of the test and null hypotheses will be given, in both statistical and narrative terms

T-Test

- The t-test is a parametric test and is very commonly used when testing the difference between means of two data sets

- Due to limitations in the t-test, the test will be applied in cases where both background and OU data are normally distributed and contain at least 20 data points, and less than 20% of the background and OU data are classified as non-detects

- A p-value will be generated and p-values that are equal to or less than 0 05 will indicate a significant difference from background Statements of the test and null hypotheses will be given, in both statistical and narrative terms

Professional Judgement

The following general guidelines will be used individually and collectively, in conjunction with the above comparison and statistical "tools" to ascertain if a reported analytical detection(s) constitutes contamination at the OU When professional judgement is applied, documented and defensible evidence will be furnished, and DOE will bear the "burden of proof"

- **Spatial distribution** of analytes above background are or are not indicative of contamination due to waste-related activities at the OU Spatial plots, interpreted in a source-to-receptor conceptual model, in addition to compound-specific mobility considerations, generally assist in interpretation of inconclusive results

- **Temporal distribution** of analyte concentrations at a station indicates the "high" value(s) is(are) outlier(s) Time-series plots at wells or surface-water locations can generally be used to link apparently insignificant **outlier** reports to seasonal or hydrological phenomena, and vice versa

- Other associated analytes are determined not to be contaminants in the sample or at the station Then this may be added to cumulative evidence ("burden of proof") that the analyte in question is not a potential contaminant of concern **Pattern-recognition concepts** are useful in identifying anomalies as well as confirming "fingerprint" associations

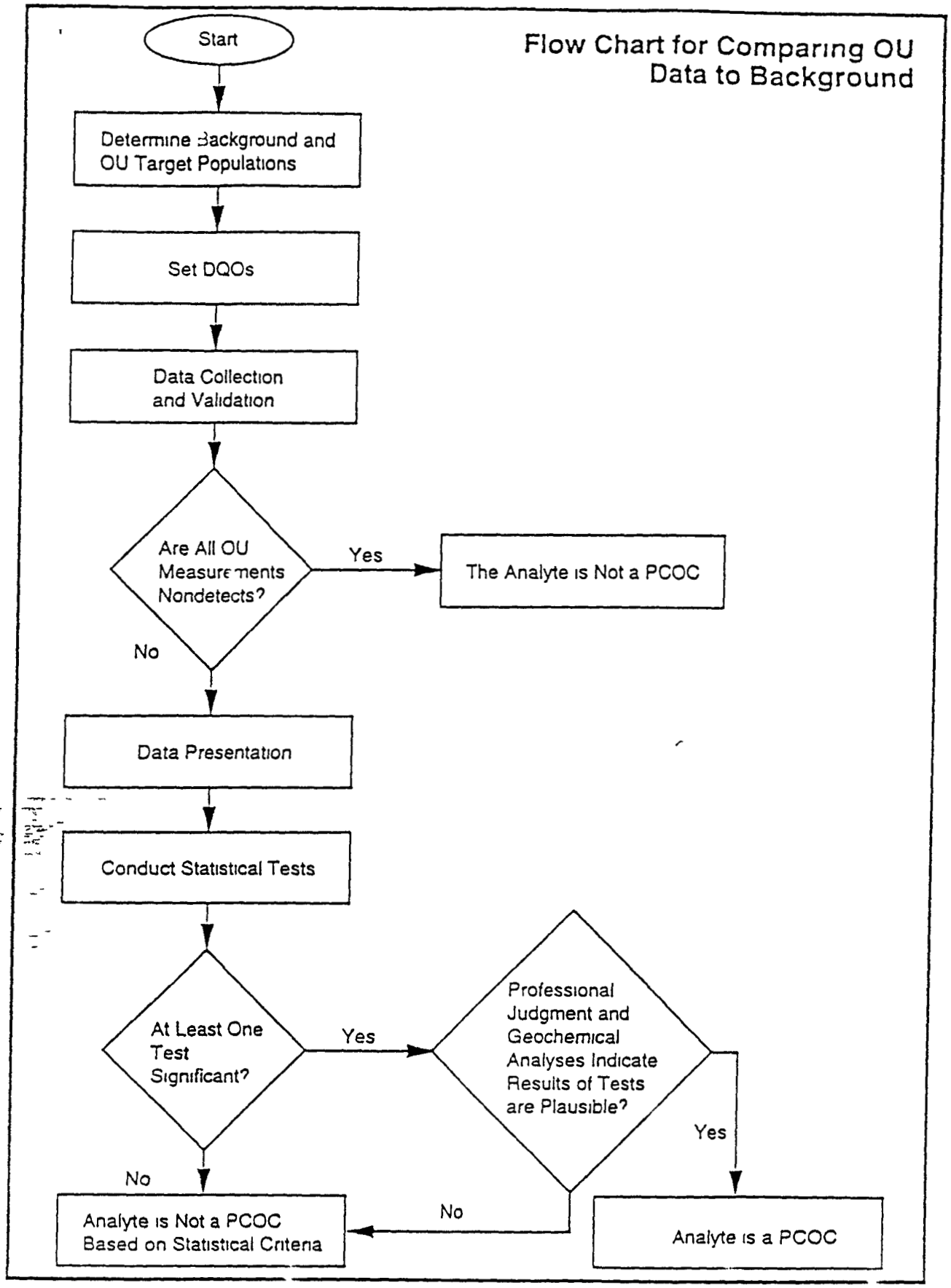

Figure 1
Flow Chart for Comparing
OU Data to Background

GENERAL APPROACH TO DETERMINING "CONTAMINANTS"

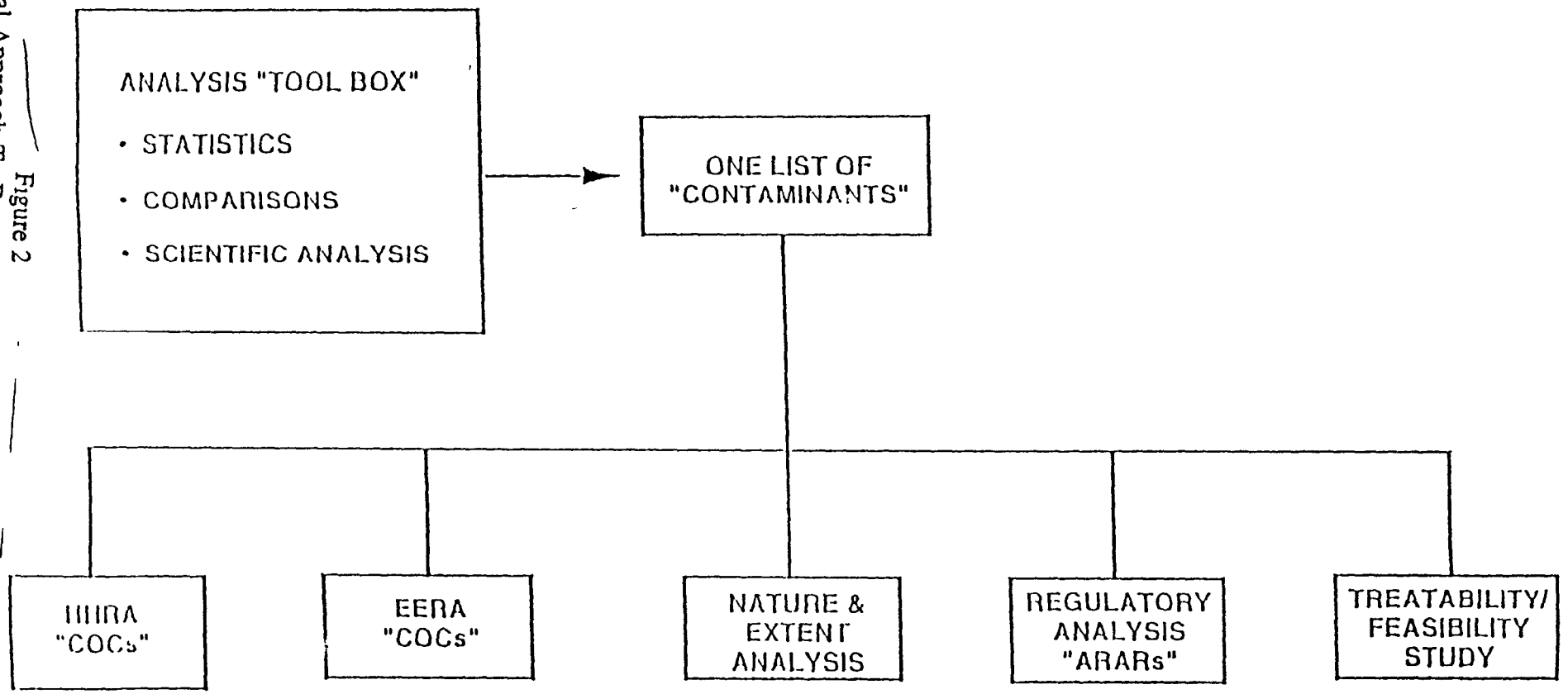

Figure 2
General Approach To Determining "Contaminants"

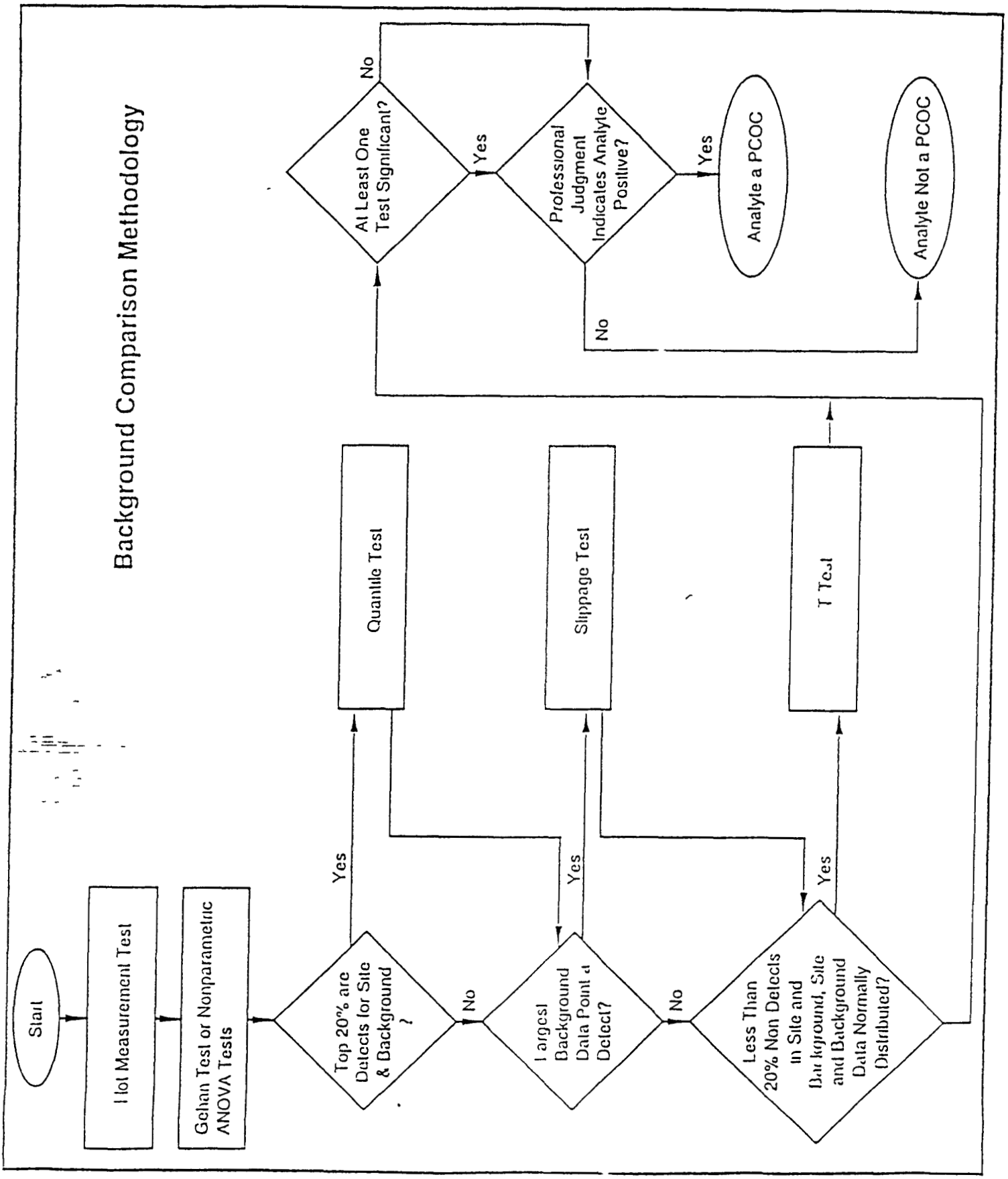

Figure 3
Background Comparison Methodology

Table C-1 Groundwater UTLs by geologic unit for dissolved metals

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, DISSOLVED METALS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	COL	35	71 43	59 18	49 50	224 21	UG/L
ANTIMONY	COL	33	33 33	14 84	9 50	46 92	UG/L
BARIUM	COL	34	79 41	77 05	39 03	207 99	UG/L
CADMIUM	COL	34	23 53	1 97	1 67	7 57	UG/L
CALCIUM	COL	35	100 00	96 314 29	34,355 90	210 868 89	UG/L
CHROMIUM	COL	32	28 12	5 87	5 93	26 03	UG/L
COPPER	COL	33	36 36	5 08	4 20	19 27	UG/L
IRON	COL	34	61 76	46 38	79 70	313 70	UG/L
LITHIUM	COL	34	88 24	122 77	84 53	406 30	UG/L
MAGNESIUM	COL	34	100 00	20,479 41	10,610 71	56 070 91	UG/L
MANGANESE	COL	35	74.29	32 10	38 69	161 12	UG/L
MOLYBDENUM	COL	33	42 42	19 35	32 15	127 67	UG/L
POTASSIUM	COL	33	84 85	2 086 36	1,903 98	8,513 03	UG/L
SELENIUM	COL	32	62 50	17 40	42 89	163 12	UG/L
SILVER	COL	31	25 81	3 22	2 81	12 84	UG/L
SODIUM	COL	35	100 00	98 454 29	64,522 31	313 594 26	UG/L
STRONTIUM	COL	34	97 06	701 88	374 80	1 959 08	UG/L
TIN	COL	31	41 94	44 01	62 59	258 16	UG/L
VANADIUM	COL	32	65 62	8 17	7 85	34 84	UG/L
ZINC	COL	35	74 29	11 30	10 64	46 78	UG/L
ALUMINUM	R-A	104	75 00	68 23	125 93	361 64	UG/L
ANTIMONY	R-A	113	49 56	18 37	12 98	48 61	UG/L
BARIUM	R-A	114	83 33	72 32	24 50	129 39	UG/L
CADMIUM	R-A	107	22 43	1 66	1 13	4 29	UG/L
CALCIUM	RFA	113	100 00	37 655 53	18 707 96	81 245 08	UG/L
CHROMIUM	RFA	113	41 59	4 86	3 33	12 63	UG/L
COPPER	RFA	112	43 75	4 79	4 13	14 40	UG/L
IRON	RFA	113	76 99	70 28	157 23	436 62	UG/L
LEAD	RFA	111	24 32	1 40	3 01	8 41	UG/L
LITHIUM	RFA	109	68 81	12 68	17 36	53 12	UG/L
MAGNESIUM	RFA	112	91 96	4 266 21	1 369 27	7 456 60	UG/L
MANGANESE	RFA	114	52 63	6 17	15 04	41 21	UG/L
MOLYBDENUM	RFA	106	35 85	19 37	34 13	98 88	UG/L
NICKEL	RFA	106	36 79	7 66	7 65	25 49	UG/L
POTASSIUM	RFA	110	79 09	925 94	705 81	2 570 48	UG/L
SILVER	RFA	105	28 57	2 73	1 88	7 11	UG/L
SODIUM	RFA	112	98 21	7 602 21	1 740 42	11 557 40	UG/L
STRONTIUM	RFA	112	86 61	132 73	91 06	344 89	UG/L
THALLIUM	RFA	92	21 74	1 68	1 64	5 50	UG/L
TIN	RFA	100	41 00	29 72	34 02	108 98	UG/L
VANADIUM	RFA	111	62 16	8 36	9 95	31 54	UG/L
ZINC	RFA	113	79 65	15 69	19 83	61 88	UG/L

Table C-2 Groundwater UTLs by geologic unit for total metals

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	COL	19	100 00	745 11	789 02	3 816 32	UG/L
ANTIMONY	COL	20	30.00	17 74	9 52	54.22	UG/L
ARSENIC	COL	20	40 00	1 93	1 65	8 24	UG/L
BARIUM	COL	20	85 00	90 87	66 40	345.29	UG/L
CADMIUM	COL	20	25 00	1 97	1 74	8 64	UG/L
CALCIUM	COL	20	100.00	99 540 00	37,654 79	243 816 53	UG/L
CHROMIUM	COL	18	22.22	4 59	4 36	21 88	UG/L
COPPER	COL	20	65 00	9 29	11 81	54 54	UG/L
IRON	COL	19	100 00	665 11	679.22	3 308 92	UG/L
LEAD	COL	18	38 89	2.28	4 27	19 18	UG/L
LITHIUM	COL	20	85 00	117 94	86 49	449 35	UG/L
MAGNESIUM	COL	20	100 00	21 320 00	11 477 51	65 296 75	UG/L
MANGANESE	COL	20	95 00	57 46	126 39	541 73	UG/L
MOLYBDENUM	COL	20	40 00	23 88	39 19	174 05	UG/L
NICKEL	COL	18	33 33	7.25	6 31	32 26	UG/L
POTASSIUM	COL	20	75.00	2,013 25	1 893 58	9 268 62	UG/L
SELENIUM	COL	18	66 67	15 04	47 11	201 61	UG/L
SILICON	COL	12	100 00	8 600 75	2,462.31	20 008 64	UG/L
SODIUM	COL	20	100 00	101 010 00	68,738 74	364 386 48	UG/L
STRONTIUM	COL	20	100 00	705 85	379 49	2,159 90	UG/L
THALLIUM	COL	20	35 00	1 68	1 76	8 43	UG/L
TIN	COL	20	40 00	35 35	34 62	167 99	UG/L
VANADIUM	COL	20	75 00	16 82	27 37	121 70	UG/L
ZINC	COL	20	95 00	31 55	36 14	170 01	UG/L
ALUMINUM	RFA	66	93 94	3 844 45	5 057 31	19 223 71	UG/L
ANTIMONY	RFA	63	42.86	21 40	15 61	68 88	UG/L
ARSENIC	RFA	61	27 87	2 07	1 76	7 43	UG/L
BARIUM	RFA	66	78 79	96 13	36 76	207 92	UG/L
CALCIUM	RFA	67	100 00	38 690 30	17 954 04	93 288 54	UG/L
CESIUM	RFA	65	23 08	150 64	202.63	766 84	UG/L
CHROMIUM	RFA	64	56 25	8 21	7 49	30 99	UG/L
COBALT	RFA	66	21.21	8 46	10 30	39 78	UG/L
COPPER	RFA	66	77.27	12 25	13 56	53 48	UG/L
IRON	RFA	66	98 48	4 262 08	5 950 89	22 389 15	UG/L
LEAD	RFA	63	71 43	3 64	3 95	1[illegible] 54	UG/L
LITHIUM	RFA	67	76 12	17 15	19 09	75 19	UG/L
MAGNESIUM	RFA	67	95 52	5 050 67	2,112 67	11 475 30	UG/L
MANGANESE	RFA	66	90 91	90 09	113 99	436 [illegible]3	UG/L
MOLYBDENUM	RFA	63	33 82	24 80	40 38	147 60	UG/L
NICKEL	RFA	66	40 91	13 25	11 32	47 69	UG/L
POTASSIUM	RFA	68	76 47	1 578 46	1 190 52	5 198 84	UG/L
SILICON	RFA	37	100 00	19 033 92	11 446 15	56 777 23	UG/L
SODIUM	RFA	67	97 01	7 797 16	1 995 38	13 865 12	UG/L
STRONTIUM	RFA	64	78 12	125 27	39 20	244 47	UG/L
TIN	RFA	68	32.35	34 01	36 65	145 45	UG/L
VANADIUM	RFA	66	78 79	14 87	11 21	48 97	UG/L
ZINC	RFA	67	8[illegible]6	40 26	67 22	244 69	UG/L

Table C-2 (cont')

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	VFA	43	97 67	2,560 55	3 909 13	14 893 86	UG/L
ANTIMONY	VFA	41	31 71	16 54	9 86	47 64	UG/L
ARSENIC	VFA	41	31 71	1 70	1 57	6 65	UG/L
BARIUM	VFA	43	83 72	112.77	30 98	210 51	UG/L
CADMIUM	VFA	43	25 58	1 79	1 78	7 39	UG/L
CALCIUM	VFA	43	100 00	60 361 72	30 137 58	155 445 78	UG/L
CESIUM	VFA	40	30 00	142.06	184 65	741 90	UG/L
CHROMIUM	VFA	42	50 00	6 96	6 89	28.69	UG/L
COBALT	VFA	43	20 93	6 73	8 52	33 63	UG/L
COPPER	VFA	43	81 40	10 43	2.48	49 80	UG/L
IRON	VFA	43	100 00	2,732.59	4 79 64	17,181 35	UG/L
LEAD	VFA	40	77 50	3 39	3.26	13 97	UG/L
LITHIUM	VFA	43	81 40	22.51	18 95	82.29	UG/L
MAGNESIUM	VFA	43	97 67	12,865 24	6 410 62	33 090 74	UG/L
MANGANESE	VFA	43	95 35	92.38	104 18	421 07	UG/L
MERCURY	VFA	43	23 26	0 12	0 04	0 26	UG/L
MOLYBDENUM	VFA	43	27 91	18 90	36 26	133.29	UG/L
NICKEL	VFA	43	44 19	8 41	7 05	30 65	UG/L
POTASSIUM	VFA	43	81 40	1 785 13	913 58	4 667 48	UG/L
SELENIUM	VFA	42	42.86	3 42	7 97	28 55	UG/L
SILICON	VFA	23	100 00	15 831 46	11 777 33	59 186 01	UG/L
SODIUM	VFA	43	100 00	32,929 90	16 184 58	83 992 25	UG/L
STRONTIUM	VFA	43	95 35	374 14	206 92	1 025 97	UG/L
THALLIUM	VFA	43	27 91	1 47	1 59	6 49	UG/L
TIN	VFA	42	38 10	31 89	32.57	134 65	UG/L
VANADIUM	VFA	43	79 07	12.20	10 56	45 52	UG/L
ZINC	VFA	43	100 00	39 93	28 56	130 03	UG/L
ALUMINUM	WCS	19	89 47	1 326 18	2 630 79	11 566 37	UG/L
ANTIMONY	WCS	17	47 06	19 09	10 53	61 58	UG/L
BARIUM	WCS	19	84 21	113 17	66 05	370.27	UG/L
CALCIUM	WCS	19	100 00	53 731 58	13 527 83	106 387 86	UG/L
CESIUM	WCS	20	35 00	188 32	215 25	1 013 07	UG/L
CHROMIUM	WCS	19	36 84	5 40	4 02	21 06	UG/L
COPPER	WCS	19	57 89	7 15	4 34	24 03	UG/L
IRON	WCS	19	89 47	1 690 19	3 323 94	14 628 42	UG/L
LEAD	WCS	19	73 68	2 68	2 62	12.89	UG/L
LITHIUM	WCS	19	73 68	29 12	15 94	91 18	UG/L
MAGNESIUM	WCS	19	100 00	11 527 89	3 792.95	26 291 71	UG/L
MANGANESE	WCS	19	68 42	37 44	56 99	259 28	UG/L
MOLYBDENUM	WCS	19	42 11	33 49	44 45	206 49	UG/L
POTASSIUM	WCS	19	73 68	1 858 95	500 67	3 807 76	UG/L
SELENIUM	WCS	18	50 00	9 10	19 03	84 48	UG/L
SILICON	WCS	10	100 00	10 474 00	5 966 37	40 745 70	UG/L
SODIUM	WCS	19	100 00	27 557 89	9 531 60	64 659 09	UG/L
STRONTIUM	WCS	19	100 00	390 47	150 51	976 33	UG/L
THALLIUM	WCS	18	27 78	1 95	1 96	9 71	UG/L
TIN	WCS	19	31 58	36 28	39 56	190 26	UG/L
VANADIUM	WCS	19	68 42	10 57	9 20	46 39	UG/L
ZINC	WCS	19	84 21	25 91	17 93	95 69	UG/L

Table C-2 (cont')

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL METALS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	KAR	37	91 89	1 791 87	2,773 43	10 937 17	UG/L
ANTIMONY	KAR	35	31 43	15.62	10 40	50 28	UG/L
ARSENIC	KAR	35	54.29	2.76	2.02	9 51	UG/L
BARIUM	KAR	36	86 11	113 95	51 97	286 27	UG/L
CALCIUM	KAR	37	100 00	36 382.43	23 881 47	115 130 79	UG/L
CESIUM	KAR	35	25 71	131 59	175 16	715 62	UG/L
CHROMIUM	KAR	36	38 89	5.25	4 61	20 54	UG/L
COPPER	KAR	36	61 11	11 99	21 82	84 34	UG/L
IRON	KAR	37	94 59	2,239 92	3 697 44	14 432 11	UG/L
LEAD	KAR	36	61 11	3 82	4 29	18 06	UG/L
LITHIUM	KAR	37	86 49	40 69	29.29	137 26	UG/L
MAGNESIUM	KAR	37	94 59	6 679 46	5 030 81	23,268 40	UG/L
MANGANESE	KAR	37	86 49	61 87	125 21	474 75	UG/L
MERCURY	KAR	37	27 03	0 13	0.05	0 28	UG/L
MOLYBDENUM	KAR	36	[illegible].22	18 59	33 45	129 48	UG/L
NICKEL	KAR	35	34.29	8 70	7.25	32.89	UG/L
POTASSIUM	KAR	37	89 19	2,846 38	1 725 69	8 536 77	UG/L
SELENIUM	KAR	36	33 33	1 19	0 63	3.27	UG/L
SILICON	KAR	20	100 00	9 427 50	6 631 12	34 835 00	UG/L
SODIUM	KAR	37	100 00	139 228 38	134 404 33	582,422.16	UG/L
STRONTIUM	KAR	37	97 30	399 78	312 58	1 430 50	UG/L
THALLIUM	KAR	36	27 78	1 40	1 50	6 36	UG/L
TIN	KAR	37	29 73	27 46	31 18	130 28	UG/L
VANADIUM	KAR	36	69 44	10 43	11 26	47 75	UG/L
ZINC	KAR	36	97 22	52.45	51 31	222 56	UG/L

Table C-3 Groundwater UTLs by geologic unit for dissolved radionuclides

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, DISSOLVED RADIONUCLIDES

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	COL	2	100 00	0 36	0 42	78 73	pCi/L
GROSS ALPHA	COL	30	100 00	41 31	78 79	312.85	pCi/L
GROSS BETA	COL	27	100 00	17 51	29 87	123 04	pCi/L
RADIUM 226	COL	15	100 00	0 21	0 10	0 64	pCi/L
STRONTIUM-89 90	COL	23	100 00	0 25	0.24	1 13	pCi/L
TRITIUM	COL	31	100 00	76 12	109 42	450 48	pCi/L
URANIUM-233,234	COL	30	100 00	31 82	56 44	226 34	pCi/L
URANIUM 235	COL	30	100 00	0 86	1 39	5 83	pCi/L
URANIUM-238	COL	24	100.00	26 70	42.13	180 03	pCi/L
CESIUM-137	RFA	15	100 00	0.27	0.29	1 48	pCi/L
GROSS ALPHA	RFA	82	100 00	0 59	0 80	3 02	pCi/L
GROSS BETA	RFA	76	100 00	1 86	1 52	6 28	pCi/L
RADIUM-226	RFA	2	100 00	0 17	0 04	7 91	pCi/L
RADIUM-228	RFA	2	100 00	2.20	0 42	8 95	pCi/L
STRONTIUM-89 90	RFA	81	100 00	0 27	0 23	0 98	pCi/L
TRITIUM	RFA	63	100 00	163 03	223 01	841 20	pCi/L
URANIUM 233,234	RFA	7	100 00	0.23	0 21	0 88	pCi/L
URANIUM-235	RFA	78	100 00	0 03	0 07	0 23	pCi/L
URANIUM-238	RFA	69	100 00	0 14	0 14	0 56	pCi/L
CESIUM-137	VFA	17	100 00	0 58	0 71	3 43	pCi/L
GROSS ALPHA	VFA	60	100 00	2.93	3 17	12 94	pCi/L
GROSS BETA	VFA	55	100 00	3 20	1 69	8 54	pCi/L
RADIUM-226	VFA	13	100 00	0 31	0 11	0 81	pCi/L
RADIUM 228	VFA	4	100 00	2.06	0 62	9 76	pCi/L
STRONTIUM-89 90	VFA	59	100 00	0 49	0 38	1 68	pCi/L
TRITIUM	VFA	42	100 00	115 00	137 64	549 26	pCi/L
URANIUM-233 234	VFA	60	100 00	2 05	2 77	10 80	pCi/L
URANIUM 235	VFA	60	100 00	0 08	0 12	0 47	pCi/L
URANIUM 238	VFA	49	100 00	1 66	2 30	8 92	pCi/L
CESIUM-137	WCS	4	100 00	0 32	0 20	2 86	pCi/L
GROSS ALPHA	WCS	41	100 00	7 70	5 95	26 47	pCi/L
GROSS BETA	WCS	38	100 00	4 85	3 22	15 41	pCi/L
RADIUM 226	WCS	6	100 00	0 32	0 06	0 78	pCi/L
STRONTIUM-89 90	WCS	17	100 00	0 24	0 24	1 21	pCi/L
TRITIUM	WCS	29	100 00	3 42	118 54	388 30	pCi/L
URANIUM 233,234	WCS	39	100 00	8 59	21 06	77 33	pCi/L
URANIUM-235	WCS	39	100 00	0 20	0 51	1 88	pCi/L
URANIUM-238	WCS	35	100 00	3 54	3 19	14 17	pCi/L
CESIUM 137	KAR	4	100 00	0 22	0 30	3 92	pCi/L
GROSS ALPHA	KAR	60	100 00	3 13	6 24	22 81	pCi/L
GROSS BETA	KAR	54	100 00	3 23	2 84	12.19	pCi/L
RADIUM 226	KAR	2	100 00	1 72	1 78	331 75	pCi/L
STRONTIUM-89 90	KAR	42	100 00	0 47	1 19	4 21	pCi/L
TRITIUM	KAR	49	100 00	56 88	135 94	485 77	pCi/L
URANIUM 233 234	KAR	57	100 00	1 64	2 85	10 63	pCi/L
URANIUM 235	KAR	57	100 00	0 03	0 06	0 23	pCi/L
URANIUM 238	KAR	54	100 00	0 77	1 53	5 58	pCi/L

Table C-4 Groundwater UTLs by geologic unit for total radionuclides

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL RADIONUCLIDES

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
AMERICIUM-241	COL	25	100 00	0 00	0 00	0 01	pCi/L
CESIUM-137	COL	23	100 00	0 18	0 35	1 49	pCi/L
GROSS ALPHA	COL	6	100 00	150 35	142 75	1,197 38	pCi/L
GROSS BETA	COL	6	100 00	81 55	85 25	706 79	pCi/L
PLUTONIUM-239 240	COL	26	100 00	0 01	0 01	0 04	pCi/L
STRONTIUM-89,90	COL	7	100 00	0.26	0 11	0 95	pCi/L
TRITIUM	COL	17	100 00	201 15	193 39	981 82	pCi/L
URANIUM-233,234	COL	8	100 00	58 74	66 80	446 99	pCi/L
URANIUM-235	COL	8	100 00	2 14	2 39	16 03	pCi/L
URANIUM-238	COL	6	100 00	36 04	46 48	376 92	pCi/L
AMERICIUM 241	RFA	82	100 00	0 01	0 01	0 03	pCi/L
CESIUM-137	RFA	75	100 00	0 08	0 33	1 09	pCi/L
GROSS ALPHA	RFA	5	100 00	1 89	1 28	13 30	pCi/L
GROSS BETA	RFA	5	100 00	2 25	1 48	15 45	pCi/L
PLUTONIUM-238	RFA	7	100 00	0 00	0 00	0 01	pCi/L
PLUTONIUM 239,240	RFA	85	100 00	0 00	0 00	0 01	pCi/L
STRONTIUM-89,90	RFA	13	100 00	0 11	0 21	1 04	pCi/L
TRITIUM	RFA	21	100 00	226 72	307 18	1,386 83	pCi/L
URANIUM-233 234	RFA	12	100 00	0 48	0 45	2 58	pCi/L
URANIUM 235	RFA	12	100 00	0 12	0 20	1 05	pCi/L
URANIUM 238	RFA	11	100 00	0 40	0 50	2 83	pCi/L
AMERICIUM-241	VFA	56	100 00	0 01	0 01	0 05	pCi/L
CESIUM 137	VFA	44	100 00	0 10	0 30	1 05	pCi/L
GROSS ALPHA	VFA	7	100 00	3 66	2 05	16 84	pCi/L
GROSS BETA	VFA	7	100 00	4 54	2 83	22 56	pCi/L
PLUTONIUM-238	VFA	6	100 00	0 01	0 01	0 09	pCi/L
PLUTONIUM-239 240	VFA	62	100 00	0 01	0 04	0 12	pCi/L
STRONTIUM-89,90	VFA	8	100 00	0 43	0 37	2 56	pCi/L
TRITIUM	VFA	27	100 00	142 98	180 02	779 97	pCi/L
URANIUM-233,234	VFA	7	100 00	1 58	1 00	8 01	pCi/L
URANIUM-235	VFA	7	100 00	0 10	0 10	0 75	pCi/L
URANIUM-238	VFA	2	100 00	1 23	1 20	223 18	pCi/L

Table C-4 (cont')

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, TOTAL RADIONUCLIDES (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
AMERICIUM-241	WCS	20	100 00	0 01	0 01	0 07	pCi/L
CESIUM-137	WCS	14	100 00	0.28	0 36	1 86	pCi/L
GROSS ALPHA	WCS	5	100 00	12 65	12 46	124 04	pCi/L
GROSS BETA	WCS	5	100 00	8.27	5 11	53 95	pCi/L
PLUTONIUM-239,240	WCS	21	100 00	0 00	0 00	0 02	pCi/L
RADIUM-226	WCS	4	100 00	0 36	0 15	2.19	pCi/L
STRONTIUM-89 90	WCS	4	100 00	0 05	0 26	3.25	pCi/L
TRITIUM	WCS	19	100 00	2,128 76	8,937 88	36,918 91	pCi/L
URANIUM 233,234	WCS	8	100 00	7 49	6 30	44 13	pCi/L
URANIUM-235	WCS	8	100 00	0.28	0 26	1 81	pCi/L
URANIUM-238	WCS	3	100 00	5 11	4 96	123 65	pCi/L
AMERICIUM 241	KAR	43	100 00	0 01	0 02	0 07	pCi/L
CESIUM-137	KAR	39	100 00	0 00	0 29	0 96	pCi/L
GROSS ALPHA	KAR	6	100 00	11 08	16 63	133 08	pCi/L
GROSS BETA	KAR	6	100 00	12 01	13 45	110 67	pCi/L
PLUTONIUM-238	KAR	5	100 00	0 01	0 01	0 14	pCi/L
PLUTONIUM 239 240	KAR	48	100 00	0 00	0 01	0 02	pCi/L
RADIUM 226	KAR	3	100 00	0 59	0 45	11 30	pCi/L
STRONTIUM-89 90	KAR	4	100 00	0 10	0 26	3 34	pCi/L
TRITIUM	KAR	16	100 00	62 93	367 23	1 577 10	pCi/L
URANIUM 233 234	KAR	4	100 00	0 77	0 57	7 79	pCi/L
URANIUM 235	KAR	4	100 00	0 03	0 02	0 27	pCi/L
URANIUM 238	KAR	2	100 00	0 35	0 26	48 13	pCi/L

Table C-5 Groundwater UTLs by geologic unit for water-quality parameters

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, WATER-QUALITY PARAMETERS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	COL	52	100 00	393 871 94	175,851 17	948 682.39	UG/L
CHLORIDE	COL	42	100 00	18,114 29	10,104 20	49,993 05	UG/L
FLUORIDE	COL	51	100 00	1,053 73	536 87	2,747 56	UG/L
NITRATE/NITRITE	COL	56	64.29	1,683 75	3,700 64	13,359 28	UG/L
ORTHOPHOSPHATE	COL	27	48 15	11 93	7 48	38 34	UG/L
PHOSPHORUS	COL	10	40 00	30 50	29 86	181 98	UG/L
SILICA	COL	44	100 00	12,037 35	6,549 60	32,701 34	UG/L
SULFATE	COL	48	100 00	215,566 67	264,980 47	1,051,580 04	UG/L
TOTAL DISSOLVED SOLIDS	COL	52	100 00	687,230 77	409,401 70	1,978 893 12	UG/L
TOTAL SUSPENDED SOLIDS	COL	52	67 31	18,038 46	24 207 00	94 411 55	UG/L
BICARBONATE	RFA	114	100 00	114,859 08	56,766 87	247,125 88	UG/L
CHLORIDE	RFA	95	91 58	8,707 47	13,538 26	40,251 63	UG/L
FLUORIDE	RFA	108	96 30	306 39	90 85	518 06	UG/L
NITRATE/NITRITE	RFA	115	97 39	1 448 26	765 26	3 231 31	UG/L
NITRITE	RFA	23	43 48	33 13	53 44	229 87	UG/L
ORTHOPHOSPHATE	RFA	81	56 79	14 44	12 92	53 73	UG/L
PHOSPHORUS	RFA	22	68 18	44 27	49 43	228 50	UG/L
SILICA	RFA	105	100 00	15 873 61	8 274 40	35 152 97	UG/L
SULFATE	RFA	103	99 03	22 384 47	19,440 47	67,680 75	UG/L
TOTAL DISSOLVED SOLIDS	RFA	115	100 00	189,817 39	94,386 90	409 738 67	UG/L
TOTAL SUSPENDED SOLIDS	RFA	111	66 49	182,684 68	334 207 01	961,387 02	UG/L
BICARBONATE	VFA	78	100 00	242 462 09	116 731 17	597,441 57	UG/L
CHLORIDE	VFA	67	97 01	16,061 19	12,727 88	54 766 69	UG/L
CYANIDE	VFA	21	28 57	9 39	5 70	30 92	UG/L
FLUORIDE	VFA	76	97 37	505 27	186 31	1 071 82	UG/L
NITRATE/NITRITE	VFA	72	65 28	202 08	257 28	984 46	UG/L
NITRITE	VFA	12	25 00	19 17	15 05	88 90	UG/L
ORTHOPHOSPHATE	VFA	54	55 56	17 82	27 04	103 13	UG/L
PHOSPHORUS	VFA	15	46 67	44 67	42 49	224 10	UG/L
SILICA	VFA	76	100 00	15 164 53	8 599 63	41 315 99	UG/L
SULFATE	VFA	69	100 00	54,486 96	74,995 26	282,547 55	UG/L
TOTAL DISSOLVED SOLIDS	VFA	76	100 00	334,744 54	167,754 49	844 885 9[illegible]	UG/L
TOTAL SUSPENDED SOLIDS	VFA	72	88 89	90 727 64	141 259 37	520 297 38	UG/L

Table C-5 (cont')

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GROUNDWATER, WATER-QUALITY PARAMETERS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	WCS	67	100 00	255,472 87	134,489 69	664 456 02	UG/L
CHLORIDE	WCS	53	83 02	9,094 34	11,230 61	44 526 93	UG/L
CYANIDE	WCS	7	28 57	10 00	7 07	55 34	UG/L
FLUORIDE	WCS	65	98 46	893 69	595 09	2,703 37	UG/L
NITRATE/NITRITE	WCS	62	87 10	715 40	1,067 15	3,960 61	UG/L
NITRITE	WCS	11	63 64	28 82	27 52	161 71	UG/L
ORTHOPHOSPHATE	WCS	29	44 83	14 48	11 52	54 50	UG/L
PHOSPHORUS	WCS	9	66 67	28 89	31 30	197 58	UG/L
SILICA	WCS	49	100 00	10,404 94	6,489 24	30 878 48	UG/L
SULFATE	WCS	58	100 00	131,008 62	241,197 17	891,985 69	UG/L
TOTAL DISSOLVED SOLIDS	WCS	67	100 00	405 940 30	375,873 93	1,548,972 91	UG/L
TOTAL SUSPENDED SOLIDS	WCS	66	69 70	187,939 39	787,142 93	2 581,641 05	UG/L
ALKALINITY AS CACO3	KAR	3	100 00	305,166 67	160,234 46	4,131,059 44	UG/L
BICARBONATE	KAR	93	100 00	233 546 17	102,980 99	473 491 87	UG/L
CARBONATE	KAR	92	28 26	3,318 77	4,245 24	13,210 17	UG/L
CHLORIDE	KAR	79	96 20	100 205 95	128 066 02	489,654 73	UG/L
FLUORIDE	KAR	92	97 83	949 35	465 34	2 033 58	UG/L
NITRATE/NITRITE	KAR	90	78 89	861 22	945 96	3 737 87	UG/L
NITRITE	KAR	16	56 25	190 62	295 19	1 407 78	UG/L
ORTHOPHOSPHATE	KAR	54	61 11	18 46	10 16	50 52	UG/L
PHOSPHORUS	KAR	14	64 29	173 57	264 99	1 322 89	UG/L
SILICA	KAR	83	100 00	8 077 25	5,808 92	25 742 17	UG/L
SULFATE	KAR	82	95 12	123,943 90	250 872 10	886,845 95	UG/L
TOTAL DISSOLVED SOLIDS	KAR	94	100 00	545 138 30	445 290 59	1,582 665 38	UG/L
TOTAL SOLIDS	KAR	5	80 00	318 240 00	356,657 98	3 506 414 55	UG/L
TOTAL SUSPENDED SOLIDS	KAR	58	77 27	403,085 23	727 972 80	2 616,850 51	UG/L

Table C-6 Groundwater UTLs by flow-system for dissolved metals

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, DISSOLVED METALS

ANALYTE	FLOW SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	LOWER	66	78.79	48 81	44 02	182 67	UG/L
ANTIMONY	LOWER	63	44 44	15 50	9 17	43 37	UG/L
ARSENIC	LOWER	59	49 15	2.41	1 70	7 77	UG/L
BARIUM	LOWER	66	86 36	84 18	21 79	150 44	UG/L
CADMIUM	LOWER	62	22.58	1 76	1 33	5 80	UG/L
CALCIUM	LOWER	67	100 00	34 535 82	23 552.79	106 159 84	UG/L
CESIUM	LOWER	54	29 63	160 88	179 94	728 59	UG/L
CHROMIUM	LOWER	65	26 15	3 97	3 15	13 55	UG/L
COPPER	LOWER	65	27 69	4 17	3 83	15 82	UG/L
IRON	LOWER	67	79 10	33 67	35 32	141 06	UG/L
LEAD	LOWER	64	20 31	1 80	5 27	17 83	UG/L
LITHIUM	LOWER	66	81 82	38 53	27 84	123 21	UG/L
MAGNESIUM	LOWER	67	97 01	6 072.16	4 067 56	18 441 63	UG/L
MANGANESE	LOWER	67	71 64	9 29	7 24	31 31	UG/L
MOLYBDENUM	LOWER	64	53 13	16 86	27 01	99 00	UG/L
NICKEL	LOWER	65	23 08	5 81	6 26	24 86	UG/L
PHOSPHORUS	LOWER	4	100 00	174 75	85 65	1 235 68	UG/L
POTASSIUM	LOWER	67	89 55	2,731 18	1 612.39	7 634 46	UG/L
SELENIUM	LOWER	54	25 63	1 34	1 09	4 78	UG/L
SILVER	LOWER	59	28 81	2 69	2.01	9 03	UG/L
SODIUM	LOWER	67	100 00	142 012.69	135 521 56	554 133 75	UG/L
STRONTIUM	LOWER	66	100 00	383 02	294 27	1 277 90	UG/L
THALLIUM	LOWER	56	21 43	1 72	1 87	7 62	UG/L
TIN	LOWER	65	40 00	23 07	25 30	100 01	UG/L
VANADIUM	LOWER	65	56 92	6 71	7 60	29 81	UG/L
ZINC	LOWER	67	83 58	10 96	10 20	41 99	UG/L
ALUMINUM	UPPER	246	77 64	59 52	87 29	262 91	UG/L
ANTIMONY	UPPER	248	48 39	17 34	11 10	43 20	UG/L
BARIUM	UPPER	256	83 59	83 42	34 56	163 94	UG/L
CADMIUM	UPPER	240	22.08	1 73	1 26	4 66	UG/L
CALCIUM	UPPER	256	100 00	55 414 55	32 564 11	131 288 91	UG/L
CESIUM	UPPER	211	21 33	202 20	285 69	867 87	UG/L
CHROMIUM	UPPER	250	36 00	4 84	3 80	13 69	UG/L
COPPER	UPPER	248	39 11	5 01	4 42	15 32	UG/L
CYANIDE	UPPER	3	33 33	5 83	3 82	97 09	UG/L
IRON	UPPER	255	76 47	56 26	113 44	320 57	UG/L
LEAD	UPPER	251	23 90	1 59	4 71	12 57	UG/L
LITHIUM	UPPER	250	75 20	33 95	54 30	160 47	UG/L
MAGNESIUM	UPPER	253	95 65	10 038 28	8 309 40	29 399 19	UG L
MANGANESE	UPPER	255	60 78	27 47	67 43	184 57	UG/L
MOLYBDENUM	UPPER	241	37 34	19 64	33 94	98 73	UG/L
NICKEL	UPPER	236	32 63	7 01	7 18	23 73	UG/L
PHOSPHORUS	UPP R	8	100 00	167 00	52 43	471 74	UG/L
POTASSIUM	UPPER	252	81 75	1 371 50	1 069 01	3 862.30	UG/L
SELENIUM	UPPER	219	31 96	5 58	19 07	50 02	UG/L
SILVER	UPPER	235	28 51	2 84	2 12	7 79	UG/L
SODIUM	UPPER	254	99 21	32 012 98	43 667 67	133 758 65	UG/L
STRONTIUM	UPPER	252	92 86	323 60	303 58	1 030 95	UG/L
THALLIUM	UPPER	212	22 17	1 64	1 63	5 44	UG/L
TIN	UPPER	235	42 98	30 96	37 34	117 96	UG/L
VANADIUM	UPPER	249	64 66	7 92	8 73	28 25	UG/L
ZINC	UPPER	256	80 47	14 03	17 87	55 66	UG/L

Table C-7 Groundwater UTLs by flow-system for total metals

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, TOTAL METALS

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	LOWER	37	91 89	1,791 87	2,773 43	10 937 17	UG/L
ANTIMONY	LOWER	35	31 43	15 62	10 40	50 28	UG/L
ARSENIC	LOWER	35	54 29	2.76	2 02	9 51	UG/L
BARIUM	LOWER	36	86 11	113 95	51 97	286 27	UG/L
CALCIUM	LOWER	37	100 00	36 382.43	23 881 47	115 130 79	UG/L
CESIUM	LOWER	35	25 71	131 59	175 16	715 62	UG/L
CHROMIUM	LOWER	36	38 89	5.25	4 61	20 54	UG/L
COPPER	LOWER	36	61 11	11 99	21 82	84 34	UG/L
IRON	LOWER	37	94 59	2,239 92	3,697 44	14 432 11	UG/L
LEAD	LOWER	36	61 11	3 82	4 29	18 06	UG/L
LITHIUM	LOWER	37	86 49	40 69	29 29	137 26	UG/L
MAGNESIUM	LOWER	37	94 59	6 579 46	5 030 81	23 268 40	UG/L
MANGANESE	LOWER	37	86 49	61 87	125 21	474 75	UG/L
MERCURY	LOWER	37	27 03	0 13	0 05	0 28	UG/L
MOLYBDENUM	LOWER	36	47.22	18 59	33 45	129 48	UG/L
NICKEL	LOWER	35	34 29	8 70	7.25	32 89	UG/L
POTASSIUM	LOWER	37	89 19	2,846 38	1 725 69	8 536 77	UG/L
SELENIUM	LOWER	36	33 33	1 19	0 63	3 27	UG/L
SILICON	LOWER	20	100 00	9 427 50	6 631 12	34 835 00	UG/L
SODIUM	LOWER	37	100 00	139 228 38	134 404 33	582 422.16	UG/L
STRONTIUM	LOWER	37	97.30	399 78	312 58	1 430 50	UG/L
THALLIUM	LOWER	36	27 78	1 40	1 50	6 36	UG/L
TIN	LOWER	37	29 73	27 46	31 18	130 28	UG/L
VANADIUM	LOWER	36	69 44	10 43	11 26	47 75	UG/L
ZINC	LOWER	36	97 22	52.45	51 31	222 56	UG/L
ALUMINUM	UPPER	147	95 24	2 742 80	4 248 73	12 642 33	UG/L
ANTIMONY	UPPER	141	38 30	19 19	12 85	49 14	UG/L
ARSENIC	UPPER	138	28 26	1 95	1 71	5 93	UG/L
BARIUM	UPPER	148	81 76	102 44	45 37	208 14	UG/L
CALCIUM	UPPER	149	100 00	55 030 23	31 667 78	128 816 15	UG/L
CESIUM	UPPER	142	24 65	154 42	198 79	617 60	UG/L
CHROMIUM	UPPER	143	47 55	7 01	6 68	22 58	UG/L
COPPER	UPPER	148	74 32	10 67	12.21	39 12	UG/L
IRON	UPPER	147	97 96	3 017 34	4 994 50	14 654 53	UG/L
LEAD	UPPER	140	69 29	3 26	3 64	11 75	UG/L
LITHIUM	UPPER	149	78 52	33 75	48 76	147 37	UG/L
MAGNESIUM	UPPER	149	97 32	10 315 64	7 956 43	28 854 11	UG/L
MANGANESE	UPPER	148	89 86	79 59	108 18	331 64	UG/L
MERCURY	UPPER	148	20 27	0 12	0 04	0 22	UG/L
MOLYBDENUM	UPPER	150	34 00	24 09	39 47	116 04	UG/L
NICKEL	UPPER	145	37 24	10 58	9 49	32 68	UG/L
POTASSIUM	UPPER	150	77 33	1 731 21	1 176 59	4 472 65	UG/L
SELENIUM	UPPER	144	30 56	4 57	18 64	47 99	UG/L
SILICON	UPPER	2	100 00	15 564 97	10 797 33	48 399 65	UG/L
SODIUM	UPPER	149	98 66	30 081 85	40 019 71	123 327 78	UG/L
STRONTIUM	UPPER	146	89 04	312 61	271 09	944 25	UG/L
THALLIUM	UPPER	146	23 97	1 67	1 76	5 77	UG/L
TIN	UPPER	149	34 90	33 88	35 33	116 20	UG/L
VANADIUM	UPPER	148	77 03	13 81	14 09	46 64	UG/L
ZINC	UPPER	149	91 95	37 16	49 80	153 21	UG/L

Table C-8 Groundwater UTLs by flow-system for dissolved radionuclides

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, DISSOLVED RADIONUCLIDES

ANALYTE	FLOW-SYSTEM	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	LOWER	4	100 00	0 22	0 30	3 92	pCi/L
GROSS ALPHA	LOWER	60	100 00	3 13	6 24	2[illegible] 51	pCi/L
GROSS BETA	LOWER	54	100 00	3 23	2.84	1[illegible] 19	pCi/L
RADIUM-226	LOWER	2	100 00	1 72	1 78	331 75	pCi/L
STRONTIUM-89,90	LOWER	42	100 00	0 47	1 19	4.21	pCi/L
TRITIUM	LOWER	49	100 00	56 88	135 94	485 77	pCi/L
URANIUM-233,234	LOWER	57	100 00	1 64	2.85	10 63	pCi/L
URANIUM-235	LOWER	57	100 00	0 03	0 06	0 23	pCi/L
URANIUM 238	LOWER	54	100 00	0 77	1 53	5 58	pCi/L
AMERICIUM-241	UPPER	2	100 00	0 01	0 01	2.11	pCi/L
CESIUM-137	UPPER	38	100 00	0 42	0 53	2.14	pCi/L
GROSS ALPHA	UPPER	213	100 00	8 35	32.32	93 86	pCi/L
GROSS BETA	UPPER	196	100 00	4 89	12.23	37 25	pCi/L
RADIUM-226	UPPER	36	100 00	0.26	0 11	0 63	pCi/L
RADIUM-228	UPPER	6	100 00	2.12	0 52	5 94	pCi/L
STRONTIUM-89 90	UPPER	180	100 00	0 34	0 31	1 05	pCi/L
TRITIUM	UPPER	165	100 00	101 70	180 30	578 79	pCi/L
URANIUM-233 234	UPPER	207	100 00	6 91	25 44	74 22	pCi/L
URANIUM-235	UPPER	207	100 00	0 20	0 64	1 88	pCi/L
URANIUM-238	UPPER	177	100 00	4 83	17 67	51 60	pCi/L

Table C-9. Groundwater UTLs by flow-system for total radionuclides

GRO NDWATER

TOTAL RADIONUC IDES

ANALYTE	FLOW SYSTEM	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	
AMERICIUM 241	LOWER	43	100 00	0 01	0 02	0 07	pCi/L
CESIUM 137	LOWER	39	100 00	0 00	0 29	0 96	pCi/L
GROSS ALPHA	LOWER	6	100 00	11 08	16 63	133 08	pCi/L
GROSS BETA	LOWER	6	100 00	12 01	13 45	110 67	pCi/L
PLUTONIUM 238	LOWER	5	100 00	0 01	0 01	0 14	pCi/L
PLUTONIUM-239 240	LOWER	48	100 00	0 00	0 01	0 02	pCi/L
RADIUM 226	LOWER	3	100 00	0 59	0 45	11 30	pCi/L
STRONTIUM-89 90	LOWER	4	100 00	0 10	0 26	3 34	pCi/L
TRITIUM	LOWER	16	100 00	62.93	367 23	1 577 10	pCi/L
URANIUM 233 234	LOWER	4	100 00	0 77	0 57	7 79	pCi/L
URANIUM 235	LOWER	4	100 00	0 03	0 02	0 27	pCi/L
URANIUM 238	LOWER	2	100 00	0 35	0 26	48 13	pCi/L
AMERICIUM 241	UPPER	183	100 00	0 01	0 01	0 03	pCi/L
CESIUM 137	UPPER	156	100 00	0 12	0 33	1 00	pCi/L
GROSS ALPHA	UPPER	23	100 00	43 50	94 28	390 58	pCi/L
GROSS BETA	UPPER	23	100 00	24 95	53 34	221 31	pCi/L
PLUTONIUM 238	UPPER	15	100 00	0 00	0 01	0 03	pCi/L
PLUTONIUM 239 240	UPPER	194	100 00	0 00	0 02	0 06	pCi/L
RADIUM 226	UPPER	6	100 00	0 36	0 13	1 29	pCi/L
STRONTIUM-89 90	UPPER	32	100 00	0 22	0 28	1 15	pCi L
TRITIUM	UPPER	84	100 00	624 85	4 246 75	13 539 22	pCi/L
URANIUM 233 234	UPPER	35	100 00	15 62	38 75	144 83	pCi/L
URANIUM 235	UPPER	35	100 00	0 62	1 38	5 23	pCi/L
URANIUM 238	UPPER	22	100 00	10 84	27 73	114 17	pCi/L

Table C-10 Groundwater UTLs by flow-system for water-quality parameters

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GROUNDWATER, WATER-QUALITY PARAMETERS

ANALYTE	FLOW SYSTEM	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALKALINITY AS CACO3	LOWER	3	100 00	305 166 67	160 234 46	4 134 059 44	UG/L
BICARBONATE	LOWER	93	100 00	233 546 17	102 980 99	473 491 87	UG/L
CARBONATE	LOWER	92	28 26	3 318 77	4 245 24	13 210 17	UG/L
CHLORIDE	LOWER	79	96 20	100 205 95	128 066 02	489 654 73	UG/L
FLUORIDE	LOWER	92	97 83	949 35	485 34	2,033 58	UG/L
NITRATE/NITRITE	LOWER	90	78 89	861 22	945 96	3 737 87	UG/L
NITRITE	LOWER	16	56 25	190 62	295 19	1 407 78	UG/L
ORTHOPHOSPHATE	LOWER	54	61 11	18 46	10 16	50 52	UG/L
PHOSPHORUS	LOWER	14	64 29	173 57	264 99	1 322.89	UG/L
SILICA	LOWER	83	100 00	8 077 25	5 808 92	25 742.17	UG/L
SULFATE	LOWER	82	95 12	123 943 90	250 872.10	886 845 95	UG/L
TOTAL DISSOLVED SOLIDS	LOWER	94	100 00	545 138 30	445 290 59	1 582 665 38	UG/L
TOTAL SOLIDS	LOWER	5	80 00	318 240 00	356 657 98	3 506 414 55	UG/L
TOTAL SUSPENDED SOLIDS	LOWER	88	77.27	403 085.23	727 972.80	2 616 850 51	UG/L
ALKALINITY AS CACO3	UPPER	3	100 00	156 901 00	158 643 41	3 947 773 53	UG/L
BICARBONATE	UPPER	311	100 00	223 807 08	151 717 58	577 309 04	UG/L
CHLORIDE	UPPER	257	92 61	12,241 67	12,930 51	42 369 76	UG/L
FLUORIDE	UPPER	300	9 67	611 07	472.04	1 710 92	UG/L
NITRATE/NITRITE	UPPER	305	81 64	1 048 34	1 807 86	5 260 65	UG/L
N TRITE	UPPER	54	37 04	27 94	38 25	148 61	UG/L
ORTHOPHOSPHATE	UPPER	191	53 40	15 05	17 47	55 76	UG/L
PH	UPPER	3	100 00	7 17	0 46	18 20	UG/L
PHOSPHORUS	UPPER	56	57 14	39 45	41 60	170 70	UG/L
SILICA	UPPER	274	100 00	14 082 92	8 075 96	32 899 91	UG/L
SULFATE	UPPER	278	99 64	86 370 14	174 613 96	493 220 67	UG/L
TOTAL DISSOLVED SOLIDS	UPPER	310	100 00	355 495 44	312 010 29	1 082 479 41	UG/L
TOTAL SOLIDS	UPPER	4	75 00	24 025 00	36 789 98	479 752 89	UG L
TOTAL SUSPENDED SOLIDS	UPPER	301	80 07	133 396 64	429 323 86	1 133 721 25	UG/L

Table C-11 Geologic material UTLs by geologic unit for total metals

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL METALS

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	COL	28	100 00	10 541 43	4 945 95	27 861 88	MG/KG
ARSENIC	COL	28	85 71	3 57	1 74	9 65	MG/KG
BARIUM	COL	28	100 00	133.20	94 05	462.57	MG/KG
BERYLLIUM	COL	28	96 43	5 47	5 47	24 62	MG/KG
CADMIUM	COL	26	57 69	0 86	0 42	2.35	MG/KG
CALCIUM	COL	28	100 00	9 082.14	6 3[illegible] 14	31 386 50	MG/KG
CESIUM	COL	24	75 00	206.24	56 68	413 26	MG/KG
CHROMIUM	COL	28	100 00	13 79	5 86	34 31	MG/KG
COBALT	COL	28	25 00	6 11	3 87	19 66	MG/KG
COPPER	COL	28	96 43	14 67	5 48	33 87	MG/KG
IRON	COL	28	100 00	15 028 07	6 715 26	38 544 51	MG/KG
LEAD	COL	28	100 00	16.23	4 62	32.40	MG/KG
LITHIUM	COL	28	28 57	8 52	7 56	34 99	MG/KG
MAGNESIUM	COL	28	78 57	2,987 32	1 577 90	8 513 05	MG/KG
MANGANESE	COL	28	100 00	191 87	160 26	753 10	MG/KG
MERCURY	COL	27	22 22	0 18	0 20	0 88	MG/KG
NICKEL	COL	28	92.86	16 97	8 28	45 97	MG/KG
POTASSIUM	COL	28	35 71	979 61	721 36	3 505 78	MG/KG
SELENIUM	COL	27	22.22	0 85	0 65	3 15	MG/KG
SILVER	COL	19	42.11	5 85	9 46	42.68	MG/KG
STRONTIUM	COL	28	85 71	55 92	27 04	150 63	MG/KG
TIN	COL	23	26 09	87 36	147 51	630 37	MG/KG
VANADIUM	COL	28	100 00	30 31	12 23	73 15	MG/KG
ZINC	COL	28	100 00	56 13	21 92	132 87	MG/KG
ALUMINUM	RFA	62	100 00	13 565 95	13 657 25	55 097 66	MG/KG
ARSENIC	RFA	62	69 35	4 15	5 70	21 48	MG/KG
BARIUM	RFA	62	83 87	84 46	100 14	388 97	MG/KG
BERYLLIUM	RFA	62	87 10	4 65	4 66	18 83	MG/KG
CADMIUM	RFA	46	47 83	0 84	0 48	2.36	MG/KG
CALCIUM	RFA	62	82.26	6 676 41	19 969 15	67 402 61	MG/KG
CESIUM	RFA	62	75 81	[illegible]42 09	337 12	1 267 28	MG/KG
CHROMIUM	RFA	62	100 00	22 08	30 15	113 77	MG/KG
COBALT	RFA	62	35 48	8 [illegible]6	13 16	48 79	MG/KG
COPPER	RFA	62	87 10	11 68	15 59	59 10	MG/KG
IRON	RFA	62	100 00	14 347 10	16 126 79	63 388 67	MG/KG
LEAD	RFA	62	100 00	9 05	7 07	30 54	MG/KG
LITHIUM	RFA	62	59 68	14 33	12.85	53 41	MG/KG
MAGNESIUM	RFA	62	58 06	2 482 38	4 093 78	14 931 58	MG/KG
MANGANESE	RFA	62	100 00	235 92	417 44	1 505 36	MG/KG
MERCURY	RFA	54	42 59	0 29	0 80	2.81	MG/KG
NICKEL	RFA	59	88 14	23 35	25 45	103 63	MG/KG
POTASSIUM	RFA	61	27 87	1 545 33	3 036 93	10 780 63	MG/KG
SILVER	RFA	55	30 91	2 48	5 55	19 99	MG/KG
STRONTIUM	RFA	62	30 65	77 93	87 02	342 55	MG/KG
VANADIUM	RFA	62	96 77	32 03	34 96	138 33	MG/KG
ZINC	RFA	61	93 44	29 97	61 25	216 23	MG/KG

Table C-11 (cont')

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL METALS (CONT')

ANALYTE	GEOLOGIC UNIT	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	WCS	8	100 00	14,181.25	5 023.23	43 375.23	MG/KG
ARSENIC	WCS	9	77 78	2.94	1 55	11 27	MG/KG
BARIUM	WCS	9	88 89	64 81	26 27	206 40	MG/KG
BERYLLIUM	WCS	9	100 00	3 57	1 09	9 45	MG/KG
CADMIUM	WCS	9	22.22	0 63	0.27	06	MG/KG
CALCIUM	WCS	9	66 67	2,213 33	1 356 05	9 5[illegible]0 93	MG/KG
CESIUM	WCS	9	100 00	214 89	5 99	247 16	MG/KG
CHROMIUM	WCS	9	100 00	20 70	5 93	52.65	MG/KG
COPPER	WCS	9	100 00	12.14	5 91	43 99	MG/KG
IRON	WCS	9	100 00	14,262.22	4 066 80	36 177 70	MG/KG
LEAD	WCS	9	100 00	6 68	3 15	23 66	MG/KG
MAGNESIUM	WCS	9	55 56	2,033 89	1 253 36	8,788 12	MG/KG
MANGANESE	WCS	9	100 00	171 88	99 17	706 30	MG/KG
NICKEL	WCS	9	100 00	15 31	6 87	52.31	MG/KG
SELENIUM	WCS	9	66 67	1 9[illegible]	1.25	8 71	MG/KG
SILVER	WCS	9	100 00	24 29	6 94	61 68	MG/KG
TIN	WCS	9	100 00	278 00	65 04	628 52	MG/KG
VANADIUM	WCS	9	100 00	31 42	11 01	90 76	MG/KG
ZINC	WCS	9	100 00	23 62	8 30	68 34	MG/KG
ALUMINUM	KAR	21	100 00	7 482.60	2,681 30	17 608 83	MG/KG
ARSENIC	KAR	21	66 67	3 72	3 26	16 05	MG/KG
BARIUM	KAR	21	95 24	99 40	55 10	307 51	MG/KG
BERYLLIUM	KAR	21	100 00	3 35	3 16	15 29	MG/KG
CADMIUM	KAR	19	57 89	0 83	0 37	2 28	MG/KG
CALCIUM	KAR	21	100 00	5 477 14	1 831 78	12 395 06	MG/KG
CESIUM	KAR	16	93 75	223 62	31 26	352 50	MG/KG
CHROMIUM	KAR	21	100 00	8 91	2.98	20 18	MG/KG
COBALT	KAR	21	23 81	6 74	7 20	33 94	MG/KG
COPPER	KAR	20	100 00	15 76	5 93	38 48	MG/KG
IRON	KAR	20	100 00	12,9[illegible] 25	8 753 38	46 502 32	MG/KG
LEAD	KAR	21	100 00	18 91	6 19	42.29	MG/KG
LITHIUM	KAR	21	28 57	7 17	8 39	38 84	MG/KG
MAGNESIUM	KAR	21	66 67	2,053 71	1,213 43	6 636 37	MG/KG
MANGANESE	KAR	21	100 00	171 90	183 74	865 82	MG/KG
MERCURY	KAR	21	33 33	0 23	0 24	1 13	MG/KG
NICKEL	KAR	19	84 21	18 78	13 39	70 90	MG/KG
SELENIUM	KAR	19	31 58	0 90	1 01	4 85	MG/KG
SILVER	KAR	16	25 00	3 72	6 22	29 37	MG/KG
STRONTIUM	KAR	21	90 48	69 50	30 95	186 40	MG/KG
VANADIUM	KAR	20	90 00	20 70	8 76	54 25	MG/KG
ZINC	KAR	21	100 00	60 24	19 22	132 82	MG/KG

Table C-12 Geologic material UTLs by geologic unit for total radionuclides

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT

GEOLOGIC MATERIALS, TOTAL RADIONUCLIDES

ANALYTE	GEOLOGY	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM-137	COL	28	100 00	0 01	0 04	0 17	pCi/g
GROSS ALPHA	COL	28	100 00	31 95	8 90	63 10	pCi/g
GROSS BETA	COL	28	100 00	27 00	3 52	39 32	pCi/g
PLUTONIUM-239,240	COL	28	100 00	0 01	0 01	0 03	pCi/g
RADIUM-226	COL	21	100 00	1 07	0 18	1 77	pCi/g
RADIUM-228	COL	21	100 00	1 57	0.29	2.65	pCi/g
STRONTIUM-89 90	COL	28	100 00	-0 01	0 36	1 24	pCi/g
TRITIUM	COL	28	100 00	62.14	106 16	433 90	pCi/g
URANIUM, TOTAL	COL	28	100 00	1 86	0 73	4 41	pCi/g
URANIUM-233,234	COL	28	100 00	1 14	1 56	6 66	pCi/g
URANIUM-235	COL	28	100 00	0 04	0 06	0 24	pCi/g
URANIUM-238	COL	28	100 00	0 94	0 34	2.15	pCi/g
AMERICIUM-241	RFA	28	100 00	-0 00	0 01	0 02	pCi/g
CESIUM-137	RFA	62	100 00	0 01	0 04	0 14	pCi/g
GROSS ALPHA	RFA	62	100 00	22.32	8 18	47 21	pCi/g
GROSS BETA	RFA	62	100 00	24 10	6 75	44 62	pCi/g
PLUTONIUM-239 240	RFA	62	100 00	0 00	0 01	0 02	pCi/g
RADIUM 226	RFA	58	100 00	0 63	0 10	0 96	pCi/g
RADIUM 228	RFA	58	100 00	1 34	0 31	2.32	pCi/g
STRONTIUM-89 90	RFA	62	100 00	0 03	0 35	1 [illegible]	pCi/g
TRITIUM	RFA	62	100 00	172.90	122.68	545 96	pCi/g
URANIUM TOTAL	RFA	62	100 00	1.29	0 81	3 76	pCi/g
URANIUM 233,234	RFA	62	100 00	0 64	0 46	2 04	pCi/g
URANIUM-235	RFA	62	100 00	0 01	0 03	0 11	pCi/g
URANIUM-238	RFA	62	100 00	0 64	0 38	1 79	pCi/g
CESIUM 137	WCS	9	100 00	0 01	0 03	0 19	pCi/g
GROSS ALPHA	WCS	9	100 00	20 89	5 88	52.59	pCi/g
GROSS BETA	WCS	9	100 00	21 89	5 53	51 70	pCi/g
PLUTONIUM 239 240	WCS	9	100 00	0 01	0 01	0 07	pCi/g
RADIUM 226	WCS	4	100 00	0 68	0 15	2 53	pCi/g
RADIUM 228	WCS	4	100 00	1 42	0 29	4 98	pCi/g
STRONTIUM-89 90	WCS	9	100 00	0 17	0 44	2 56	pCi/g
TRITIUM	WCS	9	100 00	174 44	114 47	791 30	pCi/g
URANIUM TOTAL	WCS	9	100 00	1 36	0 21	2 50	pCi/g
URANIUM-233 234	WCS	9	100 00	0 60	0 12	1 26	pCi/g
URANIUM 235	WCS	9	100 00	0 02	0 07	0 38	pCi/g
URANIUM 238	WCS	9	100 00	0 73	0 12	1 39	pCi/g
CESIUM-137	KAR	21	100 00	0 00	0 00	0 00	pCi/g
GROSS ALPHA	KAR	21	100 00	29 98	8 42	61 78	pCi/g
GROSS BETA	KAR	21	100 00	25 76	3 85	40 29	pCi/g
PLUTONIUM 239 240	KAR	21	100 00	0 00	0 01	0 03	pCi/g
RADIUM 226	KAR	14	100 00	1 09	0 12	1 63	pCi/g
RADIUM 228	KAR	14	100 00	1 30	0 19	2 14	pC g
STRONTIUM-89 90	KAR	21	100 00	-0 11	0 36	1 24	pCi/g
TRITIUM	KAR	21	100 00	65 95	122 69	529 32	pCi/g
URANIUM TOTAL	KAR	21	100 00	1 96	0 64	4 40	pCi/g
URANIUM 233 234	KAR	21	100 00	0 96	0 39	2 42	pCi/g
URANIUM 235	KAR	21	100 00	0 04	0 08	0 35	pCi/g
URANIUM 238	KAR	21	100 00	0 98	0 25	1 92	pC g

Table C-13 Geologic material UTLs by geologic unit for total "water-quality" parameters

UPPER TOLERANCE LIMITS BY GEOLOGIC UNIT GEOLOGIC MATERIALS, TOTAL "WATER-QUALITY" PARAMETERS							
ANALYTE	GEOLOGY	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
PH	COL	28	100 00	8.26	0 45	5 / 10	PH UNITS
SULFIDE	COL	27	18 52	1 87	1 39	6 36	MG/KG
PH	RFA	60	100 00	7 97	0 77	5 / 10 4	PH UNITS
SULFIDE	RFA	53	32 08	2.27	3 02	30 082.97	MG/KG
NITRATE/NITRITE	WCS	9	33 33	1 08	0 62	4 44	MG/KG
PH	WCS	9	100 00	7 41	0 18	5 / 9	PH UNITS
SULFIDE	WCS	9	22.22	3 00	1 84	6 00	MG/KG
PH	KAR	21	100 00	8 43	0 87	5 / 11 7	PH UNITS

Table C-14 Geologic material UTLs by flow-system for total metals

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GEOLOGIC MATERIALS, TOTAL METALS

ANALYTE	FLOW SYSTEM	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	LOWER	21	100 00	7 482.60	2,681 30	17 608 83	MG/KG
ARSENIC	LOWER	21	66 67	3 72	3 26	16 05	MG/KG
BARIUM	LOWER	21	95 24	99 40	55 10	307 51	MG/KG
BERYLLIUM	LOWER	21	100 00	3 35	3 16	15 29	MG/KG
CADMIUM	LOWER	19	57 89	0 83	0 37	2.28	MG/KG
CALCIUM	LOWER	21	100 00	5 477 14	1 831 78	12 395 06	MG/KG
CESIUM	LOWER	16	93 75	223 62	31 26	352.50	MG/KG
CHROMIUM	LOWER	21	100 00	8 91	2.98	20 18	MG/KG
COBALT	LOWER	21	23 81	6 74	7 20	33 94	MG/KG
COPPER	LOWER	20	100 00	15 76	5 93	38 48	MG/KG
IRON	LOWER	20	100 00	12,963 25	8 753 38	46 502 32	MG/KG
LEAD	LOWER	21	100 00	18 91	6 19	42 29	MG/KG
LITHIUM	LOWER	21	28 57	7 17	8 39	38 84	MG/KG
MAGNESIUM	LOWER	21	66 67	2,053 71	1 213 43	6 636 37	MG/KG
MANGANESE	LOWER	21	100 00	171 90	183 74	865 82	MG/KG
MERCURY	LOWER	21	33 33	0 23	0 24	1 13	MG/KG
NICKEL	LOWER	19	84 21	18 78	13 39	70 90	MG/KG
SELENIUM	LOWER	19	31 58	0 90	1 01	4 85	MG/KG
SILVER	LOWER	16	25 00	3 72	6 22	29 37	MG/KG
STRONTIUM	LOWER	21	90 48	69 50	30 95	186 40	MG/KG
VANADIUM	LOWER	20	90 00	20 70	8 76	54 25	MG/KG
ZINC	LOWER	21	100 00	60 24	19 22	132 82	MG/KG
ALUMINUM	UPPER	98	100 00	12 752 03	11 310 57	39 105 66	MG/KG
ARSENIC	UPPER	99	74 75	3 88	4 63	14 66	MG/KG
BARIUM	UPPER	99	88 89	96 46	96 46	321 20	MG/KG
BERYLLIUM	UPPER	99	90 91	4 78	4 71	15 75	MG/KG
CADMIUM	UPPER	81	48 5	0 82	0 44	2 17	MG/KG
CALCIUM	UPPER	99	85 86	6 951 09	16 215 59	44 733 41	MG/KG
CESIUM	UPPER	95	77 89	230 46	273 51	867 74	MG/KG
CHROMIUM	UPPER	99	100 00	19 61	24 33	76 30	MG/KG
COBALT	UPPER	99	30 30	7 50	10 77	32 60	MG/KG
COPPER	UPPER	99	90 91	12 57	12 82	42 43	MG/KG
IRON	UPPER	99	100 00	14 531 98	13 257 27	45 421 42	MG/KG
LEAD	UPPER	99	100 00	10 87	7 05	27 29	MG/KG
LITHIUM	UPPER	99	45 45	11 76	11 45	38 45	MG/KG
MAGNESIUM	UPPER	99	63 64	2 584 42	3 365 51	10 426 06	MG/KG
MANGANESE	UPPER	99	100 00	217 64	341 96	1 014 41	MG/KG
MERCURY	UPPER	86	33 72	0 24	0 64	2.20	MG/KG
NICKEL	UPPER	96	90 62	20 73	20 74	69 05	MG/KG
POTASSIUM	UPPER	98	28 57	1 311 57	2 442 62	7 002 88	MG/KG
SELENIUM	UPPER	82	25 6	1 22	1 79	6 68	MG/KG
SILVER	UPPER	83	40 96	5 62	9 46	34 39	MG/KG
STRONTIUM	UPPER	99	43 43	65 62	72 88	235 42	MG/KG
TIN	UPPER	92	22 83	61 75	112 28	323 37	MG/KG
VANADIUM	UPPER	99	97 98	31 49	28 50	97 89	MG/KG
ZINC	UPPER	98	95 92	36 86	51 12	155 97	MG/KG

Table C-15 Geologic material UTLs by flow-system for total radionuclides

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

GEOLOGIC MATERIALS, TOTAL RADIONUCLIDES

ANALYTE	FLOW SYSTEM	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
CESIUM 137	LOWER	21	100 00	0 00	0 00	0 00	pCi/g
GROSS ALPHA	LOWER	21	100 00	29 98	8 42	61 78	pCi/g
GROSS BETA	LOWER	21	100 00	25 76	3 85	40 29	pCi/g
PLUTONIUM 239,240	LOWER	21	100 00	0 00	0 01	0 03	pCi/g
RADIUM 226	LOWER	14	100 00	1 09	0 12	1 63	pCi/g
RADIUM 228	LOWER	14	100 00	1 30	0 19	2 14	pCi/g
STRONTIUM-89 90	LOWER	21	100 00	-0 11	0 36	1 24	pCi/g
TRITIUM	LOWER	21	100 00	65 95	122 69	529 32	pCi/g
URANIUM TOTAL	LOWER	21	100 00	1 96	0 64	4 40	pCi/g
URANIUM-233 234	LOWER	21	100 00	0 96	0 39	2 42	pCi/g
URANIUM 235	LOWER	21	100 00	0 04	0 08	0 35	pCi/g
URANIUM 238	LOWER	21	100 00	0 98	0 25	1 92	pCi/g
AMERICIUM 241	UPPER	28	100 00	-0 00	0 01	0 02	pCi/g
CESIUM 137	UPPER	99	100 00	0 01	0 04	0 11	pCi/g
GROSS ALPHA	UPPER	99	100 00	24 91	9 28	49 48	pCi/g
GROSS BETA	UPPER	99	100 00	24 72	6 06	40 75	pCi/g
PLUTONIUM 239 240	UPPER	99	100 00	0 00	0 01	0 02	pCi/g
RADIUM 226	UPPER	83	100 00	0 75	0 23	1 45	pCi/g
RADIUM 228	UPPER	83	100 00	1 40	0 32	2 37	pCi/g
STRONTIUM-89 90	UPPER	99	100 00	0 03	0 36	0 98	pCi/g
TRITIUM	UPPER	99	100 00	141 72	126 75	477 09	pCi/g
URANIUM TOTAL	UPPER	99	100 00	1 46	0 79	3 55	pCi/g
URANIUM 233 234	UPPER	99	100 00	0 78	0 93	3 25	pCi/g
URANIUM 235	UPPER	99	100 00	0 02	0 05	0 14	pCi/g
URANIUM 238	UPPER	99	100 00	0 73	0 38	1 73	pCi/g

Table C-16 Geologic material UTLs by flow-system for total "water-quality" parameters

UPPER TOLERANCE LIMITS BY FLOW-SYSTEM

TOTAL "WATER-QUALITY" PARAMETERS

ANALYTE	FLOW SYSTEM	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	UTL 99 / 99	UNITS
PH	LOWER	21	100 00	8 43	0 87	11 73	PH UNIT
PH	UPPER	97	100 00	8 00	0 69	9 61	PH UNIT
SULFIDE	UPPER	88	27 27	2.22	2 52	9 88	MG/KG

T ble C-17 Stream water UTLs for dissolved metals

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM WATER, DISSOLVED METALS						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	134	41 79	89 80	185 40	475 18	UG/L
ANTIMONY	92	29 35	18 01	17 68	59 20	UG/L
BARIUM	145	57.24	45 17	35 44	127 74	UG/L
CALCIUM	154	93 51	23 621 75	11 474 97	50 358 44	UG/L
COPPER	125	37 60	5 90	4 97	17 48	UG/L
IRON	153	68 63	144 92	178 41	560 62	UG/L
LEAD	113	27 43	1 33	1 63	5 14	UG/L
LITHIUM	119	33 61	15 71	20 58	63 66	UG/L
MAGNESIUM	150	76.67	4,735 82	2,173 67	9 800 47	UG/L
MANGANESE	149	71 14	28 02	47 73	139 22	UG/L
PHOSPHORUS	6	100 00	194 83	124 91	1 111 00	UG/L
POTASSIUM	126	51 59	1 427 16	926 51	3 585 92	UG/L
SELENIUM	85	25 88	2.24	3 63	13 26	UG/L
SODIUM	153	94 12	16 603 04	7 508 05	34 096 80	UG/L
STRONTIUM	139	69 06	241 81	313 57	972 43	UG/L
TIN	99	21.21	28 52	23 40	83 05	UG/L
ZINC	139	58 99	13 59	18 14	55 86	UG/L

Table C-18 Stream water UTLs for total metals

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM WATER, TOTAL METALS						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	139	78 42	747 63	1 349 84	3 892 76	UG/L
ARSENIC	110	27.27	1 73	1 76	5 84	UG/L
BARIUM	131	68 70	58 84	34 02	138 1	UG/L
CALCIUM	153	94 77	23 601 21	11 100 19	49 464 66	UG/L
COPPER	121	41 32	5 59	4 87	16 95	UG/L
IRON	157	89 81	1 247 08	2 866 81	7 926 75	UG/L
LEAD	131	35 88	1 88	2.35	7 36	UG/L
LITHIUM	126	41.27	11 77	17 42	52.35	UG/L
MAGNESIUM	146	81 51	4 901 94	2 107 61	9 812.55	UG/L
MANGANESE	151	78 81	84 76	343 57	885 29	UG/L
PHOSPHORUS	6	83 33	186 25	138 68	1 203 40	UG/L
POTASSIUM	128	57 03	1 669 97	1 071 73	4 167 09	UG/L
SELENIUM	120	21 67	1 55	2 05	6 33	UG/L
SILICON	67	100 00	6 076 23	3 [illegible] 7 17	16 346 19	UG/L
SODIUM	155	92.90	16 060 41	7 620 96	33 817 24	UG/L
STRONTIUM	135	63 70	171 63	179 61	590 13	UG/L
TIN	118	20 34	20 18	20 13	67 07	UG/L
VANADIUM	120	27 50	6 97	9 36	28 76	UG/L
ZINC	151	67 55	31 91	61 69	175 64	UG/L

Table C-19 Stream water UTLs for dissolved radionuclides

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM WATER, DISSOLVED RADIONUCLIDES						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	34	100 00	0 07	0 13	0 50	pCi/L
CESIUM 134	3	100 00	2.27	0 10	4 67	pCi/L
CESIUM-137	10	100 00	0 82	1.22	6 99	pCi/L
GROSS ALPHA	61	100 00	1 81	8 85	28 71	pCi/L
GROSS BETA	61	100 00	4 69	6 78	25 30	pCi/L
GROSS GAMMA	24	100 00	0 70	0 25	1 63	pCi/L
PLUTONIUM-236	4	100 00	0 00	0 01	0 07	pCi/L
PLUTONIUM-238	4	100 00	0 01	0 01	0 07	pCi/L
PLUTONIUM-239 240	36	100 00	0 12	0 20	0 79	pCi/L
RADIUM-226	3	100 00	0 19	0.21	5 23	pCi/L
RADIUM 228	2	100 00	1 05	0 49	92.93	pCi/L
STRONTIUM-89 90	87	100 00	0 73	0 55	2.42	pCi/L
TRITIUM	56	100 00	185 58	416 00	1 498 07	pCi/L
URANIUM TOTAL	6	100 00	0 72	0 48	4 27	pCi/L
URANIUM 233,234	56	100 00	0 92	4.21	14 20	pCi/L
URANIUM 235	56	100 00	0 14	0 20	0 78	pCi/L
URANIUM-238	56	100 00	0 71	3 24	10 93	pCi/L

Table C-20 Stream water UTLs for total radionuclides

UPPER TOLERANCE LIMITS (SITE-WIDE) STREAM WATER, TOTAL RADIONUCLIDES						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	106	100 00	0 00	0 01	0 02	pCi/g
CESIUM-134	8	100 00	1 53	1 29	9 04	pCi/g
CESIUM 137	93	100 00	0 23	0 60	1 63	pCi/g
GROSS ALPHA	88	100 00	2 96	8 25	28 06	pCi/g
GROSS BETA	84	100 00	5 49	8 17	30 35	pCi/g
PLUTONIUM 236	12	100 00	-0 00	0 00	0 01	pCi/g
PLUTONIUM 238	12	100 00	-0 00	0 01	0 03	pCi/g
PLUTONIUM-239 240	105	100 00	0 00	0 01	0 02	pCi/g
RADIUM 226	4	100 00	1 07	1 25	16 56	pCi/g
STRONTIUM-89 90	75	100 00	0 92	1 30	4 88	pCi/g
TRITIUM	73	100 00	75 71	209 22	711 94	pCi/g
URANIUM TOTAL	17	100 00	0 59	0 52	2.69	pCi/g
URANIUM 233 234	79	100 00	0 49	0 55	2 16	pCi/g
URANIUM 235	75	100 00	0 05	0 07	0 28	pCi/g
URANIUM 238	55	100 00	0 36	0 43	1 73	pCi/g

Table C-21 Stream water UTLs for water-quality parameters

UPPER TOLERANCE LIMITS (SITE-WIDE)						
STREAM WATER, WATER-QUALITY PARAMETERS						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	154	100 00	97 571.20	40 237.29	191 324 08	UG/L
CARBONATE	154	24 03	2,999 74	1 937 53	7 514 19	UG/L
CBOD5	10	100 00	7 635 00	3 912.66	27 486 77	UG/L
CHLORIDE	151	92.05	16 833 01	15 608 95	53 201 88	UG/L
CYANIDE	129	31 01	2,221 93	5 220 92	14 386 67	UG/L
DISSOLVED ORGANIC CARBON	35	100 00	6 102.57	3 267 38	16 997 16	UG/L
FLUORIDE	100	98 00	338 41	107 90	589 81	UG/L
NITRATE/NITRITE	153	56 86	324 55	438 84	1 347 05	UG/L
NITRITE	85	22.35	13 98	14 74	58 81	UG/L
OIL AND GREASE	105	33 33	4 024 29	3 756 06	12,775 89	UG/L
PH	51	98 04	7 34	0 63	9 32	PH UNITS
PHOSPHORUS	102	35 29	43 68	55 07	171 98	UG/L
SILICA	95	97 89	11 128 11	7 265 36	28 056 40	UG/L
SULFATE	151	98 01	18 782.45	8 174 66	37 829 40	UG/L
TOTAL DISSOLVED SOLIDS	151	100 00	170 119 21	56 721 65	302,280 65	UG/L
TOTAL ORGANIC CARBON	49	100 00	7 466 94	4 621 53	22 047 87	UG/L
TOTAL SUSPENDED SOLIDS	159	59 75	18 877 99	45 772.72	125 528 42	UG/L

Table C-22 Seep/spring water UTLs for dissolved metals

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING WATER, DISSOLVED METALS						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	43	25 58	42 77	30 04	137 54	UG/L
ANTIMONY	30	30 00	25 89	28 49	124 08	UG/L
BARIUM	47	44 68	71 95	42.39	205 69	UG/L
CALCIUM	50	98 00	50 222.00	34 498.38	159 064 39	UG/L
COPPER	41	24 39	6 01	5 51	23 40	UG/L
IRON	49	69 39	1 927 00	4 082.76	14 808 10	UG/L
LEAD	42	21 43	1 08	0 86	3 81	UG/L
LITHIUM	43	32.56	29 45	20 72	94 84	UG/L
MAGNESIUM	47	72 34	7 002 07	5 198 40	23 403 02	UG/L
MANGANESE	44	86 36	127 57	185 52	712.90	UG/L
MERCURY	22	22.73	0 18	0 26	1 16	UG/L
MOLYBDENUM	34	20 59	33 81	21 07	104 49	UG/L
POTASSIUM	39	41 03	1 389 94	1 640 62	6 745 06	UG/L
SODIUM	50	98 00	12,297 00	5 585 54	29 919 38	UG/L
STRONTIUM	45	77 78	481 40	401 87	1 749 29	UG/L
ZINC	46	45 65	15 68	21 13	82.33	UG/L

Table C-23 Seep/spring water UTLs for total metals

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING WATER, TOTAL METALS						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	48	83 33	18 115 18	47 149 24	166 871 02	UG/L
ANTIMONY	34	32 35	46 68	108 89	411 91	UG/L
ARSENIC	44	59 09	69 77	192 06	675 73	UG/L
BARIUM	44	75 00	913 39	1 692 11	6 252 00	UG/L
BERYLLIUM	38	34 21	2 81	3 37	13 86	UG/L
CADMIUM	33	30 30	9 08	17 25	67 29	UG/L
CALCIUM	53	90 57	94 329 72	128 636 27	500 177 15	UG/L
CESIUM	33	24 24	419 98	449 37	1 936 79	UG/L
CHROMIUM	40	40 00	23 69	49 27	183 74	UG/L
COBALT	35	34 29	43 39	90 97	346 73	UG/L
COPPER	44	52 27	43 89	99 94	359 20	UG/L
CYANIDE	5	40 00	5 95	7 48	72 83	UG/L
IRON	51	88 24	175 074 71	518 671 63	1 811 483 71	UG/L
LEAD	45	66 67	91 14	207 26	745 05	UG/L
LITHIUM	35	48 57	29 43	26 57	118 02	UG/L
MAGNESIUM	50	80 00	10 370 60	7 644 36	34 488 56	UG/L
MANGANESE	51	80 39	1 798 04	5 027 04	17 658 34	UG/L
MOLYBDENUM	33	27 27	33 46	39 12	155 51	UG/L
NICKEL	35	37 14	50 68	116 39	438 78	UG/L
POTASSIUM	41	48 78	3 386 23	3 069 81	13 071 50	UG/L
SELENIUM	36	38 89	3 31	3 72	15 64	UG/L
SILICON	11	100 00	8 408 18	3 027 84	23 029 71	UG/L
SILVER	32	31 25	10 05	25 69	97 35	UG/L
SODIUM	53	88 68	12,005 80	5 016 89	27 834 09	UG/L
STRONTIUM	42	61 90	506 16	476 35	2 009 06	UG/L
TIN	35	37 14	94 03	190 89	730 54	UG/L
VANADIUM	41	51 22	117 09	280 76	1 002 88	UG/L
ZINC	50	82 00	195 22	431 42	1 556 36	UG/L

Table C-24 Seep/spring water UTLs for dissolved radionuclides

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING WATER, DISSOLVED RADIONUCLIDES						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	8	100 00	0 13	0 28	1 76	pCi/L
CESIUM-137	3	100 00	-0 27	0 21	4 71	pCi/L
GROSS ALPHA	13	100 00	2.78	5 21	26 09	pCi/L
GROSS BETA	14	100 00	5 94	10 09	49 69	pCi/L
GROSS GAMMA	5	100 00	1 09	1 25	12.27	pCi/L
PLUTONIUM-239 240	8	100 00	0 10	0 16	1 02	pCi/L
RADIUM 226	2	100 00	0 99	1 30	242.36	pCi/L
STRONTIUM-89 90	20	100 00	0 52	0 39	2.01	pCi/L
TRITIUM	13	100 00	301.25	298 70	1 637 06	pCi/L
URANIUM TOTAL	3	100 00	1 90	2.43	59 89	pCi/L
URANIUM-233,234	13	100 00	0 91	0 73	4 19	pCi/L
URANIUM 235	12	100 00	0 12	0 13	0 72	pCi/L
URANIUM-238	13	100 00	0 60	0 54	3 03	pCi/L

Table C-25 Seep/spring water UTLs for total radionuclides

UPPER TOLERANCE LIMITS (SITE-WIDE)						
SEEP / SPRING WATER TOTAL RADIONUCLIDES						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM 241	37	100 00	0 01	0 02	0 08	pCi/L
CESIUM-137	37	100 00	0 58	1 99	7 16	pCi/L
GROSS ALPHA	36	100 00	42.52	89 77	340 13	pCi/L
GROSS BETA	10	100 00	2.15	1 50	9 74	pCi/L
PLUTONIUM 239 240	33	100 00	0 21	0 78	2.85	pCi/L
RADIUM 226	12	100 00	7 72	9 10	49 88	pCi/L
RADIUM-228	5	100 00	16 38	14 11	142.53	pCi/L
STRONTIUM-89 90	32	100 00	0 32	0 38	1 61	pCi/L
TRITIUM	31	100 00	-87 72	1 275 95	4 277 76	pCi/L
URANIUM TOTAL	9	100 00	0 85	0 63	4 23	pCi/L
URANIUM 233 234	33	100 00	0 64	1.29	4 99	pCi/L
URANIUM 235	32	100 00	0 02	0 08	0 31	pCi/L
URANIUM-238	28	100 00	0 64	1.21	4 89	pCi/L

Table C-26 Seep/spring water UTLs for water-quality parameters

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING WATER WATER-QUALITY PARAMETERS

ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
BICARBONATE	60	100 00	321 643 17	574 858 46	2 135 321 61	UG/L
CARBONATE	55	43 64	4 495 68	4 965 08	20 160 52	UG/L
CHLORIDE	53	90 57	12,523 58	17 061 93	66 353 96	UG/L
CYANIDE	46	26 09	7 11	7 00	29 21	UG/L
DISSOLVED ORGANIC CARBON	5	100 00	5 000 00	2,236 07	24 988 27	UG/L
FLUORIDE	18	100 00	552 22	264 88	1 601 23	UG/L
NITRATE/NITRITE	53	60 38	945 19	2 118 91	7 630 34	UG/L
OIL AND GREASE	24	37 50	2,448 13	1 934 86	9 490 08	UG/L
PH	35	100 00	7,22	0 43	8 64	PH UNITS
PHOSPHORUS	18	61 11	354 94	804 15	3 539 67	UG/L
SILICA	17	100 00	17 025 45	8 569 50	51 617 95	UG/L
SULFATE	53	96 23	46 962.26	87 305 62	322 411 50	UG/L
TOTAL DISSOLVED SOLIDS	53	100 00	263 867 92	174 307 09	813 806 81	UG/L
TOTAL ORGANIC CARBON	7	100 00	9 014 29	3 184 56	29 433 51	UG/L
TOTAL SUSPENDED SOLIDS	54	87 04	2,712,305 56	7 791 125 40	27 293 306 20	UG/L

Table C-27 Stream sediment UTLs for total metals

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM SEDIMENTS, TOTAL METALS

ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	59	100 00	5 887 61	4 912 73	21 387 27	MG/KG
ANTIMONY	52	44 23	4 55	4 16	17 68	MG/KG
ARSENIC	59	69 49	2.24	2.50	10 13	MG/KG
BARIUM	57	84.21	74 47	56 85	253 82	MG/KG
BERYLLIUM	57	63 16	0 93	3 40	11 65	MG/KG
CADMIUM	51	39 22	0 72	0 58	2.55	MG/KG
CALCIUM	59	81 36	3 554 57	4 719 98	18 446 12	MG/KG
CESIUM	56	82.50	101 77	107 96	442 39	MG/KG
CHROMIUM	59	84 75	8 25	7 49	31 88	MG/KG
COBALT	59	76 27	5 16	3 57	16 43	MG/KG
COPPER	59	83 05	10 81	8 23	36 78	MG/KG
IRON	59	100 00	8 852.63	6 263 19	28 612 98	MG/KG
LEAD	59	100 00	22.02	36 79	138 09	MG/KG
LITHIUM	57	91 23	10 01	9 83	41 01	MG/KG
MAGNESIUM	59	79 66	1 404 18	1 253 37	5 358 56	MG/KG
MANGANESE	59	100 00	229 52	214 85	907 35	MG/KG
MERCURY	49	48 98	0 12	0 11	0 46	MG/KG
MOLYBDENUM	58	53 45	5 48	8 33	31 75	MG/KG
NICKEL	57	75 44	7 01	5 44	24 16	MG/KG
POTASSIUM	58	70 69	812.50	743 98	3 159 74	MG/KG
SELENIUM	58	43 10	0 45	0 55	2.18	MG/KG
SILICON	19	100 00	331 53	362 31	1 741 79	MG/KG
SILVER	54	33 33	0 86	0 71	3 11	MG/KG
SODIUM	59	79 66	161 47	136 80	593 09	MG/KG
STRONTIUM	58	89 66	45 62	77 91	291 42	MG/KG
THALLIUM	50	24 00	0 34	0 24	1 10	MG/KG
TIN	54	53 70	9 69	9 79	40 57	MG/KG
VANADIUM	57	91 23	18 15	14 34	63 39	MG/KG
ZINC	58	98 28	44 44	29 98	139 04	MG/KG

Table C-28 Stream sediment UTLs for total radionuclides

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM SEDIMENTS, TOTAL RADIONUCLIDES

ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM 241	37	100 00	0 17	0 48	1 77	pCi/g
CESIUM-137	35	100 00	0 26	0 38	1 54	pCi/g
GROSS ALPHA	45	100 00	22.98	20 46	87 54	pCi/g
GROSS BETA	43	100 00	35 35	9 98	66 83	pCi/g
PLUTONIUM-238	5	100 00	0 00	0 00	0 00	pCi/g
PLUTONIUM 239,240	45	100 00	0 54	1 61	5 62	pCi/g
RADIUM 226	21	100 00	0 85	0 36	2 2	pCi/g
RADIUM 228	20	100 00	1 70	0 74	4 55	pCi/g
STRONTIUM-89 90	43	100 00	0 21	0 27	1 07	pCi/g
TRITIUM	42	100 00	194 30	265 07	1 030 59	pCi/g
URANIUM TOTAL	6	100 00	1 48	0 69	6 57	pCi/g
URANIUM 233,234	47	100 00	1 68	1 15	5.29	pCi/g
URANIUM-235	49	100 00	0 06	0 05	0 21	pCi/g
URANIUM 238	36	100 00	1 40	1 03	4 82	pCi/g

Table C-29 Stream sediment UTLs for total "water-quality" parameters

UPPER TOLERANCE LIMITS (SITE-WIDE)

STREAM SEDIMENTS, TOTAL "WATER-QUALITY" PARAMETERS

ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALKALINITY AS CACO3	28	92 86	1 970 44	5 102 72	19 839 86	MG/KG
BICARBONATE AS CACO3	4	100 00	1 041 25	1 449 27	18 993 76	MG/KG
NITRATE/NITRITE	52	71 15	7 76	15 67	57 19	MG/KG
NITRITE	12	83 33	0 34	0 19	1 21	MG/KG
PH	51	100 00	7 26	0 66	9 34	PH UNITS
TOTAL ALKALINITY	6	100 00	4 470 00	8 116 00	63 997 31	MG/KG

Table C-30 Seep/spring sediment UTLs for total metals

UPPER TOLERANCE LIMITS (SITE-WIDE)

SEEP / SPRING SEDIMENTS, TOTAL METALS

ANALYTE	SAMPLE SIZE, N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALUMINUM	20	100 00	10 354 30	5 010 71	29 553 14	MG/KG
ANTIMONY	18	44 44	8 81	8 14	41 04	MG/KG
ARSENIC	20	90 00	12.55	14 23	67 25	MG/KG
BARIUM	20	95 00	204 61	155 62	800 88	MG/KG
BERYLLIUM	16	81.25	1 13	0 92	4 94	MG/KG
CADMIUM	16	43 75	1 65	1 66	8 52	MG/KG
CALCIUM	20	100 00	19 407 50	16 059 56	80 940 62	MG/KG
CESIUM	17	52.94	260 47	200 55	1 070 01	MG/KG
CHROMIUM	18	94 44	10 98	5 27	31 87	MG/KG
COBALT	19	84 21	8 47	5 48	29 81	MG/KG
COPPER	18	94 44	18 74	10 68	61 04	MG/KG
IRON	18	100 00	20 763 89	22,673 64	110 559 63	MG/KG
LEAD	18	100 00	36 37	22 64	126 03	MG/KG
LITHIUM	18	88 89	19 79	20 12	99 49	MG/KG
MAGNESIUM	20	80 00	2,249 30	1 152.86	6 666 56	MG/KG
MANGANESE	19	100 00	261 63	273 79	1 327 33	MG/KG
MERCURY	15	33 33	0 23	0 31	1 55	MG/KG
MOLYBDENUM	19	57 89	15 77	19 74	92.59	MG/KG
NICKEL	17	88.24	12.99	7 51	43 31	MG/KG
POTASSIUM	18	61 11	1 050 72	616 83	3 493 61	MG/KG
SELENIUM	19	68 42	1 25	0 98	5 07	MG/KG
SILICON	10	100 00	1 698 70	2 117 17	12,440 63	MG/KG
SILVER	15	46 67	2.15	1 98	10 49	MG/KG
SODIUM	20	60 00	251 62	294 04	1 378 24	MG/KG
STRONTIUM	20	90 00	113 70	92 03	466 32	MG/KG
THALLIUM	13	30 77	1 42	2 44	12 33	MG/KG
TIN	19	57 89	22 18	18 75	95 16	MG/KG
VANADIUM	19	100 00	27 63	14 21	82 96	MG/KG
ZINC	20	100 00	56 13	22 67	143 00	MG/KG

Table C-31 Seep/spring sediment UTLs for total radionuclides

UPPER TOLERANCE LIMITS (SITE-WIDE) SEEP / SPRING SEDIMENTS, TOTAL RADIONUCLIDES						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
AMERICIUM-241	14	100 00	0 13	0 31	1 46	pCi/g
CESIUM 137	13	100 00	0 61	0 60	3 51	pCi/g
GROSS ALPHA	15	100 00	19 71	14 00	78 83	pCi/g
GROSS BETA	14	100 00	23 73	5 08	45 78	pCi/g
PLUTONIUM 238	3	100 00	0 00	0 00	0 01	pCi/g
PLUTONIUM-239 240	16	100 00	0 61	1 71	7 68	pCi/g
RADIUM-226	9	100 00	0 71	0 24	1 97	pCi/g
RADIUM-228	9	100 00	1 18	0 32	2.88	pCi/g
STRONTIUM-89 90	14	100 00	0 35	0 52	2.63	pCi/g
TRITIUM	13	100 00	198 54	127 73	769 75	pCi/g
URANIUM TOTAL	3	100 00	1 87	0 59	15 87	pCi/g
URANIUM 233,234	16	100 00	0 82	0 38	2.39	pCi/g
URANIUM 235	17	100 00	0 04	0 05	0 25	pCi/g
URANIUM 238	14	100 00	0 73	0 41	2.52	pCi/g

Table C-32 Seep/spring sediment UTLs for total "water-quality" parameters

UPPER TOLERANCE LIMITS (SITE-WIDE) SEEP / SPRING SEDIMENTS, "WATER-QUALITY" PARAMETERS						
ANALYTE	SAMPLE SIZE N	PERCENT DETECTS	MEAN	STANDARD DEVIATION	99 / 99 UTL	UNITS
ALKALINITY AS CACO3	8	100 00	14 192.25	27 343 99	173 110 00	MG/KG
NITRATE/NITRITE	17	52.94	4 14	3 90	19 89	MG/KG
NITRITE	3	100 00	1 33	1 53	37 91	MG/KG
PH	18	100 00	7 24	0 56	9 47	PH UNITS
TOTAL ALKALINITY	4	75 00	750 25	1 499 83	19 329 11	MG/KG

SURFICIAL SOILS FROM ROCK CREEK

TOTAL METALS

Analyte	MEAN	STD DEV	N	TOL FACT	99 / 99 UTL	UNITS
Aluminum	12992 9	2251 53	1	3 9604	21909 86	MG/KG
Antimony	10 525	1 724	18	3 9604	17 35	MG/KG
Arsenic	5 817	1 818	18	3 9604	13 02	MG/KG
Barium	195 2	84 63	18	3 9604	530 37	MG/KG
Beryllium	0 983	0 256	18	3 9604	2 00	MG/KG
Cadmium	1 048	0 302	17	4 0367	2 51	MG/KG
Calcium	5068 1	2220 5	18	3 9604	13862 17	MG/KG
Cesium	61 43	61 43	18	3 9604	304 72	MG/KG
Chromium	15 207	2 798	19	3 8924	26 10	MG/KG
Cobalt	7 781	4 305	18	3 9604	24 83	MG/KG
Copper	12 964	3 629	18	3 9604	27 34	MG/KG
Iron	15381 7	3226 62	18	3 9604	28160 41	MG/KG
Lead	37 535	6 024	18	3 9604	61 39	MG/KG
Lithium	10 98	2 273	18	3 9604	19 98	MG/KG
Magnesium	2853 3	1049 95	18	3 9604	7011 52	MG/KG
Manganese	443 67	457 01	18	3 9604	2253 61	MG/KG
Mercury	0 09256	0 0306	18	3 9604	0 21	MG/KG
Molybdenum	3 31997	1 59652	18	3 9604	9 64	MG/KG
Nickel	12 578	3 588	18	3 9604	26 79	MG/KG
Potassium	2977 9	575 47	18	3 9604	5256 99	MG/KG
Selenium	0 4785	0 1468	18	3 9604	1 06	MG/KG
Silicon	780 95	700 452	18	3 9604	3555 06	MG/KG
Silver	1 726	0 693	18	3 9604	4 47	MG/KG
Sodium	175 14	75 031	18	3 9604	472 29	MG/KG
Strontium	35 331	13 811	18	3 9604	90 03	MG/KG
Thallium	0 3773	0 1204	18	3 9604	0 85	MG/KG
Tin	38 346	9 2105	18	3 9604	74 82	MG/KG
Vanadium	31 603	6 049	18	3 9604	55 56	MG/KG
Zinc	55 824	7 795	18	3 9604	86 70	MG/KG

SURFICIAL SOILS FROM ROCK CREEK

TOTAL RADIONUCLIDES

Analyte	MEAN	STD DEV	N	TOL FACT	99 / 99 UTL	UNITS
Americium 241	0 01854	0 0092	15	4 2224	0 06	PCI/G
Cesium 137	1 41	0 4897	12	4 633	3 68	PCI/G
Gross alpha	9 825	4 916	10	5 0737	44 77	PCI/G
Gross beta	32 031	5 599	19	3 8924	54 21	PCI/G
Plutonium 239 240	0 05523	0 02023	16	3 9604	0 14	PCI/G
Radium 226	0 94538	0 12813	10	5 0737	1 60	PCI/G
Radium 228	2 1767	0 5309	10	5 0737	4 87	PCI/G
Strontium-89 90	0 61837	0 29768	9	5 3889	2 22	PCI/G
Uranium 233 234	1 14497	0 15557	16	4 1233	1 79	PCI/G
Uranium 235	0 05263	0 00271	16	4 1233	0 19	PCI/G
Uranium 238	1 18301	0 16799	16	4 1233	1 95	PCI/G

Where "TOL FACT" is the tolerance factor for the 99/99 UTL, and "STD DEV" is the standard deviation for sample size N. The 99/99 UTL is calculated as (TOL FACT * STD DEV) + MEAN. Metals are 89 percent validated, and radionuclides are 64 percent validated in this table.

RESPONSES TO EPA LETTER 8HWM-FF - STATISTICAL COMPARISONS TO BACKGROUND AT ROCKY FLATS DATED SEPTEMBER 21, 1993:

GENERAL COMMENTS

1 Overall, the report is outstanding It succinctly outlines a comprehensive paradigm for the background analysis of inorganic chemicals at RFP It is obvious that the multitiered approach, incorporating specific data quality objectives, presentation and graphic analysis, and a series of six statistical tests has been well thought-out and all possible scenarios considered and problems anticipated It directly addresses the predominant contentious and divisive issue, the proper application of the upper tolerance limit (UTL) approach that has been advanced by DOE

On a purely technical level, the approach is well-balanced However, the report appears to be overly concerned with Type I or false positive errors and not as concerned with Type II or false negative errors From a risk assessment standpoint, a Type I error can be easily managed if it is unknowingly included in the risk assessment since the analysis can be revisited and professional judgement applied if the risk associated with the chemical in question becomes unacceptable In contrast, a Type II error cannot be so easily managed If a Type II error is made, the chemical will be incorrectly eliminated early in the COC selection process and will not be further considered Although it is desirable to minimize or eliminate both types of errors from the analysis, from a public health perspective it is preferable to make a Type I error Chemicals included in the risk assessment from a Type I error will not automatically be remediated. EPA recommends that for risk assessment, sampling design should specify the probability of a Type I error as 20% and the probability of a Type II error as 10% or less This is an important item to reach consensus on between EPA, CDH, and DOE

> **Clarification.** It is necessary to reach a compromise between acceptable Type I error rates, acceptable Type II error rates, and cost Each OU should have addressed these issues in the OU-specific workplan approved by DOE and the Agencies The corresponding background data are now a matter of historical record, as this sampling program was terminated after four years of data collection At the September 29, 1993 meeting, all parties agreed to the Type I error rates incorporated into the current plan, which is 5% for the Gehan, quantile, slippage, t-test, and Wilcoxon Rank Sum tests, with the Type II error rate left unspecified However, it should be noted that the actual Type II error rate has been reduced, and the Type I error rate has been increased, because of the battery of tests The UTL test will increase the Type I error rate and reduce the Type II error rate as well

2 One additional problem that is not addressed in Dr Gilbert's report, perhaps because it was outside the scope of work, involves data aggregation This is a fundamental issue that has yet to receive the proper amount of focused attention Without an established methodology for aggregating data within different environmental media, the time and effort expended in executing the sophisticated statistical approach presented in this report will be misspent Although the report touches on some aspects of this broad problem, it does not directly discuss the issue

Therefore, EPA, CDH, and DOE need to address it

Clarification. Data aggregation is another topic, being addressed by DOE/RFO, CDH, and EPA separately from this forum, which deals strictly with site-to-background comparison

3 If the agencies can agree that the above concerns will be addressed, the background analysis approached developed by Dr Gilbert provides a well-balanced methodology that will, if implemented properly, lead to a robust background analysis This objective, scientific approach will result in verifiable conclusions, expedite the review and comment period, and prevent an overreliance on professional judgement

No response necessary.

SPECIFIC COMMENTS

1 Page 2 Seventh Bullet It is suggested that the same field sampling and laboratory procedures be used for both background and site data The statement should be extended to include data aggregation Past review of RFP data from operable units showed inconsistencies in the methodology used to aggregate data Problems encountered at this phase will be magnified at later stages of the background analysis

Concur. The same field sampling and laboratory procedures were used for both background and site data

Clarification. Data aggregation is another topic, being addressed by DOE/RFO, CDH, and EPA separately from this forum, which deals strictly with site-to-background comparison

2. Page 4, Task 1, Observation 1, Third Bullet This statement suggests that background analysis should be the initial state in selecting COCs This is consistent with the COC selection methodology developed for Rocky Flats by DOE, EPA, and CDH However, in order to manage DOE's effort in background comparisons, we point out that it is not necessary to carry all chemicals through an elaborate, time consuming statistical analysis if they can be eliminated as essential nutrients or as infrequently detected chemicals It may be more cost-effective and expeditious to simply eliminate chemicals on the basis of these two preliminary criteria than to conduct a background analysis only to eliminate them later based on the background analysis We suggest that DOE consider this in the development of a plan to implement Dr Gilbert's approach

Clarification. Essential nutrients have not been eliminated from the protocol in the statistical methodology This comment was withdrawn by EPA at the September 29, 1993 meeting

3 Page 5, Task 1, Observation 4 Second Bullet This statement expresses concern about measurements that are less than the contract required detection limits (CRQL) but above instrument detection limits (IDL) According to Risk Assessment Guidance for Superfund,

Human Health Evaluation Manual, Volume I, Part A, these measurements should be "J" coded and interpreted as estimated values They should not be viewed as non-detected chemicals If they are currently classified as non-detect chemicals in the RFP background geochemical report, the entire validation process currently in place should be revaluated

Clarification. There has been confusion over the detection limits and their application A qualifier of "J" indicates that the reported value is between the instrument detection limits and the contract required detection limits. A non-detect has a reported value of a detection limit, not the detected value, and conveys less information than a "J"

4 Page 9, Paragraphs 3 and 4 The essence of this discussion is that a hot measurement (HM) concentration should serve as a "safety net" that can prevent "hot spots" from passing unnoticed in a risk assessment. It should be noted that this need has been previously recognized and was addressed in the original flow chart devised during the summer 1992 meetings involving EPA, DOE, and CDH At that time, it was agreed that a risk-based concentration (RBC) would effectively serve as the "hot measurement " Although a UTL has some utility in identifying hot spots, there is no need to conduct a lengthy analysis if the highest detected concentrations do not exceed a predetermined RBC and pose an unacceptable human health risks Thus, it is possible to have measurements above the UTL but below an RBC in which case there would be little reason to consider the chemical further

Clarification. The Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data at the Rocky Flats Plant (called The Guide subsequently) addresses statistical determination of the presence or absence of analytes, and does not address human health effects For each OU, additional tests will determine if the analyte concentrations present are below regulatory (ARARs) and/or human health effect (PRGs) levels, but that is external to the statistical discussion at hand.

5. Page 10, Third and Fourth Bullet. This statement refers to lowering the potential for a Type I, false positive error to using a 99 percent UTL on the 99 percentile. However, this concern is not properly balanced against the potential for a Type II error. A false negative could have profound consequences on the risk assessment and subsequent remedy selected for the site

Do not concur. If the 95% UTL were used, then a very high percentage of data points would be considered pCoCs, because theoretically, even a background population will have 5% of readings above the UTL A site, even if its concentration levels are slightly above background, may have considerably more than 5% of its readings above the $UTL_{95/95}$ Any analytes that show a false negative on this test will still be considered pCoCs if they test positive on any of the other statistical tests

6 Page 11, Second Paragraph This paragraph suggests that data quality objectives (DQOs) be established at the design stage of the studies Although this is a relevant comment in the context of planning a background analysis, the background and most of the OU planning and sampling has already been completed Thus, this comment is appropriate in theory but there is little chance for implementation Revitalized effort should be directed to establishing DQOs where they were not previously established, and analyzing whether the sampling efforts

completed to date have succeeded in meeting these DQOs DOE, EPA, and CDH will need to look at options for correcting the situation if the DQOs have not been met

Concur. The draft RIs for each OU have a section for reviewing data quality Each OU manager bears the responsibility for ensuring that DQOs are met for his or her OU. This issue will be dealt with independently from the statistical methodology, as was agreed to by EPA, CDH, and DOE at the September 29, 1993 meeting.

7. Task 4. Flow Chart for Comparing OU Data to Background With a minor exception, this flow chart adequately describes the framework for a background analysis The exception is an inadequate description of appropriate conditions under which particular statistical tests should applied.

Explicit guidelines for the application of specific statistical tests under well-defined conditions should be presented to circumvent future misunderstandings. It would be highly useful for EPA, DOE, and CDH to agree to a predetermined paradigm in which all possible circumstances and conditions have been anticipated and the appropriate statistical tests identified Knowing in advance what particular test will be applied under what circumstances will prevent protracted discussions and possible disagreements.

Concur. The Background Comparison Methodology chart shows the specific tests and gives the conditions under which they are or are not applicable In addition, The Guide's text states which tests will be conducted, under what circumstances.

IMPLEMENTATION ISSUES

1 EPA, DOE, and CDH must reach consensus on procedures for defining non-detects

Concur. The Guide states that non-detects will be considered to be one-half of the reported detection limit, in accordance with EPA guidance

2. EPA, DOE, and CDH must reach consensus on what hot measurement value should be used

Concur. Our methodology uses a value of $UTL_{99/99}$.

3 EPA, DOE, and CDH must establish data quality objectives which address acceptable power and confidence levels, required detection limits, and anticipated data aggregation

Clarification. The draft RIs for each OU have a section for reviewing data quality Each OU manager bears the responsibility for ensuring that DQOs are met for his or her OU This issue will be dealt with independently from the statistical methodology, as was agreed to by EPA, CDH, and DOE at the September 29, 1993 meeting

4 EPA, DOE, and CDH must revisit the assumptions which Dr Gilbert lists on page two of his cover letter. Are these assumptions valid? What are the consequences if the assumptions are violated? Can this be handled in an uncertainty analysis?

Clarification. All of the assumptions listed, except for the last four, are difficult to quantify and are thus not "valid" or "invalid". These last four are now answered individually

The same field-sampling techniques are used for background and site, so this assumption is valid

Measurements are not always validated by third-party subcontractors before the draft RFI/RI statistical testing has been completed, so this assumption is not valid When the data validation results have been obtained, the data are reanalyzed, and the final RFI/RI contains no rejected data

Background data were checked for outliers, per EPA comments upon the 1992 Background Geochemical Report, and extreme outliers were excluded from statistical analysis in the 1993 Background Geochemical Report, so this assumption is not entirely valid. However, OU data outliers are not typically deleted, although data from the OUs are checked for "geochemical reasonableness", and any unusual results are discussed in the ensuing reports

The instrument detection limits are not always reported in the data bases, so this assumption is not completely valid However, the costs of recovering this information would be considerable.

5 EPA, DOE, and CDH must reach consensus on a paradigm for implementation The issues to be worked out include

a The appropriate background data sets by analyte, medium, and location

Concur. The section of The Guide entitled "Determine Background and OU Target Populations" addresses how this will be done

b How to deal with clearly non-random (e g , spatial) patterns

Concur. The Guide states in the Professional Judgement section that spatial patterns are subject to professional judgement, which is then subject to EPA and CDH review

c Measurement errors and multiple non-detects

Concur. Measurement errors are an inevitable part of physical data Efforts are taken throughout the data-collection process to minimize errors When non-detect replacement is necessary (i e , for t-tests or UTL tests), non-detects are dealt with by replacing the data value with ½ of the reported detection limit

d Structure for the formal statistical tests

Concur. The Guide furnishes this structure

e Data aggregation for comparison in the statistical tests

Clarification. Data aggregation is another topic, being addressed by CDH and EPA separately from this forum, which deals strictly with site-to-background comparison

RESPONSES TO CDH LETTER - STATISTICAL METHODS FOR THE COMPARISON OF REMEDIAL INVESTIGATION DATA TO BACKGROUND DATA AT ROCKY FLATS PLANT, DATED SEPTEMBER 13, 1991

1 The Division would like to emphasize the importance of effective graphical presentation of data to enhance the understanding and interpretation of the statistical tests The Division believes that the development of effective graphical procedures to display and interpret both site and background data is essential to the usefulness of the methodology and hould not be overlooked or down-played The Division requests that specific graphical techniques be developed and included in the "statistical strawman" methodology

Concur. The Guide specifically addresses graphical techniques

2 The Division does not recommend the use of a risk based hot measurement comparison value in the hot measurement comparison The use of risk based decisions is not appropriate in the context of comparisons to background

Concur. The hot-measurement comparison value is not risk-based

3 As noted in Dr Gilbert's report, the proper treatment of non-detects and multiple detection limits is critical to the implementation of his recommendations Both of these issues occur frequently in Rocky Flats data sets Therefore, the Division recommends that DOE emphasize specific protocol for proper treatment of non-detects and multiple detection limits in the "strawman" methodology

Concur. The Guide states that non-detects will be dealt with by replacing the data value with ½ of the reported detection limit

4. The Division agrees with Dr. Gilbert that professional judgement is necessary in evaluating the results of statistical tests However, it is not the Division's intention that professional judgement be a substitute for an inadequate site investigation or as a tool to dismiss dubious data The scope of appropriate professional judgement and limitations on its application should be outlined in the "strawman" methodology Guidelines and criteria for making decision based on professional judgement should also be identified

Concur. The Guide restricts professional judgement to several specific areas

Response to EPA: Hestmark letter 8HWM-FF received 10/25/93

1 To determine the appropriate background and operable unit populations for comparison, we understand that some matching of the two populations is done by geologists and chemists Data for an analyte in a non-background area are grouped according to a combination of background classes which represent indepe dent background populations A table that cross references the operable unit populations and the background populations will be provided.

Concur The strawman has been changed to require tables that cross-reference OU media to background media

2 A more explicit statement of the null hypothesis that is being tested will be included In addition, a fixed p value of 0 05 will be used for each of the inferential statistical tests as written in the strawman proposal There was some inconsistency in what was written in the proposal and what was stated in the meeting regarding the p value A fixed value of 0 05 is what we will accept.

Concur The strawman states that p values must be less than or equal to 0 05 to demonstrate a significant difference from background. Footnote 3 on page 5 of the strawman, which was not clear on this point, has been deleted

3 All references to comparison of background and operable unit populations for organics will be removed Background comparisons apply to inorganics and radionuclides only

Do not concur. Although background comparisons for organics are not commonly used, there are instances when it may be applicable, in which wide-ranging organic contamination is due to non-site-specific anthropogenic sources We want to retain the option of performing background comparisons for these organics, when geochemists or geologists determine that it is applicable to do so In these instances, we will retain the burden of proof, and the applicability of the comparison will be subject to EPA and CDH approval

The strawman has been rewritten to state that background comparisons for organics will be done on a limited, case-by-case basis, subject to EPA and CDH approval

4 The use of professional judgement in interpreting the results of the graphical displays and statistical analyses will be limited to consideration of spatial distribution, temporal distribution, and pattern recognition concepts The strawman proposal included five additional criteria These will be deleted in the final implementation document

Concur The five criteria (intermedia interactions and geochemical processes, not an expected contaminant, blank data, regional background range, and influence of field activities) have been deleted.

5 The non-background population is defined as the entire operable unit remedial investigation set The data aggregation for the purpose of background comparison will be done within the area defined by the operable unit boundaries

Concur Analysis will be done on an OU-wide basis

6 The attached flowchart, "Background Comparison Methodology", distributed at the meeting will be clarified. It is EPA's understanding that all the data sets will undergo the hot measurement test and the battery of inferential statistical tests (Gehan, Quantile, Slippage, and T-Test) provided the data satisfies the conditions stated in the strawman and on the flowchart If any one of these tests, including the hot measurement test, shows significance, the analyte will be further considered, using professional judgement, as a contaminant of concern The flowchart would benefit from the addition of decision blocks after each test indicating the next step if significance is demonstrated or not

Clarification The chart "Background Comparison Methodology" attached to EPA's memo is not the same as that distributed at the September 29, 1993 meeting and contained within the strawman proposal The difference is that nonparametric ANOVA tests are given as options to the Gehan test in the chart within the strawman proposal Because the Gehan method is not standard and will therefore incur practical liabilities (e g , the method has not been adequately tested and verified, preliminary usage shows it to require excessive man-hours, and subcontractors will need to be instructed in its use), we want to retain the option of performing standard nonparametric ANOVA testing, using the Wilcoxon or Kruskal-Wallis tests, instead of the Gehan test

Additional clarification The suggested decision blocks are not necessary All tests will be performed, if applicable, regardless of whether other tests demonstrate significance

Concur with the need to redo the flowchart This has been done

6 (continued) We also have some specific questions that need to be addressed in the final document

a What happens to data which is carried through the slippage test but does not qualify for the t-test?

Clarification The data that do not qualify for the t-test will be routed to the "At Least One Test Significant?" block The flowchart has been revised to show this

b What is the basis for the 20% detect value as the criteria for the Quantile test? How does this criteria relate to the criteria for applying this test as stated in Dr Gilbert's report on page 20?

Clarification Dr Gilbert's method proposed looking up tabulated values for n and r parameters The quantile test could be correctly applied only if the largest n values were all detects Our statisticians have stated that, typically, this restriction equates to the

largest 20% or less of the combined sample sizes being detects, and recommend using a flat 20% to simplify application

c What is the basis for the criteria of N>20 value for background and operable unit data?

Clarification Our statisticians derived this value from application of the Central Limit Theorem for a two sample problem If both samples have N=20, then there will be 38 total degrees of freedom, which will permit assumptions about the distribution

7 EG&G's claim that these impacts [of implementing Dr Gilbert's recommendations] could range from $30,000 up to $120,000 per operable unit is not supported by the information provided In fact, it appears that there is some evidence that implementation will not negatively impact costs or schedules

Do not concur Because the Gilbert method requires additional work, there will be cost and/or schedule impacts

In addition to the impacts mentioned above, cost impacts may result if the Gehan method is used For OU11, approximately 200 hours were required to perform the Gehan test, when less than 40 hours would have been sufficient to perform standard ANOVA testing However, the majority of these costs appear to be one-time costs such as coding development Subsequent testing on the same OU indicate that the cost impacts may be as little as 30 hours for a small data set

Response to CDH letter "DOE Proposed Methodology for Statistical Comparison of Remedial Investigation Data at the Rocky Flats Plant" from G Baughman to R Schassburger, dated 10/13/93

1 To minimize any potential future misunderstandings of this agreement, the Division feels that it is critical for the Agencies to develop a formal guidance/policy document institutionalizing the agreement The Strawman document was written for the purpose of facilitating agreement among the Agencies However, the end users of this document will be the operable unit managers and sub-contractors preparing and reviewing RFI/RI reports The majority of these people were not involved in the development of this methodology It is critical to the future of this agreement that final documentation of this agreement be developed to clearly and concisely guide future end users in the implementation of this methodology This formal guidance should be completed in parallel with the implementation of the agreement

Concur. When the strawman has been completed and accepted by all concerned parties, it will then be rewritten as a procedure for statistical comparison of OU data to background.

2 The Division recommends that the title of this document be revised to more accurately reflect its content and intent, that being methodology and guidelines for the comparison of site data to background data. The Division proposes the title, "Guide for Conducting Statistical Comparisons of RFI/RI Data and Background Data at the Rocky Flats Plant," for consideration.

Concur. The CDH's proposed title is an improvement to the current title, and has been adopted.

3. One of the central themes of Dr. Gilbert's recommendations was the need for statisticians to be involved throughout the entire process However, statistician involvement is not discussed in the methodology The division requests that the role of the statistician in implementation of this methodology be clarified in this document.

Concur. Statisticians will be employed to verify that the methods used are correct The strawman has been rewritten to incorporate this.

4. The Division does not believe that references to specific DOE sub-contractors are appropriate in this document The Division recommends DOE review all references to sub-contractors and, where appropriate, modify the reference to more accurately reflect DOE's role and responsibilities

Concur References to DOE subcontractors have been eliminated

5 This section (Determine Background and OU Target Populations) outlines the steps for matching site and background populations However, it is unclear exactly how the matching will be implemented. The Division recommends that the rationale for combining media/geology groupings for testing be detailed in this section For example, any criteria for minimum group size necessary for statistical testing should be specified The Division further recommends adding a table or diagram depicting the general rationale for grouping data by media and geology

Concur The strawman states that the OU will match one or more of several specified background media In addition, the strawman has been changed to require that a cross-reference be performed between the site and one or more background media

6 As discussed during the September 29th meeting, and emphasized by Dr Gilbert, it is critical to statistical hypothesis testing that the hypothesis to be tested is explicitly defined and clearly stated The Division recommends a statement of the test and null hypotheses, in both "english" (narrative qualitative description) and statistical terms, be added to this section of the methodology so there is no misunderstanding of what is being tested This statement should also address confidence and power requirements for the tests.

Concur The strawman has been modified to require statistical and prose statements of the null and alternative hypotheses

7 The Division does not agree with the blanket statement at the beginning of this discussion, "Under current IAG schedule conditions, analytical data will not be 'validated' when the background comparisons will be made in each draft report " This claim is not substantiated by the schedules submitted by DOE in the approved OU work plans and is in direct contradiction to Dr Gilbert's Task 5 recommendations Dr Gilbert states that, "These data quality evaluations are conducted prior to descriptive graphical analyses and formal statistical tests." In finalizing this methodology, the Division recommends that DOE follow Dr Gilbert's recommendations for data validation <u>before</u> formal graphical presentation and statistical testing. The need for variance from this approach will be considered by the Division on an OU specific basis

Do not concur Under the present system of data validation, the non-validated data are used only for the draft RFI/RI. The final I FI/RI is based solely upon validated data The lag time between receiving data from the laboratory, and validated data from the independent subcontractor can exceed one month. Waiting for 100% validation may impact schedules, but will probably not change the results in the final RFI/RI The potential impacts of using non-validated data at each OU will be discussed on a case-by-case basis

8 The Division recommends DOE add a discussion of detection limits to this section of the methodology In the past there has been confusion as to what detection limits are being reported and used (instrument detection limits vs contract limits vs reporting limits) Part of this confusion may be because detection limits have not been formal discussed. This section should state what detection limits are to be used in statistical testing and how they are

determined from the RFEDS data set

Concur. The strawman addresses detection limits, and it specifies how determinations are made on how to handle non-detects

9 The Division recommends that this section (Preliminary Exploratory Data Appraisal) be moved to the Data Presentation section

Concur. This section has been moved to the Data Presentation section

10 The Division interprets this section as describing the informal data analysis conducted during RFI/RI preparation and not normally included in the formal RFI/RI report The Division recommends adding language to indicate that this informal data analysis will be made available and reviewed with the regulators in evaluating the appropriateness of the scope of the formal RFI/RI proposal

Clarification. We have added language to this section to clarify that this informal data analysis will be informally discussed with CDH, EPA, and DOE/RFO However, this will not constitute a formal deliverable

11. The Division does not agree with DOE's recommendations that box plots are applicable only when there are no non-detects The problem of estimating percentiles for data sets with multiple non-detects was not resolved by Dr Gilbert The Division recommends that when a reasonably small percentage of non-detects are present, percentiles be estimated using Maximum Likelihood Estimation (MLE) techniques in constructing box plots

Concur We will provide box plots unless the percentage of non-detects exceeds 50% The 50% figure is chosen for consistency with the 1993 Background Geochemical Characterization Report (September 30, 1993)

12 The Division does not agree with DOE's suggestion that histograms are not useful for small or highly censored data sets, such as inorganics. As stated by Dr. Gilbert, such histograms are not likely to be useful in visually assessing whether the data sets are better modeled by a normal or lognormal distribution However, they may still be useful to visually compare the spread, central tendency, and skewness of the two data sets to look for differences that may be important.

Concur. We will provide histograms unless the percentage of non-detects exceeds 50% Bars in the histogram will be shaded to indicate the percentage of detects and non-detects within each bar interval.

13 The Division recommends that a discussion be added to this section of the methodology to address what to do when a UTL 99/99 can not be reasonably estimated or is unknown (ie small or highly censored background data set).

Concur We have modified the strawman to state that professional judgement, and use of

geochemical background data from the literature, will be used The result will be a geochemical interpretation of data, subject to agency review and approval

14. The reference in Footnote 2 to OU 1 is not appropriate and should be removed. The inferential tests conducted at OU 1 were the result of a compromise agreement, are not precedent setting for other OUs and are not the tests being proposed in this document. However, as stated in this note, limited professional judgement as presented later in this document may be applicable

Concur This footnote has been deleted

15 This discussion (Footnote 3) should be moved to the DQOs or statistical test definition section of the document

Clarification This footnote has been deleted We intend to use a p value of 0 05, and the footnote made that intent unclear

16. The Division does not agree with the limitations DOE has placed upon the Slippage Test The slippage test can be applied to data sets when the largest background point is a non-detect If the largest background data point is a non-detect then logic must be applied to determine if the slippage test is applicable, but the test should not be categorically eliminated.

Concur. We have r written the strawman to state that, if the largest background data point is a non-detect, we will apply judgement to investigate whether or not the slippage test is applicable

17. The Division recommends limiting the use of professional judgement to the first three criteria, spatial distribution, temporal distribution, and pattern recognition. In addition, it is recommended that the introduction to this section include acknowledgement that in applying professional judgement, the "burden of proof" lies solely on DOE Professional judgement will only be considered by the Division on a limited basis where well documented and defensible evidence is presented.

Concur. We have eliminated the last five criteria from the strawman, and acknowledged that we will bear the burden of proof.

18 To make the process more efficient the task of eliminating non-detected analytes should be completed prior to data presentation The flow chart should be modified to reflect this change

Concur We have changed the flowchart CDH's comment improved the process

19 This flow chart is confusing and difficult to follow due to the many multiple and undefined branches To minimize the potential for misunderstanding this chart must either be clarified or deleted

Concur. The flowchart is too important to delete. It has been clarified. Lines denoting the flow of information have been deleted, keeping only the lines denoting flow of control, in accordance with common flowcharting techniques Decision blocks have been transformed into diamond shapes Alternative "No" paths have been added for the blocks labeled "No Non-Detect Present OU Data Normally Distributed?", and "At Least One Test Significant?" Finally, the block representing the conditions which must be met prior to performing the t-test has been changed to reflect the conditions given in the text.