Addendum to
Final Report: Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State

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Dioxins in Washington State Agricultural Soils

November 1999

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Dioxins in Washington State Agricultural Soils

by
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Abstract

This Addendum report completes the Dioxins in Washington State Soils study[1] by reporting and assessing typical dioxin concentrations in the agricultural soils of the state.

Fifty-four samples of representative agricultural surface soils were analyzed for chlorinated dioxins and furans. Crop-county combinations were selected randomly for each of the 54 sampling sites. Each soil sample was a composite of 10 sub-samples collected from the soil surface to a depth of 5 cm. Sampling sites were chosen to represent typical (or "background") conditions.

When compared to concentrations found in soils from other land uses and other countries, dioxin and furan concentrations reported as TEQ (non-detected values set to zero) in Washington State agricultural soils were generally low, ranging from 0.0078 to 1.2 ng/kg (parts per trillion, pptr). These results were log-normally distributed with a geometric mean of 0.062 pptr.

Dioxin concentrations in agricultural lands were lower than those found previously in soils from other Washington State land uses. The geometric mean for open (prairie and grazed) lands was 0.24 pptr TEQ (n=8), while it was 1.9 pptr TEQ (n=14) for urban lands. Results for open and urban lands were both log-normally distributed. Forest soil results were normally distributed and had an arithmetic mean of 2.3 pptr TEQ (n=8).

We are not certain why dioxin concentrations are lower in agricultural soils. Possible factors include distance from urban sources of dioxin and differences in land use practices, including tilling which may dilute surface dioxin concentrations.

A review of available literature yielded no directly comparable data for North America. Of the data reviewed and used for comparison, dioxin concentrations in Washington State agricultural soils appear to be low. These include limited data on agricultural soils from Germany and Russia.

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[1] This *Addendum* report and chapter 3 in *Final Report: Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State* (Rogowski et al., 1999).

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Introduction

This Addendum report completes the Dioxins in Washington State Soils study. It reports results for 54 dioxin and furan analyses of soil samples collected at agricultural sites across the state.

The Dioxins in Washington State Soils study is one of several studies commissioned by the Washington State Legislature in response to concerns expressed by citizens about fertilizers and soil amendments containing metals and dioxins. These studies – including results for analyses of urban, open, and forest soils – are included in a report issued in April 1999, *Final Report: Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State* (Rogowski, Golding, Bowhay, and Singleton, 1999).

Background information about the persistence, toxicological, and biological behavior of the dioxins, as well as summary information on potential sources of dioxin, can be found in the *Final Report* (Rogowski et al., 1999).

Purpose

The objective of the Dioxins in Washington State Soils study is to provide an initial assessment of typical dioxin[2] concentrations in Washington State soils. This Addendum focuses on agricultural soils.

For the purposes of this study, the phrase *typical concentrations* means dioxin concentrations in surface soils distant from known or likely sources of these pollutants. While the concept of *typical* is similar to that of *background*, we have chosen to use the term *typical*, because *background* implies natural conditions and there is uncertainty about the extent to which these concentrations are natural.

The Dioxins in Washington State Soils study provides information that will help decision-makers assess regulatory and management options for addressing dioxins in soils and fertilizers.

Project Description

Fifty-four agricultural soils were collected for dioxin analysis. Soil samples were analyzed for a standard list of dioxin congeners at an accredited laboratory under contract with Ecology's Manchester Environmental Laboratory. Soils were also tested for organic carbon content and grain size distribution.

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[2] Unless otherwise specified, the term *dioxin(s)* is used to refer to the seventeen 2,3,7,8-substituted polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs).

The field, quality assurance, and analytical methods used in this study are the same methods that were employed to evaluate urban, open, and forest soils (Rogowski et al., 1999). A single contract laboratory conducted dioxin analyses for soils from all land uses. Of the four land uses examined, we have the most confidence in the agricultural soils data set, because of its relative large sample size (n=54) and the randomized site selection process.

Study Design

For this study, *agricultural land* in Washington State is defined as the approximately 5,284,000 harvested acres identified from available data sources: *Washington Agricultural Statistics 1996-1997* (WASS, 1997), *Washington Minor Crops* (Schreiber and Ritchie, 1995) and *Census of Agriculture – National Agricultural Statistics* (U.S. Dept. of Commerce, 1995).

More than 230 food, feed, and seed crops are produced commercially in the state (Schreiber and Ritchie, 1995). Crops raised on agricultural land include field crops, orchards, vineyards, legumes, berry crops, mints, hops, potatoes, vegetables, seed crops, and many others. As defined here, *agricultural lands* do not include sites used for ornamentals, floriculture, greenhouses, turf grass, silviculture, Christmas tree farms, or rangeland.

Of 84 samples collected for the Dioxins in Washington State Soils study, 54 (plus five duplicate samples) were assigned to agricultural lands. The other 30 samples were assigned to open, urban, and forest land use areas and have previously been reported (Rogowski et al., 1999).

Distribution of Sampling Sites

To represent the diversity of Washington agricultural soils, sampling sites were distributed by county and crop type. The state's agricultural acreage was represented by 5,284 units; each unit representing 1,000 acres. These units were each assigned a specific crop type and county. These assignments were proportional to the number of agricultural acres in the state associated with specific crops in specific counties.

We then randomly selected 55 units from the data set. Using a random number generator, each of the 5,284 units was assigned a number. These numbers were sorted in ascending order, and the first 55 were used to designate sites for this study.

Thus, each of the 55 units was associated with a specific county and crop. Table 1 shows how the chosen sites were distributed by county and crop. Only 54 samples were ultimately collected, due to difficulty finding a site devoted to one of the crop/county combinations.

This process yielded sites representing the distribution of Washington State agriculture by crop acreage and region. For example:

- 31 (~57%) of the 54 sites are associated with wheat lands. WASS (1997) reports wheat harvest on 2,745,000 acres, which represents ~52% of Washington agricultural lands.
- Fifty (~93%) of the 54 sites are associated with eastern Washington counties, reflecting the predominance (~95%) of agricultural acreage east of the Cascade Mountains (WASS, 1997).

Table 1. Distribution of agricultural sites selected for soil analyses, based on crop and county.

	Barley	Corn, silage & grain	Alfalfa	Hay	Legumes - lentils	Orchards & grapes	Peppermint	Potatoes	Wheat, spring/winter	Total
Adams							1	1	4	**6**
Benton						1		1	3	**5**
Clallam				1						**1**
Columbia									2	**2**
Douglas									3	**3**
Franklin		1	2						1	**4**
Garfield									1	**1**
Grant		2	1					1	3	**7**
Jefferson				1						**1**
Klickitat									1	**1**
Lewis		1								**1**
Lincoln	1		1						3	**5**
Okanogan						1				**1**
Spokane	1				1				3	**5**
Walla Walla									4	**4**
Whatcom				1						**1**
Whitman	1								3	**4**
Yakima				1		1				**2**
Total	**3**	**4**	**4**	**4**	**1**	**3**	**1**	**3**	**31**	**54**

Figure 1 shows the county-by-county distribution of sites on a map of Washington.

Selection of Sampling Locations

Plans to conduct sampling on agricultural lands in 1998 were delayed by two factors:

1. Concern among growers that sample results could be associated with specific farms and crops, and
2. Difficulty developing a feasible way of randomly selecting, and subsequently contacting, representative farms with the crop/county combinations shown in Table 1.

The first problem was addressed by redesigning the study in a way that disassociated sample results from sampling locations. The second was resolved by obtaining U.S. Department of Agriculture (USDA) Farm Service Agency (FSA) lists.

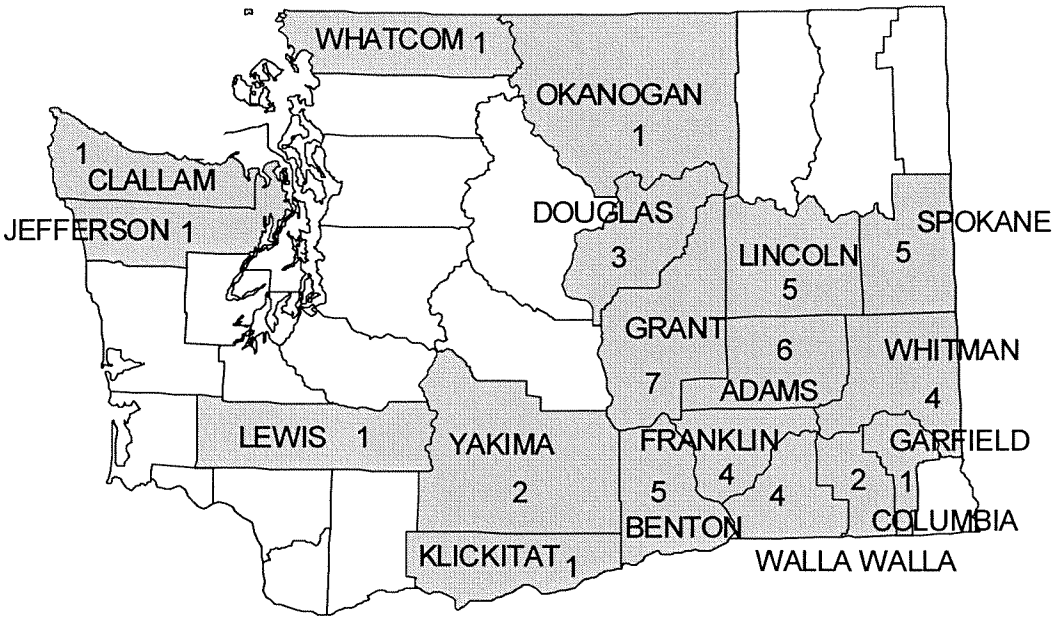

Figure 1. Distribution of agricultural soil sampling sites by county.

The FSA maintains a list of growers for each county who have participated in FSA programs. Although the FSA lists were the best available tool for identifying and contacting growers who could provide access to sampling sites, there were difficulties associated with using the lists:

- The lists include some growers associated with operations that were not included in the crop and county allocation process. The lists include, for instance, operators of non-commercial farms, greenhouses, tree farms, and livestock operations.
- Small farms are far more prevalent than large farms, yet they represent a relatively small portion of Washington's agricultural acreage. For instance, the USDA (1999) data show that while operations of less than 10 acres account for about 18% of Washington's farms, these farms account for about 0.1% of the state's harvested crop land. FSA grower lists reflected weighting towards small farms.

Although there is no reason to believe that results from small farms would be different than from large farms, we wanted the results to represent conditions associated with the majority of the agricultural acreage in the state. For this reason we chose to use sites only from farms larger than 10 acres.

Growers were chosen from the FSA lists at random and contacted by phone. Growers were then asked the following qualifying questions:

1. *We are looking for farms over 10 acres and that grew these crops (*name crops*) in (*name county*) in 1998 or 1999 to participate in this study. Do you have such a farm?*
2. *Have you ever used biosolids on your croplands?*

Farms that had used biosolids were disqualified.

Qualifying farmers were asked to participate in the study. To minimize potential bias, the study design permitted no more than 50% of qualified growers to decline the chance to participate. The final rejection rate was 20.6% (14 rejections in 68 contacts).

Methods

Sampling Procedures

Samplers worked with the property owners to locate sample areas that (1) would minimize crop damage and (2) avoided obvious, potential sources of dioxin contamination. Sample areas were located away from roads, railroad tracks, buildings, and treated wood poles and fences. Areas of significant erosion were also avoided.

We used a sampling unit of 0.4 hectare (one acre). This was the largest practical unit that allowed for representative composite sampling of all four land uses as described in the previously published *Final Report* (Rogowski et al., 1999).

Each sample was a composite of 10 sub-samples collected within the sampling unit. Soil samples were collected over the depth interval of 0-5 cm. The initial sub-sample was collected at a starting point (center), with nine additional sub-samples collected at the end of a radius originating from the starting point, extending a distance of 36 m (39 yards) and rotated at intervals of 40°. Sample collection techniques, including equipment-cleaning procedures, are described in detail in the *Final Report* (Rogowski et al., 1999).

Containers and holding requirements for dioxin, grain size, and total organic carbon (TOC) aliquots are shown in Table 2.

Grain size and TOC are ancillary analyses often done in conjunction with dioxin analyses of soils and sediments. Dioxin results are often correlated with these variables.

Table 2. Analyses, containers, and summary of holding conditions.

Target Analyses	Minimum Sample Size	Holding Requirements
2,3,7,8-substituted PCDD/PCDF Method 8290 (EPA, 1994a)	10g sample in ultra clean glass jars with Teflon lids.	Cool to 4°C and keep dark; maximum hold 30 days[3]; analyze within 45 days of extraction.
Grain size (PSEP, 1996)	200g	Cool to 4°C.
Total organic carbon (PSEP, 1996)	20g	Cool to 4°C.

[3] The holding time of 30 days from collection to extraction is a recommendation. PCDDs and PCDFs are very stable in a variety of matrices, and holding times for samples stored at 4°C in the dark may be as high as a year for certain matrices.

Sample labeling, shipping, and chain-of-custody followed procedures designated by the Manchester Environmental Laboratory *Lab User's Manual* (Ecology, 1994) with several modifications.

The following modifications were instituted to ensure the confidentiality of results, addressing the concerns of growers and landowners. Information about samples and sample locations was disassociated. Samples were labeled with randomly selected sample numbers; no other information (i.e., site location, crop type) was recorded. This approach was used to ensure that individual sample results could not be associated with specific locations, crops, counties, or growers.

Analytical Procedures

Analysis of the 2,3,7,8-substituted PCDD/PCDF congeners was conducted at MAXIM Technologies Inc./Pace Analytical Laboratory, using high resolution GC/MS EPA Method 8290, with enhancements derived from EPA Method 1613B. These are the same laboratory and methods used for the previous analysis of soil samples from other Washington State land uses (Rogowski et al., 1999).

Detection limits varied depending on the physical state (e.g., moisture and organic content) of the samples, but the target detection limit was 0.1 pptr. EPA Method 8290, Section 7.9.5, defines the sample specific Estimated Detection Limit (EDL) as the concentration of a given analyte required to produce a signal with a peak height at least 2.5 times higher than the background signal level. Not all congeners were responsive enough to provide EDLs at 0.1 pptr.

Samples were analyzed by Ecology's Manchester Laboratory for TOC by combustion/CO_2 measurement (PSEP,1996). Rosa Environmental and Geotechnical Laboratories conducted grain size analysis, determining apparent grain size distribution using the method of sieves as described by PSEP (1996). This method was modified to report four size fractions: gravel (>2 mm), sand (62 μm – 2 mm), silt (4 μm – 62 μm), and clay (<4 μm).

Data Quality

Results of dioxin, TOC, and grain size analyses were all acceptable for inclusion in this report.

The Dioxins in Washington State Soils study is a pilot study. It is intended to be informative and descriptive, and was not designed to test specific hypotheses. It is intended to generate information about typical dioxin concentrations in Washington State soils, with this Addendum report focusing on agricultural soils.

The Dioxins in Washington State Soils study does not statistically test whether soils associated with specific land uses have different dioxin concentrations. It was designed to allow general comparisons among land uses.

Of the four land uses examined, we have the most confidence in the agricultural soils data set, because of its relative large sample size (n=54) and the randomized site selection process. Methods used to select sites for other land uses are described by Rogowski et al., 1999.

Representativeness

This study was designed to provide an initial assessment of dioxin levels in agricultural surface soils in Washington State. For this study, surface soils consist of soils from the surface to a depth of 5 cm.

The study design provided a sample population that was largely random and representative; however, representativeness may have been influenced in several ways:

- *Agricultural lands* are defined for this study in the *Study Design* section. In addition, operations of less than 10 acres were excluded. This was done to ensure that sampled farms were of a size that represents a substantial portion of the state's harvested acreage (see *Selection of Sampling Sites*).

- The process of distributing sampling sites by crop and county was random to provide a representative sampling of agricultural soils in the state of Washington. The process used for selecting individual farms introduced some uncertainty into this representativeness. Only farmers whose names appeared on FSA county lists were included in the site selection process. We do not know how completely these lists represent farmers in each of the counties sampled.

- In Lewis County, one grower who had originally agreed to provide access for sampling subsequently declined. The Conservation Service provided an alternate contact. For two counties (Jefferson and Grant), use of the FSA lists did not yield the names of growers raising the target crops. In Jefferson County, where no hay farmers were found on the FSA list, WSU cooperative extension agents provided the names of

several hay growers. In Grant County, phone calls to over 55 growers yielded only four of the seven crop-specific sites targeted. The names of growers for three crops (wheat, corn, potatoes) were obtained directly from cooperative extension agents. Although five sites (one from Jefferson, three from Grant, one from Lewis) from these three counties were not randomly selected, they are unlikely to compromise the representativeness of the data set.

Within each farm, we worked with individual growers to select accessible fields to sample. Within each field, we chose one-acre sampling units that were distant from potential sources (see *Sampling Procedures*). We also avoided areas of erosion. Although selection of the final sampling units was not random, the full site distribution and selection process likely reflects the agricultural lands of Washington State.

Quality Control Procedures

Established laboratory quality control procedures for this project met data quality objectives for laboratory precision and accuracy. Laboratory quality control tests were conducted on each set of 20 or fewer samples. These tests included analyses of blank samples, duplicate samples, and spiked samples. Manchester Laboratory quality control samples and procedures are discussed in the Manchester Laboratory *Lab User's Manual* (Ecology, 1994).

Manchester Laboratory personnel reviewed the data packages from the contract laboratories and found quality assurance and quality control measures sufficient to ensure that the dioxin and grain size results are reliable. Memoranda reporting the results of Manchester Laboratory quality assurance reviews are contained in Appendix A.

The results of TOC analyses performed at the Manchester Laboratory are also reliable. Many of these results are qualified as estimates because instrumentation problems resulted in an extended sample drying period. Appendix A includes a quality assurance memorandum for TOC.

Field duplicates and field split samples were not collected because of the need to preserve the confidentiality of individual samples. Five samples were split in the lab for duplicate analysis. The results of these duplicate sample analyses are summarized in Appendix D.

Data Analysis

In order to preserve the confidentiality of sample locations, no identifying labels were attached to samples in the field. As a result, data were not analyzed spatially. Results cannot be partitioned or analyzed by location or crop type, because this information was intentionally not recorded.

Data analyses are largely restricted to descriptive statistics including mean, geometric mean, median, range, and, as appropriate, standard deviation or geometric standard deviation.

The results of dioxin analyses are often presented as toxic equivalent (TEQ) values. The use of TEQs provides a means for converting the results of the 17 congener-specific analyses conducted on each sample into a single value. An international convention adopted by EPA (EPA, 1989) is used to provide a toxicity equivalency factor (TEF) for each of the toxic forms (congeners) of dioxin and furan present. See Rogowski et al. (1999) for a more detailed discussion of dioxin TEQs and how they are calculated.

Unless otherwise specified, TEQ values reported here assume that when a specific congener is not detected in a sample, its concentration is zero (ND = 0). Other conventions are sometimes used (e.g., assuming that undetected congeners are present at one half the detection limit, ND=1/2 DL, or that undetected congeners are present at the detection limit, ND=DL). TEQs calculated using all three approaches are reported in the appendices.

Assuming that undetected congeners have zero concentration is the convention used when calculating TEQs to interpret soil and fertilizer data discussed in previous reports (Rogowski et al., 1999). Assuming the absence of undetected congeners yields a minimum TEQ.

Simple linear correlations (Pearson) analyses of TEQ against grain size and against TOC were conducted using SYSTAT 7.01 (SPSS, 1997).

SYSTAT was also used to generate probability plots to assess the normality of untransformed and log-transformed values of TEQ for soils from each of the four categories of land use (forest, open, urban, and agriculture). The underlying distributions were evaluated by visual inspection, and the results were checked using Shapiro and Wilk's W ($n<50$) or D'Agostino's D ($n>50$) (Zar, 1984). The normality of TOC results were also evaluated.

Results and Discussion

The results of 54 dioxin analyses of agricultural surface soils are presented in detail in Appendix B. Appendix C tabulates individual sample results for TEQ, TOC, and grain size.

Table 3 summarizes dioxin results for agricultural soils. The table also includes summary statistics for other previously reported land uses. A more extensive tabulation of statistics for all land uses can be found in Appendix E.

Table 3. Summary of dioxin concentrations in Washington State soils by land use (reported as TEQ*, ng/kg = pptr)

Land Use	Range	Mean	Median	Geometric Mean	n
Urban	0.13 – 19	4.1	1.7	1.9	14
Forest	0.033 – 5.2	2.3	2.2	1.2	8
Open	0.040 – 4.6	1.0	0.27	0.24	8
Agricultural	**0.0078-1.2**	**0.14**	**0.054**	**0.062**	**54**

n = number of samples
* = non-detect values set to equal zero

Using the methods outlined in the *Data Analysis* section, we evaluated the sample populations for each of the four land uses. Dioxin results (expressed as TEQ, ND=0) were log-normally distributed for results from agricultural, open, and urban lands; geometric means provide the best measure of central tendency for these data sets. Results from forest lands were normally distributed; the arithmetic mean (mean) provides the best measure of central tendency for this data set.

Figure 2 presents these data graphically using an arithmetic scale; note crowding of data points near the x-axis. Figure 3 presents the data using a logarithmic scale for dioxin concentrations. Use of a logarithmic scale is appropriate for log-normally distributed data and spreads the data points, making them distinguishable.

Based on data in Table 3, Figure 2, and Figure 3, dioxin concentrations appear to be higher in urban, and forest lands, and comparatively lower in open and agricultural lands (see also Figure 6).

Although dioxin concentrations from the four land uses are qualitatively compared, this study was not designed to conduct these comparisons statistically.

We reviewed studies reporting the results of dioxin analyses in soils, beginning with overview documents published by EPA (1994b) and ASTDR (1998). The results of several studies conducted in Europe and Russia contained data that can be used for comparisons with Washington State results.

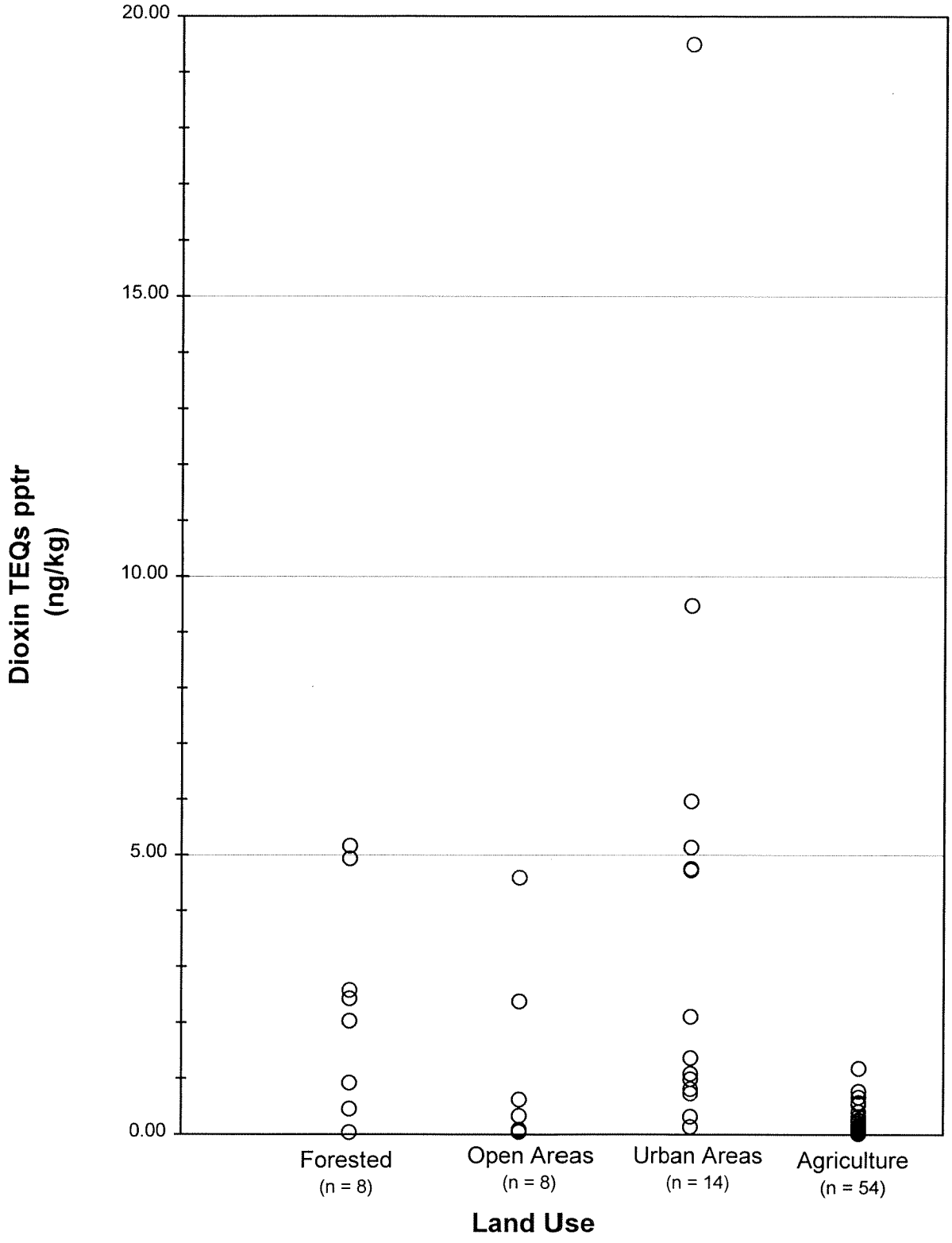

Figure 2. Dioxin concentrations in Washington State soils by land use.

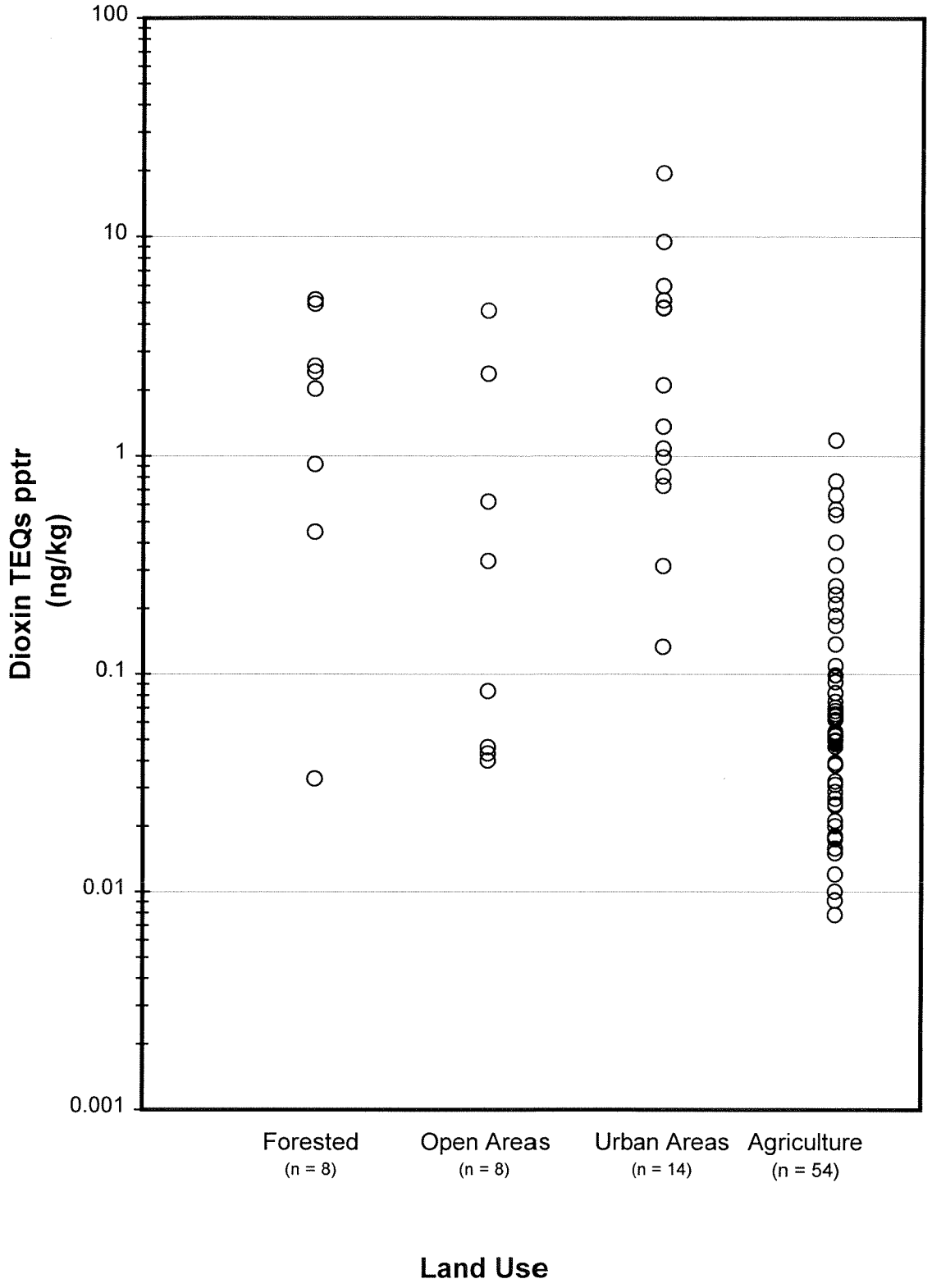

Figure 3. Dioxin concentrations in Washington State soils by land use. Concentrations shown using a logarithmic scale.

Figure 4 compares Washington State results to those reported in studies from Spain (Jimenez et al., 1996[4] and Schuhmacher et al., 1997[5]), Germany (Rotard et al., 1994[6]) and Austria (Boos et al., 1992[4]). Concentrations found in Washington's urban, forest, and open lands are generally similar to those found in these European countries.

Figure 5 compares results for Washington agricultural soils to soils analyzed in Germany (Rotard et al., 1994[4]) and Russia (Khizbullin et al., 1997[4]). Washington agricultural soils appear to have lower dioxin concentrations than the median value reported for Germany. Dioxin concentrations reported in four Russian samples span the upper range of concentrations found in Washington. The German samples were collected from the 0-10 cm interval. Sampling depth was not reported in the Russian study.

We also located a study from Minnesota (Reed et al., 1990) that reports results of four analyses of agricultural soils collected 1.2 to 2.8 km (1 to 1¾ mile) from a coal-fired power plant. The plant was not operating at the time of the sampling. TEQ (ND=0) ranged from 0.82 to 9.24 pptr, but are not included in Figure 5 because of concerns that these samples may not represent typical (or background) conditions. Two of these samples were collected from the top 2.5 cm (1 inch) of soil, and the other two from the top 15 cm (6 inches).

Figure 6 is a cumulative quantile plot showing the distribution of results for each of the four land uses addressed in Washington State. Agricultural soils appear to have the lowest dioxin concentrations. Urban and forest soil concentrations are higher, while open lands (prairies and pasture) have intermediate concentrations.

One factor that may explain the relatively low dioxin concentrations in agricultural soils is their distance from historical and current sources of dioxin in urban areas (Rogowski et al., 1999). Another factor that could account for some of the differences between agricultural lands and open lands is that agricultural soils are tilled. In undisturbed soil most (80%) of the dioxin is contained in the top 15 cm of the soil profile (Bruzy and Hites, 1995). Mixing surface soils containing the majority of dioxin with underlying soils having lower concentrations could dilute dioxin concentrations at the surface. Wind and water erosion could provide additional mechanisms for transporting soil-bound dioxin from agricultural fields.

Soils were also analyzed for grain size and organic carbon concentrations. Review of the grain size distribution revealed no correlations with dioxin content.

Table 4 summarizes organic carbon results by land use. Forest soils had the highest median organic carbon content (9.9%) followed by open (7.2%), urban (4.1%), and agricultural (1.1%) soils.

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[4] Authors calculated TEQ assuming that undetected congeners were not present (concentration equals zero).
[5] Authors calculated TEQ assuming that undetected congeners were present at ½ the detection limit.
[6] Authors do not report method for calculating TEQ.

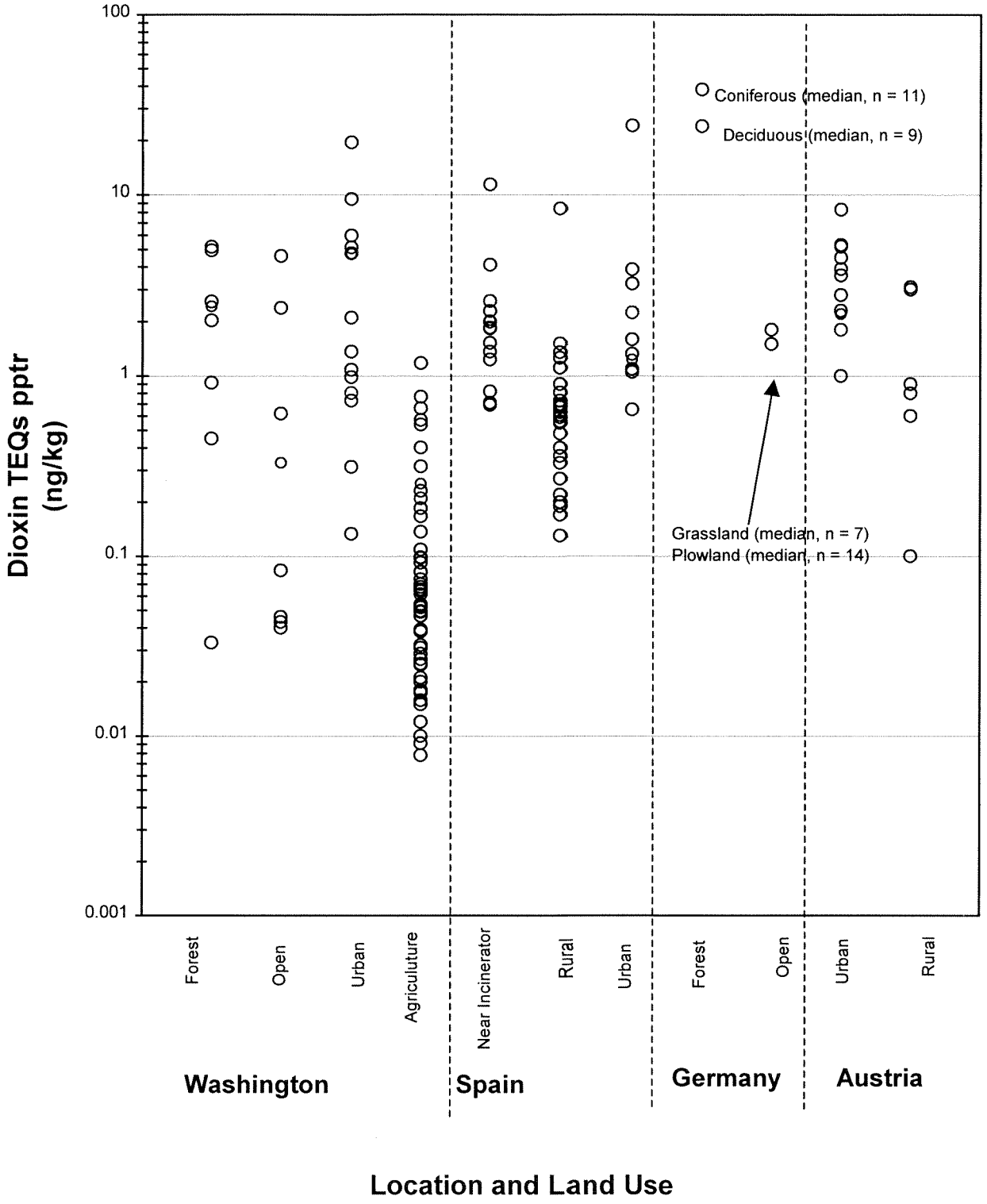

Figure 4. Dioxin concentrations in soil by land use in Washington State, Spain (Jimenez et al., 1996; Schumacher et al., 1997), Germany (Rotard et al., 1994) and Austria (Boos et al., 1992).

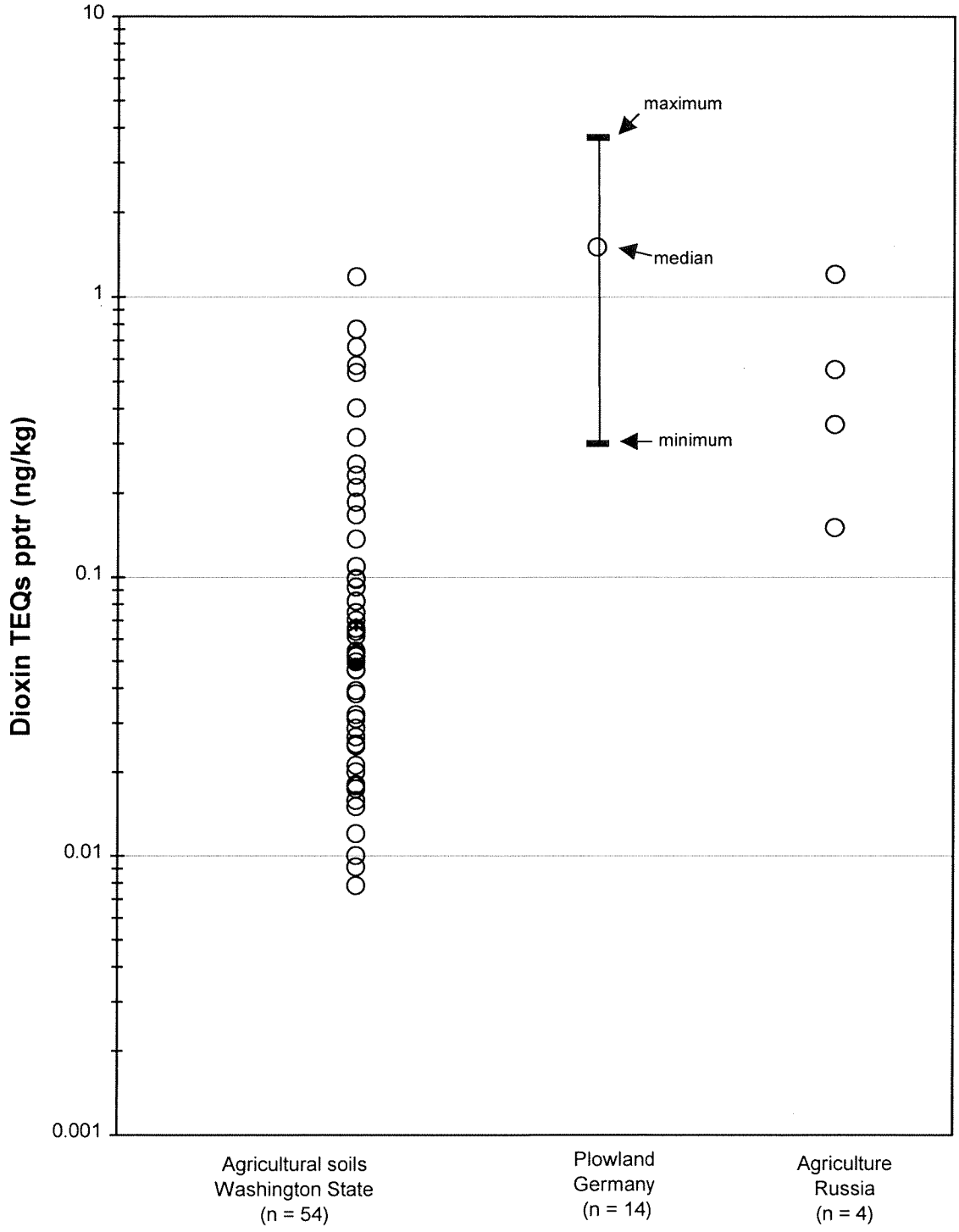

Figure 5. Dioxin concentrations in agricultural soils of Washington State compared to concentrations in Germany (Rotard et al., 1994) and Russia (Khizbullin et al., 1997)

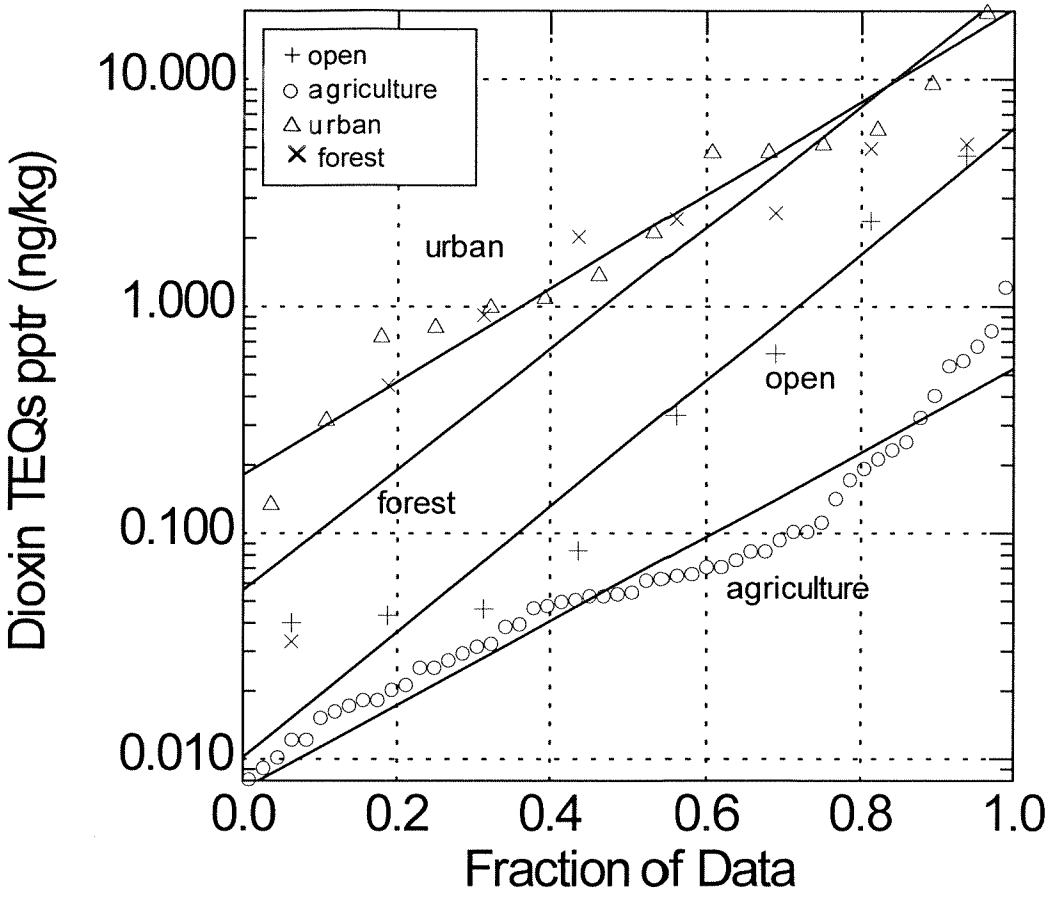

Figure 6. Cumulative distribution of dioxin concentrations in Washington State soils by land use.

Table 4. Summary of total organic carbon (TOC) results in Washington State soils by land use (reported as %).

Land Use	Range	Mean	Median	Geometric mean	n
Urban	0.17 - 7.1	4.0	4.1	3.1	14
Forest	6.2 - 44	18	9.9	14	8
Open	1.3- 39	6.2	7.2	4.0	8
Agricultural	0.40 - 4.5	1.4	1.1	1.2	54

Dioxin concentrations in agricultural soils were positively correlated with organic content. The correlation coefficient[7] between TEQ and TOC (r= 0.42) is significant (p = 0.002).

Data sets for other land uses were also tested. The correlation (r=0.79) is significant for urban soils (p=0.001), but not for soils from open (r=0.55) or forest (r=0.35) areas. The lack of significant correlation in the latter two cases may be due to small sample sizes.

The correlation (r=0.66) for the entire data set (all land uses, n=84) was also significant (p<0.0005), indicating that approximately 44% of the variability in dioxin TEQ could be accounted for by correlation with TOC.

Some investigators report organic-carbon-normalized dioxin results. Table 5 summarizes the results of dioxin analyses as nanograms of TEQ per kilogram of TOC. Note that organic carbon normalization decreases the apparent differences in the dioxin concentrations of soils reported for various land uses.

Table 5. Summary of dioxin results normalized to total organic content
(ng TEQ/kg TOC)

Land Use	Range	Mean	Median	Geometric mean	n
Urban	17 – 354	89	61	63	14
Forest	0.53 –64	18	13	10	8
Open	0.83 – 58	12	2.7	4.9	8
Agricultural	0.51 – 187	11	5.1	5.7	54

Although the dioxin concentrations and organic content of soils evaluated are correlated, the available data do not justify making clear cause-and-effect inferences.

[7] Correlation analysis requires a normal distribution, so correlation analysis was carried out on log-transformed variables for all data sets except forest lands.

Conclusions

This Addendum report completes the Dioxins in Washington State Soils study begun in 1998, by providing chlorinated dioxin and furan (here called simply *dioxin*) data for agricultural lands, the last of four land uses addressed by this project.

Fifty-four samples of representative agricultural surface soils were collected and analyzed for dioxins. Crop-county combinations were selected randomly for each of the 54 sampling sites to represent the crop types and spatial distribution typical of agriculture in Washington State. Each soil sample was a composite of 10 sub-samples, collected from a one-acre site from the top 5 cm. of soil. Sample sites were chosen to represent typical (or "background") conditions.

Dioxin concentrations (reported as TEQ, non-detect values set to zero) for Washington State agricultural soils ranged from 0.0078 to 1.2 ng /kg (pptr). These concentrations were distributed log-normally; as a consequence, the geometric mean is the most appropriate measure of central tendency for dioxin concentrations for these results. The geometric mean for agricultural soils was 0.062 pptr.

Dioxin concentrations in agricultural lands were lower than those found previously in soils from other Washington State land uses. The geometric mean for open (prairie and grazed) lands was 0.24 pptr TEQ (n=8), while it was 1.9 pptr TEQ (n=14) for urban lands. Results for open and urban lands were both log-normally distributed. Forest soil results were normally distributed and had an arithmetic mean of 2.3 pptr TEQ (n=8).

Total organic carbon was positively correlated with dioxin results (expressed as TEQ, ND=0) for agricultural and urban land uses. The entire data set (all land uses, n=84) also showed a positive correlation between TOC and TEQ.

We are not certain why dioxin concentrations are lower in agricultural soils. Possible factors include distance from urban sources of dioxin and differences in land use practices, including tilling which may dilute surface dioxin concentrations.

A review of available literature yielded no directly comparable data from North America. As reported earlier (Rogowski et al., 1999), dioxin concentrations in soils from open, forest, and urban land uses in Washington State were generally similar to those reported in several European countries.

Comparable data for dioxins in agricultural soils were also sparse. Based on very limited data, agricultural soils in Washington State may have lower dioxin concentrations than those reported in soils from Germany and Russia.

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Appendices

Appendix A

Quality assurance memoranda

Washington State Department of Ecology
Manchester Laboratory

July 1, 1999

TO: David Rogowski

FROM: Becky Bogaczyk, Chemist BB

SUBJECT: General Chemistry Quality Assurance memo for Ag Soil Dioxins week 17

SUMMARY

The data generated by the analysis of these samples can be used noting the qualifications discussed in this memo. Total organic carbon (TOC) samples 99178501, 502, 507-510, 513-524, 529-531, 537, 542-551, and 555 are estimates due to instrumentation problems causing these sample to be analyzed over the holding time. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Ag Soil Dioxins week 17 project were received by Manchester Laboratory on 5/3, 6 & 10/99 and 6/9/99 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times except TOC samples 99178501, 502, 507-510, 513-524, 529-531, 537, 542-551, and 555. Instrumentation problems arose after sample preparation causing the samples to spend a longer than normal time period in a desicator and the results are qualified due to these circumstances.

ANALYSIS PERFORMANCE

Instrument Calibration

Instrument calibration was checked by initial calibration verification standards and blanks and all initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met.

Procedural Blanks

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Precision Data

Duplicate and triplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for this parameter was within the 20% acceptance window for duplicate analysis and the triplicate Relative Standard Deviation (RSD) was within the acceptance window of 5%. Laboratory duplication and triplication is performed at a frequency of at least 10%.

Laboratory Control Sample (LCS) Analyses

LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates the analyte was not detected at or above the reported result.

The "J" qualification signifies the result is an estimate (see SUMMARY).

Please call Jim Ross at (360) 871-8808 to further discuss this project.

cc: Project File

State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366

June 2, 1999

Project: Ag Soils Dioxin

Samples: 17-8501-17, 17-8519-55

Laboratory: Rosa Environmental

By: Pam Covey

Case Summary

These samples required fifty-four (54) Grain Size analyses on soil samples using Puget Sound Estuary Protocol (PSEP) method for gravel, sand, silt and clay fractions only. The samples were received at the Manchester Environmental Laboratory in April 1999 and transported to the contract lab in May 1999 for Grain Size analyses.

The analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness. See narrative from Rosa for further explanation on sample analysis anomalies.

The results are acceptable for use as reported.

REG Lab WMBE
Rosa Environmental & Geotechnical Laboratory, LLC

815 Harrison Street, #100
Seattle, WA 98109-5187
(206) 287-9122

Client: WDOE, Manchester Laboratory	REGL Project No.: 1004-020
Client Project No.: Soil Dioxin Study	Sample Batch No.: 1004-020-01

Case Narrative

1. Samples were received on May 3, 1999, and were in good condition.
2. The samples were tested for apparent grain size distribution according to PSEP methods, with modifications for only the gravel, sand, silt and clay components.
3. The samples were run in two batches, with samples 17-8552, 8553, and 8554 being run with the second set of samples. A triplicate was run on the batch, and is reported in the attached QA summary. The second triplicate will be reported with the second set data package (our job 1004-021).
4. Sample 17-8539 had very few fines (minus #230 sieve) and did not meet one of the PSEP requirements, that at least 5 g of material be in the pipette portion of the analysis.
5. Sample 17-8503 had a QA ratio of 1.0516. Although PSEP does not have a criteria for this ratio, REGL has established an internal standards of between 0.95 and 1.05. The reason for the high QA ratio is due to a difference between the moisture content portion and the sieve portion of the analysis. The data reported for this sample was obtained using a back calculated moisture content.
6. There were no other anomalies to the samples or the testing.

Approved by: _____ Date: 5/10/99
Title: Laboratory Manager

REG Lab WMBE
Rosa Environmental & Geotechnical Laboratory, LLC

815 Harrison Street, #100
Seattle, WA 98109-5187
(206) 287-9122

Client: WDOE, Manchester Laboratory	REGL Project No.: 1004-021
Client Project No.: Ag Soil Dioxin	Sample Batch No.: 1004-021-1 and 2

Case Narrative

1. Samples were received on May 12, 1999, and were in good condition.
2. The samples were tested for apparent grain size distribution according to PSEP methods, with modifications for only the gravel, sand, silt and clay components.
3. The samples were run in two batches. A triplicate was run on each batch, and is reported in the attached QA summary.
4. Sample 99178501 was "clumpy" clay and difficult to homogenize. Samples 99178502, 507, 514, and 524 had roots and grass pieces. Sample 99178508 was "clumpy" clay with roots and was also difficult to homogenize. 99178545 was a wet sediment.
5. ON Samples 99178549 and 550, the Weight of the minus #230 Solids fell slightly below method limits of 5 to 25 grams (4.187 and 4.993 g).
6. There were no other anomalies to the samples or the testing.

Approved by: _____ Date: 5/24/99
Title: Laboratory Manager

State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366

Data Review
July 19, 1999

Project: Agricultural Soils Dioxin

Samples: 99178503,05,06,11,12,16,25-28,32-36,38,54

Laboratory: Pace Analytical

By: Stuart Magoon

Data Review for Polychlorodibenzo-p-dioxin and furan
(2,3,7,8 substituted tetra - octa PCDD/PCDF)

Data from these analyses were reviewed for qualitative and quantitative accuracy, validity, and usefulness, following the National Functional Guidelines for Organic Data Review adapted for high resolution dioxin analysis, and the EPA Region 10 SOP for the Validation of PCDD/PCDF.

Samples were prepared and analyzed according to EPA method 8290 with enhancements from EPA method 1613B.

These samples have been reported in nanograms per kilogram (ng/Kg); parts per trillion dry weight.

Pace has developed their own data "flags". Definitions of the "flags" and qualifiers are included in the report.

Flags are added by the laboratory performing the analysis, usually the analyst. Qualifiers are added by the data reviewer as part of addressing the usability of the data. Generally flags signal the reviewer to access the results and determine what to do about the fact that flags were added. For your reporting purposes the "flags" should not be considered part of the final result. The qualifiers, however, are to be considered part of the final result.

There is a number reported for each analyte that appears in one or two columns. If the number appears in the column labeled "CONC" then this analyte has been detected at the concentration reported. The number in the column labeled "LOD", is the estimated detection limit as defined in EPA method 8290, at or above which the analyte was not detected. There is an "ND", short for

not detected, that appears in the "CONC" column whenever an analyte is not detected. In order to be consistent with Manchester Environmental Laboratory's reporting convention, a result reported as ND with an associated number in the Limit of Detection column, e.g. 0.45, should be considered synonymous with 0.45 U, where "U" is a qualifier.

PCDD/PCDF Analysis

Holding times:

EPA method 8290 specifies a holding time of thirty days (30) from the date of collection to the date of extraction; and forty-five (45) days from extraction to analysis. The precise day specific samples were collected was not disclosed. However, the earliest sampling began the week of April 12. Therefore the maximum time from collection to extraction for these samples was 24 days.

Sample no.	Collect date	Extraction date	Maximum #days from collection to Extraction	Analysis date	#days from Extraction to Analysis
99178503	April 99	05/05/99	24	05/21/99	16
99178504	April 99	05/05/99	24	05/21/99	16
99178504dup	April 99	05/05/99	24	05/21/99	16
99178505	April 99	05/05/99	24	05/26/99	21
99178506	April 99	05/05/99	24	05/26/99	21
99178511	April 99	05/05/99	24	05/27/99	22
99178512	April 99	05/05/99	24	05/27/99	22
99178516	April 99	05/05/99	24	05/27/99	22
99178525	April 99	05/05/99	24	05/27/99	22
99178525dup	April 99	05/05/99	24	05/27/99	22
99178526	April 99	05/05/99	24	05/27/99	22
99178527	April 99	05/05/99	24	05/27/99	22
99178528	April 99	05/05/99	24	05/27/99	22
99178532	April 99	05/05/99	24	05/27/99	22
99178533	April 99	05/05/99	24	05/27/99	22
99178534	April 99	05/05/99	24	05/27/99	22
99178535	April 99	05/05/99	24	05/27/99	22
99128336	April 99	05/05/99	24	06/02/99	28
99128338	April 99	05/05/99	24	06/02/99	28
99128354	April 99	05/05/99	24	06/02/99	28

These samples were extracted and analyzed within holding times.

Method Blank:

Four of the seventeen congeners were detected in the associated method blank at concentrations below that of the lowest calibration standard. According to the method re-analysis is not required when a target congener is detected below the lowest calibration standard. These congeners were also detected in some of the samples. If the concentration of a congener in a sample was less than five times that of the method blank a "U" or "UJ" qualifier was added to the result. In cases where the sample concentration for a congener was greater than five times that of the method blank, the method blank result is considered insignificant relative to the concentrations detected in the samples. No qualification is warranted in these situations.

Calibration:

The calibration standards were within 20% relative standard deviations (RSD) for all target analytes and 30% for all the labeled reference compounds (Internal Standards), with a few exceptions.
The OCDD detected in samples 178505, 178536, 178538 and 178554 were qualified as an estimate ("J") because the continuing calibration standard associated with this result had an RSD of 30.3% indicating potential high bias for the result.
The OCDD detected in samples 178536, 178538, and 178554 were qualified as estimates ("J") because the continuing calibration standard associated with this result had an RSD of –33.9% indicating potential low bias for the result.
The 123678 HxCDF result for sample 178505 was qualified due to a high RPD in the associated continuing calibration standard, indicating a potential low bias. The 12378 PeCDF result (a non-detect) for this sample was also qualified as an estimate ("UJ") due to the associated continuing calibration standard.
All the ion abundance ratios were within +/- 15% of the theoretical value.

Internal Standard Recoveries:

Internal standard recoveries for these samples were within the 40–135% (method 8290 limits) or 25–150% (method 1613B) QC limits established for each congener, with one exception. The 1,2,3,6,7,8-HxCDF-13C recovery in sample 178536 was 23%. This recovery standard in from method 1613B and therefore the applicable QC limits are 25-150%. The associated target congener, 1,2,3,6,7,8-HxCDF, was positively identified in this sample. The result was qualified as an estimate.

Ion abundance ratios:

Each dioxin and furan isomer reported as detected met the isotopic abundance ratio and retention time criteria for positive identification.

Matrix Spike/Matrix Spike Duplicate (MS/MSD):

MS/MSD recoveries were within quality control limits of 60–140%; and precision data was within ±20 relative percent difference (RPD).

Summary:

This data is acceptable for use as amended. A number of congeners were qualified with a "J" because the concentration detected was below the lowest calibration standard; results derived from responses outside the calibration range are considered estimates.

Qualifiers

U	The analyte was not detected at or above the reported result
J	The analyte was positively identified. The associated numerical result is an estimate.
UJ	The analyte was not detected at or above the reported estimated result

State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366

Data Review
July 23, 1999

Project: Agricultural Soils Dioxin

Samples: 99178501,02,07-10,13-15,17,19-24,29-31,37,39-53,55

Laboratory: Pace Analytical

By: Stuart Magoon

Data Review for Polychlorodibenzo-p-dioxin and furan
(2,3,7,8 substituted tetra - octa PCDD/PCDF)

Data from these analyses were reviewed for qualitative and quantitative accuracy, validity, and usefulness, following the National Functional Guidelines for Organic Data Review adapted for high resolution dioxin analysis, and the EPA Region 10 SOP for the Validation of PCDD/PCDF.

Samples were prepared and analyzed according to EPA method 8290 with enhancements from EPA method 1613B.

These samples have been reported in nanograms per kilogram (ng/Kg); parts per trillion dry weight.

Pace has developed their own data "flags". Definitions of the "flags" and qualifiers are included in the report.

Flags are added by the laboratory performing the analysis, usually the analyst. Qualifiers are added by the data reviewer as part of addressing the usability of the data. Generally flags signal the reviewer to access the results and determine what to do about the fact that flags were added. For your reporting purposes the "flags" should not be considered part of the final result. The qualifiers, however, are to be considered part of the final result.

There is a number reported for each analyte that appears in one or two columns. If the number appears in the column labeled "CONC" then this analyte has been detected at the concentration reported. The number in the column labeled "LOD", is the estimated detection limit as defined in EPA method 8290, at or above which the analyte was not detected. There is an "ND", short for

not detected, that appears in the "CONC" column whenever an analyte is not detected. In order to be consistent with Manchester Environmental Laboratory's reporting convention, a result reported as ND with an associated number in the Limit of Detection column, e.g. 0.45, should be considered synonymous with 0.45 U, where "U" is a qualifier.

PCDD/PCDF Analysis

Holding times:

EPA method 8290 specifies a holding time of thirty days (30) from the date of collection to the date of extraction; and forty-five (45) days from extraction to analysis. The precise day specific samples were collected was not disclosed. However, the earliest sampling began the week of April 12. Therefore the maximum time from collection to extraction for these samples was 24 days.

Sample no.	Collect date	Extraction date	Maximum #days from collection to Extraction	Analysis date	#days from Extraction to Analysis
99178501	April 12 –May	05/18/99	37	06/14/99	27
99178502	April 12 –May	05/18/99	37	06/14/99	27
99178507	April 12 –May	05/18/99	37	06/14/99	27
99178508	April 12 –May	05/18/99	37	06/14/99	27
99178508dup	April 12 –May	05/18/99	37	06/14/99	27
99178509	April 12 –May	06/21/99	70	06/28/99	7
99178510	April 12 –May	05/25/99	43	06/17/99	23
99178510dup	April 12 –May	05/25/99	43	06/17/99	23
99178513	April 12 –May	05/18/99	37	06/17/99	30
99178514	April 12 –May	05/18/99	37	06/17/99	30
99178515	April 12 –May	05/18/99	37	06/17/99	30
99178517	April 12 –May	05/18/99	37	06/17/99	30
99178519	April 12 –May	05/20/99	39	06/15/99	26
99178520	April 12 –May	05/18/99	37	06/17/99	30
99178521	April 12 –May	05/18/99	37	06/17/99	30
99178522	April 12 –May	05/18/99	37	06/18/99	31
99178523	April 12 –May	05/18/99	37	06/18/99	31
99128324	April 12 –May	05/20/99	39	06/18/99	29
99128329	April 12 –May	05/20/99	39	06/18/99	29
99128330	April 12 –May	05/20/99	39	06/18/99	29
99128331	April 12 –May	05/20/99	39	06/18/99	29
99128337	April 12 –May	05/20/99	39	06/18/99	29
99128339	April 12 –May	06/16/99	65	06/24/99	8
99128340	April 12 –May	06/16/99	65	06/24/99	8

99128341	April 12 –May	06/16/99	65	06/24/99	8
99128342	April 12 –May	05/20/99	39	06/18/99	29
99128343	April 12 –May	05/20/99	39	06/22/99	33
99128344	April 12 –May	05/20/99	39	06/18/99	29
99128345	April 12 –May	05/20/99	39	06/18/99	29
99128346	April 12 –May	05/20/99	39	06/22/99	33
99128347	April 12 –May	05/20/99	39	06/28/99	39
99128348	April 12 –May	05/20/99	39	06/22/99	33
99128348dup	April 12 –May	05/20/99	39	06/22/99	33
99128349	April 12 –May	05/20/99	39	06/22/99	33
99128350	April 12 –May	05/20/99	39	06/23/99	34
99128351	April 12 –May	05/20/99	39	06/22/99	33
99128352	April 12 –May	06/16/99	65	06/25/99	9
99128353	April 12 –May	06/16/99	65	06/28/99	12
99128355	April 12 –May	05/20/99	39	06/22/99	33

It is not known whether or not these samples were extracted within thirty days form collection because the exact collection date was intentionally not documented. Method 8290 does note that PCDFs and PCDDs are very stable in a variety of matrices and under proper storage conditions holding times can be as high as a year. All the sample extracts were analyzed within the forty day holding time. No qualification was warranted based on holding times.

Method Blank:

Several congeners were detected in the associated method blanks at concentrations below that of the lowest calibration standard. According to method 1613B re-analysis is not required when a target congener is detected below the lowest calibration standard. These congeners were also detected in some of the samples. If the concentration of a congener in a sample was less than five times that of the method blank a "U" or "UJ" qualifier was added to the result. In cases where the sample concentration for a congener was greater than five times that of the method blank, the method blank result is considered insignificant relative to the concentrations detected in the samples. No qualification is warranted in these situations.

Calibration:

The calibration standards were within 20% relative standard deviations (RSD) for all target analytes and 30% for all the labeled reference compounds (Internal Standards), with a few exceptions.
1234678HpCDD results for samples 178501, 178502, 178507, 178508 and 178508dup were qualified as estimates ("J") because the internal standard in the continuing calibration associated with these results had an RSD of 32.2%, indicating potential low bias for the results. OCDF and OCDD detected in sample 178501 and OCDF detected in samples 178507, 178508, and 178508dup were also qualified as estimates ("J") because the internal standard in the continuing calibration standard associated with these results had an RSD of 30.4%, indicating potential low bias for the result. The OCDF result for sample 178509 was qualified with a "UJ" because the

associated continuing calibration standard used for quantitation had and RSD of -23.1% indicating a possible low bias.
All the ion abundance ratios were within +/- 15% of the theoretical values.

Internal Standard Recoveries:

Internal standard recoveries for these samples were within the 40–135% (method 8290 limits) or 25–150% (method 1613B) QC limits established for each congener.

Ion abundance ratios:

Each dioxin and furan isomer reported as detected met the isotopic abundance ratio and retention time criteria for positive identification.

Matrix Spike/Matrix Spike Duplicate (MS/MSD):

MS/MSD recoveries were within quality control limits of 60–140%; and precision data was within ±20 relative percent difference (RPD).

Summary:

This data is acceptable for use as amended. A number of congeners were qualified with a "J" because the concentration detected was below the lowest calibration standard; results derived from responses outside the calibration range are considered estimates.

Qualifiers

U	The analyte was not detected at or above the reported result
J	The analyte was positively identified. The associated numerical result is an estimate.
UJ	The analyte was not detected at or above the reported estimated result

Appendix B

Washington State agricultural surface soil dioxin results

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

	Congener	TEF	Sample Number 8501	8502	8503	8504	8504-Dup	8505
1	2,3,7,8-TCDD	1	0.23 U	0.45 U	0.45 U	0.40 U	0.40 U	0.69 U
2	1,2,3,7,8-PeCDD	0.5	0.54 U	0.78 U	0.58 U	1.4 U	2.3 U	1.4 U
3	1,2,3,4,7,8-HxCDD	0.1	0.43 U	0.33 U	0.85 U	0.34 U	0.65 U	0.41 U
4	1,2,3,6,7,8-HxCDD	0.1	0.51 U	0.27 U	0.57 J	0.52 U	1.1 U	1.1 J
5	1,2,3,7,8,9-HxCDD	0.1	0.29 U	0.32 U	0.47 J	0.39 U	0.50 U	1.0 J
6	1,2,3,4,6,7,8-HpCDD	0.01	3.4 J	1.3 J	2.2 UJ	3.5 UJ	3.0 UJ	17
7	OCDD	0.001	29 J	4.8 UJ	9.9	19	10	180 J
8	2,3,7,8-TCDF	0.1	0.28 U	0.35 U	0.30 J	0.33 J	0.35 J	0.34 J
9	1,2,3,7,8-PeCDF	0.05	0.18 U	0.23 U	0.22 J	0.85 U	0.45 U	0.84 UJ
10	2,3,4,7,8-PeCDF	0.5	0.21 U	0.31 U	0.45 U	0.63 U	0.41 U	0.92 U
11	1,2,3,4,7,8-HxCDF	0.1	0.16 U	0.27 U	0.36 UJ	0.27 UJ	0.22 UJ	0.41 U
12	1,2,3,6,7,8-HxCDF	0.1	0.40 U	0.47 U	1.0 U	0.21 U	0.51	1.1 J
13	2,3,4,6,7,8-HxCDF	0.1	0.45 J	0.36 U	0.53 UJ	0.53 UJ	0.36 UJ	0.57 UJ
14	1,2,3,7,8,9-HxCDF	0.1	0.25 U	0.30 U	0.55 U	0.31 U	0.78 U	0.78 U
15	1,2,3,4,6,7,8-HpCDF	0.01	6.3	0.24 J	1.1 J	1.8 J	1.3 J	5.2
16	1,2,3,4,7,8,9-HpCDF	0.01	0.39 U	0.41 U	0.92 U	0.69 U	1.4 U	0.98 U
17	OCDF	0.001	38 J	0.38 J	0.87 J	1.6 J	1.2 J	9.6 J

Congener Totals	TCDDs	0.23 U	0.45 U	0.45 U	0.43 J	0.4 U	0.44 J
	TCDFs	0.28 U	0.46 J	1.2	0.33 J	1.0	0.34 J
	PeCDDs	0.54 U	0.78 U	0.58 U	1.4 U	2.3 U	1.4 U
	PeCDFs	0.20 U	0.27 U	0.22 U	0.74 U	0.43 U	0.88 U
	HxCDDs	0.55 J	0.36 J	1.7 J	0.83 J	0.65 J	6.9
	HxCDFs	2.0 J	0.35 U	0.89 UJ	2.5 J	2.8 J	4.7 J
	HpCDDs	6.8 J	1.3 J	3.2 UJ	4.5 UJ	3.5 UJ	23
	HpCDFs	16	0.24 J	1.1 J	1.8 J	1.3 J	5.2

TEQS	**ND = 0**	**0.21**	**0.016**	**0.17**	**0.072**	**0.059**	**0.77**
	ND = 1/2 DL	0.63	0.66	0.83	0.95	1.2	1.8
	ND = DL	1.1	1.3	1.5	1.8	2.3	2.9

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8506**	**8507**	**8508**	**8508 Dup**	**8509**	**8510**
2,3,7,8-TCDD		1	0.73 U	0.93 U	0.71 U	0.35 U	0.50 U	0.69 U
1,2,3,7,8-PeCDD		0.5	0.91 U	1.80 U	1.10 U	0.17 U	0.77 U	0.67 U
1,2,3,4,7,8-HxCDD		0.1	0.48 U	0.98 U	0.70 U	0.30 U	0.69 U	0.82 U
1,2,3,6,7,8-HxCDD		0.1	0.36 J	0.95 U	0.76 U	0.50 U	0.70 U	0.60 U
1,2,3,7,8,9-HxCDD		0.1	0.84 U	1.60 U	0.56 U	0.33 U	0.37 U	0.44 U
1,2,3,4,6,7,8-HpCDD		0.01	2.1 UJ	1.9 J	1.4 J	0.86 J	2.4 J	1.4 U
OCDD		0.001	14	9.2 UJ	4.6 UJ	3.2 UJ	7.6 J	11 UJ
2,3,7,8-TCDF		0.1	0.38 J	1.2 U	0.55 U	0.28 U	0.92 U	0.50 U
1,2,3,7,8-PeCDF		0.05	0.35 U	1.10 U	0.35 U	0.30 U	0.33 U	0.41 U
2,3,4,7,8-PeCDF		0.5	0.51 U	0.87 U	0.33 U	0.16 U	0.55 U	0.74 U
1,2,3,4,7,8-HxCDF		0.1	0.28 U	1.2 U	0.55 U	0.16 U	0.49 U	0.41 U
1,2,3,6,7,8-HxCDF		0.1	0.86 U	1.2 U	0.42 U	0.11 U	0.34 U	0.30 J
2,3,4,6,7,8-HxCDF		0.1	0.44 UJ	1.2 U	0.52 J	0.39 J	0.50 U	0.52 UJ
1,2,3,7,8,9-HxCDF		0.1	0.60 U	0.94 U	0.50 U	0.26 U	0.55 U	0.82 U
1,2,3,4,6,7,8-HpCDF		0.01	0.93 J	1.3 J	0.89 U	0.51 J	0.75 J	0.41 U
1,2,3,4,7,8,9-HpCDF		0.01	0.75 U	1.2 U	0.64 U	0.23 U	0.61 U	0.47 U
OCDF		0.001	1.5 J	6.1 J	2.3 J	2.1 J	1.3 U	0.63 UJ
Congener Totals	TCDDs		0.39 J	0.93 U	0.71 U	0.35 U	0.50 U	0.69 U
	TCDFs		1.1	1.2 U	0.77 J	1.2	1.4	0.50 U
	PeCDDs		0.91 U	1.8 U	1.1 U	0.17 U	0.77 U	0.67 U
	PeCDFs		0.43 U	0.99 U	0.52 J	0.23 U	0.44 U	0.58 U
	HxCDDs		0.36 J	1.2 U	0.67 U	0.38 U	0.59 U	0.62 U
	HxCDFs		0.44 UJ	1.1 U	0.52 J	0.39 J	0.47 U	1.2 J
	HpCDDs		3.0 UJ	1.9 J	1.4 J	1.3 J	2.4 J	1.3 UJ
	HpCDFs		0.93 J	1.3 J	0.77 U	0.51 J	0.75 J	0.44 U
TEQS	**ND = 0**		**0.10**	**0.038**	**0.068**	**0.055**	**0.039**	**0.043**
	ND = 1/2 DL		1.0	1.7	1.0	0.42	0.86	0.94
	ND = DL		1.9	3.3	1.9	0.78	1.7	1.8

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8510-Dup**	**8511**	**8512**	**8513**	**8514**	**8515**
2,3,7,8-TCDD		1	0.48 U	0.64 U	0.39 U	0.29 U	0.32 U	0.27 U
1,2,3,7,8-PeCDD		0.5	0.56 U	0.77 U	0.89 U	0.67 U	0.31 U	1.0 U
1,2,3,4,7,8-HxCDD		0.1	0.54 U	0.49 U	0.64 U	0.61 U	0.75 U	0.72 U
1,2,3,6,7,8-HxCDD		0.1	0.70 U	0.84 U	0.78 J	0.49 U	0.72 U	0.50 U
1,2,3,7,8,9-HxCDD		0.1	0.46 U	0.42 U	0.37 J	0.43 U	0.47 U	0.45 U
1,2,3,4,6,7,8-HpCDD		0.01	2.2 U	1.5 UJ	12	1.4 J	1.4 J	3.4 J
OCDD		0.001	10 UJ	5.7 UJ	91	6.3 UJ	8.7 UJ	19
2,3,7,8-TCDF		0.1	0.25 U	0.41 J	0.26 J	0.40 U	0.37 J	0.30 J
1,2,3,7,8-PeCDF		0.05	0.42 U	0.45 U	0.31 U	0.36 U	0.39 U	0.68 U
2,3,4,7,8-PeCDF		0.5	0.41 U	0.47 U	0.25 J	0.44 U	0.47 U	0.55 U
1,2,3,4,7,8-HxCDF		0.1	0.55 U	0.26 UJ	0.53 U	0.65 U	0.57 U	0.48 U
1,2,3,6,7,8-HxCDF		0.1	0.70 U	1.0 U	1.4 U	0.47 U	0.24 U	0.18 U
2,3,4,6,7,8-HxCDF		0.1	0.59 U	0.41 UJ	0.73 UJ	0.47 J	0.38 U	0.52 J
1,2,3,7,8,9-HxCDF		0.1	0.41 U	0.92 U	0.46 U	0.42 U	0.40 U	0.50 U
1,2,3,4,6,7,8-HpCDF		0.01	0.71 J	0.77 J	12	0.33 U	0.63 U	0.58 U
1,2,3,4,7,8,9-HpCDF		0.01	0.46 U	1.10 U	1.50 U	0.25 U	0.68 U	0.60 U
OCDF		0.001	0.66 UJ	0.95 J	65.0	0.45 J	0.9 J	1.7 J
Congener Totals	TCDDs		0.73 UJ	0.52	0.20 J	0.29 U	0.70 J	0.27 U
	TCDFs		0.25 U	0.96 J	0.26 J	0.86 J	0.37 J	0.30 J
	PeCDDs		0.56 U	0.77 U	0.89 U	0.67 U	0.31 U	1.0 U
	PeCDFs		0.42 U	0.46 U	0.25 J	0.94 J	0.43 U	0.62 U
	HxCDDs		0.57 U	0.46 J	2.7 J	0.51 U	0.65 U	0.56 U
	HxCDFs		0.69 J	0.67 UJ	8.1 J	1.1 J	0.40 U	1.0 J
	HpCDDs		1.3 UJ	1.5 UJ	12	2.4 J	2.4 J	5.8
	HpCDFs		0.71 J	0.77 J	12	0.29 U	1.1 J	0.59 U
TEQS	**ND = 0**		**0.0071**	**0.050**	**0.66**	**0.061**	**0.052**	**0.14**
	ND = 1/2 DL		0.73	0.92	1.3	0.67	0.60	0.82
	ND = DL		1.5	1.8	1.9	1.3	1.2	1.5

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8516**	**8517**	**8519**	**8520**	**8521**	**8522**
2,3,7,8-TCDD		1	0.49 U	0.41 U	0.64 U	0.20 U	0.39 U	0.80 U
1,2,3,7,8-PeCDD		0.5	1.1 U	0.47 U	0.58 U	0.66 U	0.90 U	1.4 U
1,2,3,4,7,8-HxCDD		0.1	0.84 U	0.31 U	0.43 U	0.48 U	0.45 U	0.79 U
1,2,3,6,7,8-HxCDD		0.1	0.60 U	0.85 U	0.44 U	0.46 U	0.40 U	0.74 U
1,2,3,7,8,9-HxCDD		0.1	0.67 U	0.44 U	0.71 U	0.57 U	0.36 U	0.69 U
1,2,3,4,6,7,8-HpCDD		0.01	2.4 UJ	1.4 J	0.78 J	2.1 J	1.4 J	2.0 J
OCDD		0.001	16	9.8 UJ	4.1 UJ	9.9 UJ	6.6 UJ	11 UJ
2,3,7,8-TCDF		0.1	0.40 U	0.31 U	0.41 U	0.31 J	0.31 J	1.0 U
1,2,3,7,8-PeCDF		0.05	0.68 U	0.37 U	0.33 U	0.24 U	0.32 U	0.88 U
2,3,4,7,8-PeCDF		0.5	0.39 U	0.39 U	0.59 U	0.22 U	0.48 U	0.56 U
1,2,3,4,7,8-HxCDF		0.1	0.31 UJ	0.28 U	0.34 U	0.31 U	0.45 U	1.2 U
1,2,3,6,7,8-HxCDF		0.1	0.82 U	0.34 U	0.76 U	0.24 U	0.33 U	0.75 U
2,3,4,6,7,8-HxCDF		0.1	0.51 UJ	0.49 J	0.28 UJ	0.49 U	0.52 J	1.1 U
1,2,3,7,8,9-HxCDF		0.1	0.90 U	0.38 U	0.51 U	0.52 U	0.51 U	0.84 U
1,2,3,4,6,7,8-HpCDF		0.01	0.76 J	0.21 U	0.95 U	0.50 U	0.47 U	0.54 U
1,2,3,4,7,8,9-HpCDF		0.01	0.99 U	0.82 U	0.65 U	0.65 U	0.45 U	0.53 U
OCDF		0.001	1.6 J	0.91 J	1.3 U	0.85 J	0.96 J	2.2 U
Congener Totals	TCDDs		0.34 J	0.60 J	0.64 U	0.40 J	0.39 U	0.8 U
	TCDFs		0.40 U	0.31 U	0.41 U	2.3	1.3	1.0 U
	PeCDDs		1.1 U	0.47 U	0.58 U	0.66 U	0.90 U	1.4 U
	PeCDFs		0.54 U	0.38 U	0.46 U	0.23 U	0.40 U	1.5 J
	HxCDDs		0.70 U	0.53 U	0.53 U	0.5 U	0.40 U	0.74 U
	HxCDFs		0.82 UJ	0.49 J	0.28 UJ	0.39 U	1.3 J	0.97 U
	HpCDDs		3.3 UJ	2.4 J	0.78 J	3.3 J	2.4 J	2.0 J
	HpCDFs		1.2 J	0.52 U	0.80 U	0.43 J	0.46 U	0.54 U
TEQS	**ND = 0**		**0.025**	**0.064**	**0.0078**	**0.053**	**0.10**	**0.020**
	ND = 1/2 DL		0.93	0.65	0.83	0.54	0.78	1.3
	ND = DL		1.8	1.2	1.7	1.0	1.5	2.6

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8523**	**8524**	**8525**	**8525-Dup**	**8526**	**8527**
2,3,7,8-TCDD		1	0.43 U	0.45 U	0.46 U	0.73 U	0.46 U	0.60 U
1,2,3,7,8-PeCDD		0.5	0.81 U	0.73 U	1.1 U	0.74 U	0.64 U	0.52 U
1,2,3,4,7,8-HxCDD		0.1	0.80 U	0.37 U	1.7 U	1.0 U	0.25 J	0.58 U
1,2,3,6,7,8-HxCDD		0.1	0.63 U	0.66 U	1.0 U	1.3 U	0.81 J	0.44 U
1,2,3,7,8,9-HxCDD		0.1	0.56 U	0.26 U	0.54 U	0.75 U	0.57 J	0.47 U
1,2,3,4,6,7,8-HpCDD		0.01	1.6 J	5.5	1.3 UJ	1.0 UJ	17	1.1 U
OCDD		0.001	6.8 UJ	100	7.0 UJ	6.8 UJ	140	4.6 U
2,3,7,8-TCDF		0.1	0.67 U	0.31 J	0.49 U	0.36 J	0.43 J	0.31 J
1,2,3,7,8-PeCDF		0.05	0.76 U	0.27 U	0.51 U	0.83 U	0.23 U	0.58 U
2,3,4,7,8-PeCDF		0.5	0.67 U	0.53 U	0.32 U	0.51 U	0.24 U	0.21 U
1,2,3,4,7,8-HxCDF		0.1	0.64 U	0.55 U	0.97 U	0.91 U	0.36 U	0.61 U
1,2,3,6,7,8-HxCDF		0.1	0.52 U	0.27 J	0.60 J	0.73 U	2.4 U	0.50 U
2,3,4,6,7,8-HxCDF		0.1	0.71 U	0.43 UJ	0.47	0.44 UJ	0.47 UJ	0.32 U
1,2,3,7,8,9-HxCDF		0.1	0.59 U	0.45 U	0.68 U	0.99 U	0.52 U	0.87 U
1,2,3,4,6,7,8-HpCDF		0.01	0.84 U	0.81 J	0.49 J	0.70 J	13 U	5.3 UJ
1,2,3,4,7,8,9-HpCDF		0.01	1.3 U	0.51 U	1.5 U	0.90 U	0.32 U	0.98 U
OCDF		0.001	1.8 J	32	4.3 J	4.4 J	21	2.2 U
Congener Totals	TCDDs		0.43 U	1.3	0.46 U	0.73 U	0.50 J	0.60 U
	TCDFs		0.51 J	0.55 J	0.49 U	0.36 J	0.72 J	0.31 J
	PeCDDs		0.81 U	0.73 U	1.1 U	0.74 U	0.64 U	0.52 U
	PeCDFs		0.72 U	0.40 U	0.42 U	0.67 U	0.91 J	0.39 U
	HxCDDs		0.98 J	0.43 U	1.1 U	1.0 U	4.5 J	0.50 U
	HxCDFs		0.62 U	1.9 J	1.1 J	0.44 UJ	5.6 J	0.58 U
	HpCDDs		2.9 J	9.3	1.3 UJ	1.0 UJ	21	1.1 U
	HpCDFs		1.1 U	1.7 J	0.49 J	0.7 J	6.7 U	3.1 U
TEQS	**ND = 0**		**0.018**	**0.25**	**0.12**	**0.047**	**0.54**	**0.031**
	ND = 1/2 DL		0.89	0.94	1.0	1.1	1.2	0.76
	ND = DL		1.8	1.6	1.9	2.1	2.0	1.5

U =analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8528**	**8529**	**8530**	**8531**	**8532**	**8533**
2,3,7,8-TCDD		1	0.26 U	0.78 U	0.20 U	0.69 U	0.50 U	0.29 U
1,2,3,7,8-PeCDD		0.5	0.76 U	0.68 U	0.38 U	0.29 U	0.85 U	1.1 U
1,2,3,4,7,8-HxCDD		0.1	0.38 U	0.58 U	0.31 U	0.34 U	0.42 U	0.93 U
1,2,3,6,7,8-HxCDD		0.1	0.30 U	0.75 U	0.25 U	0.58 U	0.54 U	1.0 U
1,2,3,7,8,9-HxCDD		0.1	0.26 U	0.50 U	0.35 U	0.37 U	0.38 U	0.57 U
1,2,3,4,6,7,8-HpCDD		0.01	1.5 U	2.1 J	2.6 J	1.7 J	1.1 UJ	1.3 UJ
OCDD		0.001	8.0 UJ	9.2 J	15	10	11	10
2,3,7,8-TCDF		0.1	0.57 U	0.75 U	0.37 U	0.39 U	0.18 J	0.29 J
1,2,3,7,8-PeCDF		0.05	0.42 U	0.58 U	0.12 U	0.12 U	0.41 U	1.3 U
2,3,4,7,8-PeCDF		0.5	0.85 U	0.38 U	0.19 U	0.33 U	0.28 U	0.47 U
1,2,3,4,7,8-HxCDF		0.1	0.39 U	0.73 U	0.40 U	0.30 U	0.69 U	1.0 U
1,2,3,6,7,8-HxCDF		0.1	0.70 U	0.71 U	0.19 J	0.20 J	0.48 J	0.63 J
2,3,4,6,7,8-HxCDF		0.1	0.43 UJ	0.66 U	0.40 UJ	0.34 UJ	0.45 UJ	0.47 UJ
1,2,3,7,8,9-HxCDF		0.1	0.58 U	0.34 U	0.33 U	0.31 U	0.61 U	1.1 U
1,2,3,4,6,7,8-HpCDF		0.01	0.91 J	0.85 U	0.47	0.61 J	1.00 J	0.43 J
1,2,3,4,7,8,9-HpCDF		0.01	0.39 U	0.60 U	0.48 U	0.26 U	0.68 U	1.0 U
OCDF		0.001	1.1 U	1.9 J	0.57 J	1.1 J	13	1.1 J
Congener Totals	TCDDs		0.26 U	0.78 U	0.99	0.60 J	0.50 U	0.29 U
	TCDFs		2.7	0.75 U	0.80 J	0.36 J	0.36 J	1.8
	PeCDDs		0.76 U	0.68 U	0.38 U	0.29 U	0.85 U	1.1 U
	PeCDFs		0.64 U	0.48 U	0.16 U	0.76 J	0.35 U	0.89 U
	HxCDDs		0.47 J	0.61 U	1.1 J	0.43 U	0.45 U	0.83 U
	HxCDFs		0.76 J	0.61 U	0.59 J	0.54 J	0.93 J	1.1 J
	HpCDDs		1.5 U	4.3 J	5.4	1.7 J	1.4 UJ	1.3 UJ
	HpCDFs		0.91 J	0.81 J	1.1 J	0.61 J	6.0	0.43 J
TEQS	**ND = 0**		**0.0091**	**0.032**	**0.070**	**0.054**	**0.010**	**0.017**
	ND = 1/2 DL		0.75	0.96	0.44	0.69	0.76	0.90
	ND = DL		1.5	1.9	0.80	1.3	1.5	1.8

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8534**	**8535**	**8536**	**8537**	**8538**	**8539**
2,3,7,8-TCDD		1	0.52 U	0.83 U	0.44 U	0.83 U	0.46 U	1.2 U
1,2,3,7,8-PeCDD		0.5	1.1 U	0.63 U	0.53 U	0.62 U	0.57 U	2.5 U
1,2,3,4,7,8-HxCDD		0.1	0.95 U	0.65 U	0.51 U	0.96 U	0.42 U	1.9 U
1,2,3,6,7,8-HxCDD		0.1	1.4 U	0.60 U	0.67 U	0.83 J	1.0 U	2.3 U
1,2,3,7,8,9-HxCDD		0.1	0.68 U	0.72 U	0.52 U	0.31 J	0.36 U	1.3 U
1,2,3,4,6,7,8-HpCDD		0.01	1.8 UJ	7.8	2.2 UJ	12	3.2 UJ	1.8 J
OCDD		0.001	12	62	19 J	110	21 J	8.7 J
2,3,7,8-TCDF		0.1	0.47 U	0.47 U	0.39 J	0.28 J	0.45 J	1.5 U
1,2,3,7,8-PeCDF		0.05	0.74 U	0.88 U	0.85 U	0.62 U	0.41 U	1.1 U
2,3,4,7,8-PeCDF		0.5	0.68 U	0.64 U	0.37 U	0.50 U	0.34 U	1.1 U
1,2,3,4,7,8-HxCDF		0.1	0.26 UJ	0.38 UJ	0.53 U	0.65 U	0.20 UJ	1.6 U
1,2,3,6,7,8-HxCDF		0.1	0.50 U	0.57	1.1 J	0.74 U	0.38 U	1.2 U
2,3,4,6,7,8-HxCDF		0.1	0.66 UJ	0.54 UJ	0.35 UJ	0.42 UJ	0.46 UJ	1.8 U
1,2,3,7,8,9-HxCDF		0.1	0.98 U	0.69 U	0.60 U	0.33 U	0.53 U	2.2 U
1,2,3,4,6,7,8-HpCDF		0.01	0.79 J	2.0 J	3.6 J	2.2 J	0.49 U	2.4 U
1,2,3,4,7,8,9-HpCDF		0.01	1.8 U	0.63 U	1.1 U	0.53 U	0.92 U	2.0 U
OCDF		0.001	1.2 J	25	27	1.8 J	1.6 J	3.6 U
Congener Totals	TCDDs		0.52 U	0.83 U	0.96 J	0.20 J	0.46 U	1.2 U
	TCDFs		0.47 U	3.8	1.9	0.28 J	0.45 J	1.5 U
	PeCDDs		1.1 U	0.63 U	0.53 U	0.62 U	0.57 U	2.5 U
	PeCDFs		0.71 U	0.17 J	0.61 U	0.56 U	0.38 U	1.1 U
	HxCDDs		1.01 U	0.90 J	0.57 U	2.5 J	0.59 U	1.8 U
	HxCDFs		0.92 UJ	3.9 J	3.0 J	0.76 J	0.66 UJ	1.7 U
	HpCDDs		1.8 UJ	10	2.2 UJ	22	4.2 UJ	3.5 J
	HpCDFs		0.79 J	6.0	9.4	2.9 J	0.71 U	2.2 U
TEQS	**ND = 0**		**0.021**	**0.19**	**0.23**	**0.40**	**0.068**	**0.027**
	ND = 1/2 DL		1.0	1.2	0.87	1.3	0.73	2.3
	ND = DL		2.0	2.2	1.5	2.1	1.4	4.5

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8540**	**8541**	**8542**	**8543**	**8544**	**8545**
2,3,7,8-TCDD		1	0.60 U	0.83 U	0.76 U	0.38 U	0.45 U	0.42 U
1,2,3,7,8-PeCDD		0.5	0.89 U	1.4 U	0.65 U	0.59 U	0.43 U	1.8 U
1,2,3,4,7,8-HxCDD		0.1	0.58 U	1.2 U	0.73 U	0.44 U	0.47 U	1.1 U
1,2,3,6,7,8-HxCDD		0.1	0.89 U	1.6 U	0.56 U	0.33 U	0.81 U	2.3 U
1,2,3,7,8,9-HxCDD		0.1	0.50 U	1.0 U	0.72 U	0.34 U	0.95 U	1.9 U
1,2,3,4,6,7,8-HpCDD		0.01	1.8 J	7.6	3.2 J	1.3 J	0.77 J	1.2 J
OCDD		0.001	9.5 J	72	20	5.2 UJ	4.1 UJ	8.2 UJ
2,3,7,8-TCDF		0.1	0.43 U	0.86 U	0.64 U	0.77 U	0.23 J	0.58 U
1,2,3,7,8-PeCDF		0.05	0.41 U	0.70 U	0.46 U	0.42 U	0.24 U	0.68 U
2,3,4,7,8-PeCDF		0.5	0.43 U	1.3 U	1.0 U	0.67 U	0.40 U	0.96 U
1,2,3,4,7,8-HxCDF		0.1	0.67 U	1.7 J	0.45 U	0.97 U	0.16 J	0.61 U
1,2,3,6,7,8-HxCDF		0.1	1.1 U	2.0 J	1.3 U	1.7 U	0.46 U	1.1 U
2,3,4,6,7,8-HxCDF		0.1	0.53 U	1.1 U	0.59 U	0.54 U	0.55 U	1.3 U
1,2,3,7,8,9-HxCDF		0.1	0.54 U	1.4 U	0.84 U	0.58 U	0.41 U	1.0 U
1,2,3,4,6,7,8-HpCDF		0.01	0.80 U	4.7 J	0.63 U	0.49 U	0.23 J	1.2 U
1,2,3,4,7,8,9-HpCDF		0.01	0.52 U	2.9 U	0.89 U	0.23 U	0.33 U	0.98 U
OCDF		0.001	1.2 J	4.5 J	1.2 U	2.0 J	1.3 U	2.8 U
Congener Totals	TCDDs		0.60 U	0.83 U	0.76 U	0.43 J	0.45 U	0.42 U
	TCDFs		1.6	0.86 U	0.64 U	0.33 J	0.87 J	0.58 U
	PeCDDs		0.89 U	1.4 U	0.65 U	0.59 U	0.43 U	1.8 U
	PeCDFs		0.42 U	2.4 J	0.73 U	0.55 U	0.32 U	0.82 U
	HxCDDs		0.66 U	1.3 U	0.67 U	0.37 U	0.74 U	1.8 U
	HxCDFs		0.71 U	8.1	0.57 J	0.95 U	0.16 J	1.0 U
	HpCDDs		2.7 J	12	6.3	3.7 J	1.3 J	2.4 J
	HpCDFs		0.66 U	4.7 J	0.83 J	0.36 U	0.23 J	1.1 U
TEQS	**ND = 0**		**0.029**	**0.57**	**0.052**	**0.015**	**0.049**	**0.012**
	ND = 1/2 DL		0.94	2.0	1.2	0.82	0.67	1.4
	ND = DL		1.8	3.5	2.3	1.6	1.3	2.9

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number					
Congener		**TEF**	**8546**	**8547**	**8548**	**8548-Dup**	**8549**	**8550**
2,3,7,8-TCDD		1	0.45 U	0.35 U	0.58 U	0.71 U	0.29 U	0.74 U
1,2,3,7,8-PeCDD		0.5	0.63 U	0.60 U	0.66 U	1.2 U	0.38 U	0.98 U
1,2,3,4,7,8-HxCDD		0.1	0.43 U	0.93 U	0.57 U	0.72 U	0.44 U	0.50 U
1,2,3,6,7,8-HxCDD		0.1	0.64 U	0.63 J	1.0 U	0.80 U	0.51 U	0.68 U
1,2,3,7,8,9-HxCDD		0.1	0.64 U	0.93 U	0.42 U	0.81 U	0.24 U	0.55 U
1,2,3,4,6,7,8-HpCDD		0.01	1.9 J	7.6	3.3 J	2.5 J	1.2 J	5.1
OCDD		0.001	9.5 J	32	21	9.6 J	4.3 UJ	27
2,3,7,8-TCDF		0.1	0.46 J	6.2	0.68 U	0.62 U	0.30 J	0.62 U
1,2,3,7,8-PeCDF		0.05	0.41 U	0.95 J	0.49 U	0.69 U	0.23 U	0.51 U
2,3,4,7,8-PeCDF		0.5	0.44 U	0.59 J	0.35 U	0.62 U	0.26 U	0.52 U
1,2,3,4,7,8-HxCDF		0.1	0.77 U	0.67 U	0.82 U	0.84 U	0.26 U	0.58 U
1,2,3,6,7,8-HxCDF		0.1	0.27 U	0.67 U	0.54 U	1.0 U	0.36 U	1.3 U
2,3,4,6,7,8-HxCDF		0.1	0.65 U	0.45 U	0.49 U	1.2 U	0.33 U	0.64 U
1,2,3,7,8,9-HxCDF		0.1	0.56 U	0.68 U	0.44 U	0.70 U	0.42 U	0.61 U
1,2,3,4,6,7,8-HpCDF		0.01	0.39 U	3.1 J	0.42 J	0.65 U	0.55 U	1.2 J
1,2,3,4,7,8,9-HpCDF		0.01	0.61 U	1.0 U	0.86 U	0.53 U	0.25 U	0.73 U
OCDF		0.001	1.0 U	12	0.9 U	1.4 U	0.32 J	1.9 J
Congener Totals	TCDDs		0.45 U	0.35 U	0.58 U	0.71 U	0.35 J	0.74 U
	TCDFs		1.3	12	1.2	0.71 J	0.30 J	0.62 U
	PeCDDs		0.63 U	0.60 U	0.66 U	1.2 U	0.38 U	0.98 U
	PeCDFs		0.43 U	2.1 J	0.42 U	0.74 J	0.25 U	0.91 J
	HxCDDs		0.57 U	1.7 J	0.66 U	0.78 U	0.40 U	2.1 J
	HxCDFs		0.56 U	0.62 U	0.55 J	0.93 U	0.34 U	1.1 J
	HpCDDs		1.9 J	12	5.1	3.4 J	2.6 J	6.7
	HpCDFs		0.50 U	7.6	0.42 J	0.59 U	0.40 U	1.2 J
TEQS	**ND = 0**		**0.075**	1.2	**0.058**	**0.035**	**0.047**	**0.092**
	ND = 1/2 DL		0.78	1.7	0.87	1.2	0.49	1.1
	ND = DL		1.5	2.3	1.7	2.4	0.93	2.2

U = analyte was not detected at or above the reported result.
J = analyte was positively identified. The associated numerical result is an estimate.
ND = non-detect
Dup = duplicate sample
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit

Appendix B. Washington State agricultural surface soil dioxin results (ng/kg, pptr).

			Sample Number				
Congener		**TEF**	**8551**	**8552**	**8553**	**8554**	**8555**
2,3,7,8-TCDD		1	0.37 U	1.1 U	0.72 U	0.38 U	0.55 U
1,2,3,7,8-PeCDD		0.5	0.78 U	1.6 U	0.54 U	0.67 U	0.29 U
1,2,3,4,7,8-HxCDD		0.1	0.42 U	1.0 U	0.63 U	0.42 U	0.47 U
1,2,3,6,7,8-HxCDD		0.1	1.1 U	1.1 U	0.50 U	0.73 U	0.34 U
1,2,3,7,8,9-HxCDD		0.1	0.50 U	0.79 U	0.66 U	0.48 U	0.26 U
1,2,3,4,6,7,8-HpCDD		0.01	13	2.4 J	2.5 J	2.8 UJ	1.2 J
OCDD		0.001	98	32	42	18 J	5.3 UJ
2,3,7,8-TCDF		0.1	0.32 J	0.86 U	0.91 U	0.51 U	0.39 U
1,2,3,7,8-PeCDF		0.05	0.36 U	0.98 U	0.54 U	0.54 U	0.30 U
2,3,4,7,8-PeCDF		0.5	0.65 U	0.99 U	0.65 U	0.36 U	0.28 U
1,2,3,4,7,8-HxCDF		0.1	0.41 J	1.2 U	0.51 U	0.50 U	0.23 U
1,2,3,6,7,8-HxCDF		0.1	0.24 U	2.3 U	1.5 U	0.56 U	0.53 U
2,3,4,6,7,8-HxCDF		0.1	0.66 UJ	1.3 U	0.54 UJ	0.38 UJ	0.51 UJ
1,2,3,7,8,9-HxCDF		0.1	0.44 U	1.7 U	1.1 U	0.63 U	0.39 U
1,2,3,4,6,7,8-HpCDF		0.01	0.94 J	2.5 J	1.1 U	0.85 U	0.38 U
1,2,3,4,7,8,9-HpCDF		0.01	0.48 U	1.4 U	1.4 U	0.71 U	0.53 U
OCDF		0.001	4.6 J	28	15	1.3 U	0.48 U
Congener Totals	TCDDs		0.37 U	1.1 U	0.72 U	0.38 U	0.55 U
	TCDFs		0.32 J	1.9	0.65	1.2	0.62
	PeCDDs		0.78 U	1.6 U	0.54 U	0.67 U	0.29 U
	PeCDFs		0.51 U	0.99 U	0.6 U	0.93 J	0.29 U
	HxCDDs		3.4 J	0.96 U	0.6 U	0.54 U	0.36 U
	HxCDFs		5.0	1.6 U	1.1 J	2.2 J	0.51 UJ
	HpCDDs		18	2.4 J	2.5 J	3.8 UJ	1.9 J
	HpCDFs		0.94 J	7.0	1.3 U	0.78 U	0.46 U
TEQS	**ND = 0**		**0.32**	**0.11**	**0.082**	**0.018**	**0.012**
	ND = 1/2 DL		1.0	1.9	1.1	0.71	0.60
	ND = DL		1.8	3.6	2.1	1.4	1.2

U = analyte was not detected at or above the reported result.

J = analyte was positively identified. The associated numerical result is an estimate.

ND = non-detect

Dup = duplicate sample

DL = detection limit

ND = 0: if congener not detected, concentration assumed = 0

ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit

ND = DL: if congener not detected, concentration assumed = detect limit

Appendix C

Apparent percent grain size, percent total organic carbon, and dioxin TEQ values of soil samples collected from Washington State agricultural lands

Appendix C. Apparent percent grain size, percent total organic carbon (TOC) and dioxin TEQ* values of soil samples collected from Washington State agricultural lands.

Sample	Gravel	Sand	Silt	Clay	TOC 70°C	TOC 140°C	TEQ ND=0	TEQ ND=1/2 DL	TEQ ND=DL
8501	1.0	22.5	60.7	15.8	1.92 J	1.93 J	**0.21**	0.63	1.1
8502	0.2	19.3	72.5	8.0	1.61 J	1.63 J	**0.016**	0.66	1.3
8503	0.3	25.8	72.9	1.1	0.84	0.84	**0.17**	0.83	1.5
8504	2.4	72.7	21.5	3.3	2.7	2.72	**0.065**	1.1	2.1
8505	3.7	64.9	30	1.3	4.43	4.52	**0.77**	1.8	2.9
8506	1.4	19.3	72	7.4	0.78	0.79	**0.10**	0.71	1.4
8507	9.8	45.9	40.8	3.6	1.39 J	1.39 J	**0.038**	1.7	3.3
8508	0.5	34.9	57.9	6.7	1.01 J	1.02 J	**0.062**	1.0	1.9
8509	0.0	31.5	62.6	5.9	1.34 J	1.34 J	**0.039**	0.86	1.7
8510	0.1	23.2	72.4	4.4	0.54 J	0.54 J	**0.025**	0.83	1.6
8511	0.4	30.2	63.9	5.5	1.55	1.56	**0.050**	0.92	1.8
8512	0.3	34.4	61.6	3.8	1.2	1.12	**0.66**	1.3	1.9
8513	0.1	26.0	69.6	4.3	0.9 J	0.9 J	**0.061**	0.67	1.3
8514	1.3	34.5	52.6	11.6	1.52 J	1.53 J	**0.052**	0.60	1.2
8515	1.5	42.4	47.3	8.8	2.27 J	2.27 J	**0.14**	0.82	1.5
8516	0.4	41	56.8	1.8	0.64	0.64	**0.025**	0.93	1.8
8517	0.0	29.4	67.1	3.5	0.64 J	0.64 J	**0.064**	0.65	1.2
8519	0.4	65.9	30.8	3.0	0.63 J	0.63 J	**0.078**	0.83	1.7
8520	0.1	23.4	70.4	6.2	1.31 J	1.31 J	**0.053**	0.54	1.0
8521	0.1	32.8	56.6	10.4	1.93 J	1.95 J	**0.10**	0.78	1.5
8522	0.4	20.9	70	8.6	1.82 J	1.83 J	**0.020**	1.3	2.6
8523	0.1	59.1	31.1	9.7	0.83 J	0.84 J	**0.018**	0.89	1.8
8524	20.5	43.7	29.7	6.1	3.12 J	3.15 J	**0.25**	0.94	1.6
8525	0.2	59.6	38.7	1.5	0.42	0.42	**0.082**	1.0	2.0
8526	8.6	41.6	45.4	4.3	3.43	3.42	**0.54**	1.2	2.0
8527	8.3	61.2	28.8	1.7	0.55	0.55	**0.031**	0.76	1.5
8528	1.0	36.2	55.4	7.4	1.45	1.48	**0.0091**	0.75	1.5
8529	0.0	30.1	66.1	3.7	0.57 J	0.57 J	**0.032**	0.96	1.9
8530	5.1	49.6	42.2	3.2	0.94 J	0.95 J	**0.070**	0.44	0.80
8531	0.0	38.6	57.1	4.3	1.51 J	1.53 J	**0.054**	0.69	1.3
8532	0.7	32.4	57.5	9.4	1.94	1.95	**0.010**	0.76	1.5
8533	0.3	39.9	52.9	6.9	2.47	2.45	**0.017**	0.90	1.8

* parts per trillion, ng/kg on dry-weight basis.
ND = non-detect
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit
J = data qualifier, signifies the result is an estimate.

Appendix C (cont'd). Apparent percent grain size, percent total organic carbon (TOC) and dioxin TEQ* values of soil samples collected from Washington State agricultural lands.

Sample	Gravel	Sand	Silt	Clay	TOC 70°C	TOC 140°C	TEQ ND=0	TEQ ND=1/2 DL	TEQ ND=DL
8534	0.1	38.3	57.3	4.4	0.49	0.49	**0.021**	1.0	2.0
8535	0.4	26.4	68.7	4.5	1.14	1.13	**0.19**	1.2	2.2
8536	0.7	20.4	73.4	5.6	1.48	1.49	**0.23**	0.87	1.5
8537	8.2	56.4	28.9	6.4	4.53 J	4.53 J	**0.40**	1.3	2.1
8538	0.0	52.5	43.7	3.9	0.44	0.44	**0.068**	0.73	1.4
8539	0.3	90.4	8.9	0.3	0.68	0.69	**0.027**	2.3	4.5
8540	0.2	29	68.9	1.9	0.65	0.66	**0.029**	0.94	1.8
8541	0.4	49.6	46.8	3.2	3.29	3.24	**0.57**	2.0	3.5
8542	0.0	23.5	71.1	5.4	1.47 J	1.48 J	**0.052**	1.2	2.3
8543	0.0	18.2	77.2	4.5	0.89 J	0.89 J	**0.015**	0.82	1.6
8544	0.0	32	59.6	8.3	0.86 J	0.87 J	**0.049**	0.67	1.3
8545	0.5	52.5	41.3	5.7	1.13 J	1.14 J	**0.012**	1.4	2.9
8546	0.0	21.1	71.8	7.1	1 J	1.01 J	**0.075**	0.78	1.5
8547	0.8	69.8	27.3	2.1	0.63 J	0.63 J	**1.2**	1.7	2.3
8548	4.7	50.4	40.7	4.3	1.14 J	1.15 J	**0.046**	1.0	2.0
8549	0.2	84.3	14.5	1.1	0.56 J	0.57 J	**0.047**	0.49	0.93
8550	5.0	75.3	18.9	0.8	3.46 J	3.44 J	**0.092**	1.1	2.2
8551	0.0	65.5	30.7	3.8	2.23 J	2.26 J	**0.32**	1.0	1.8
8552	0.1	25.7	68	6.3	1.11 J	1.11 J	**0.11**	1.9	3.6
8553	0.3	21.8	64.8	13.1	1.62	1.63	**0.082**	1.1	2.1
8554	0.5	58.1	41.3	0.1	0.4	0.4	**0.018**	0.71	1.4
8555	0.1	27.8	66.8	5.4	0.83 J	0.83 J	**0.012**	0.60	1.2
Dioxin Duplicate Analyses									
8504 D	---	---	---	---	---	---	**0.059**	1.2	2.3
8508 D	---	---	---	---	---	---	**0.055**	0.42	0.78
8510 D	---	---	---	---	---	---	**0.0071**	0.73	1.4
8525 D	---	---	---	---	---	---	**0.047**	1.1	2.1
8548 D	---	---	---	---	---	---	**0.035**	1.2	2.4

* parts per trillion, ng/kg on dry-weight basis.
ND = non-detect
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit
J = data qualifier, signifies the result is an estimate.

Appendix D

Relative percent difference (RPD) of soil sample results and duplicate analyses

Appendix D. Relative percent difference (RPD) of soil sample results (pptr, ng/kg) and duplicate analyses.

Sample number and detected congeners	Sample	Duplicate	Average	RPD %
8504				
1,2,3,4,6,7,8-HpCDD	3.5	3.0	3.3	15
OCDD	19	10	15	62
2,3,7,8-TCDF	0.33	0.35	0.34	5.9
1,2,3,4,7,8-HxCDF	0.27	0.22	0.25	20
1,2,3,6,7,8-HxCDF	0.21	0.51	0.36	83
2,3,4,6,7,8-HxCDF	0.53	0.36	0.45	38
1,2,3,4,6,7,8-HpCDF	1.8	1.3	1.6	32
OCDF	1.6	1.2	1.4	29
8508				
1,2,3,4,6,7,8-HpCDD	1.4	0.86	1.1	48
OCDD	4.6	3.2	3.9	36
1,2,3,4,6,7,8-HpCDF	0.52	0.39	0.46	29
OCDF	0.89	0.51	0.70	54
8510				
OCDD	11	10	11	10
1,2,3,6,7,8-HxCDF	0.30	0.70	0.50	80
2,3,4,6,7,8-HxCDF	0.52	0.59	0.56	13
1,2,3,4,6,7,8-HpCDF	0.41	0.71	0.56	54
OCDF	0.63	0.66	0.65	4.7
8525				
1,2,3,4,6,7,8-HpCDD	1.3	1.0	1.2	26
OCDD	7.0	6.8	6.9	2.9
2,3,7,8-TCDF	0.49	0.36	0.43	31
1,2,3,6,7,8-HxCDF	0.60	0.73	0.67	20
2,3,4,6,7,8-HxCDF	0.47	0.44	0.46	6.6
1,2,3,4,6,7,8-HpCDF	0.49	0.70	0.60	35
OCDF	4.3	4.4	4.4	2.3
8548				
1,2,3,4,6,7,8-HpCDD	3.3	2.5	2.9	28
OCDD	21	9.6	15	75
1,2,3,4,6,7,8-HpCDF	0.42	0.65	0.54	43
			Median RPD	**29**

RPD = range of duplicates as percent of mean = (difference/mean)*100

Appendix E

Summary statistics of surface soil samples of the different land uses, based on three methods of calculating dioxin TEQs.

Appendix E. Summary statistics of surface soil samples of the different land uses, based on three methods of calculating dioxin TEQs.

Land Use	Descriptive Statistic	TEQs (pptr) ND = 0	ND = ½ DL	ND = DL
Agriculture	Mean	0.14	1.0	1.9
	Median	0.054	0.91	1.8
	Geometric Mean	0.062	0.93	1.7
	GM SD	3.4	1.4	1.4
	Range	0.0078 – 1.2	0.44 - 2.3	0.80 - 4.5
Forest	Mean	2.3	3.5	4.7
	Median	2.2	3.3	4.7
	Geometric Mean	1.2	3.1	4.3
	SD of mean	1.9	1.8	2.1
	Range	0.033 - 0.52	1.1 - 5.7	2.0 – 7.2
Open	Mean	1.0	1.9	2.8
	Median	0.21	1.3	2.4
	Geometric Mean	0.25	1.5	2.5
	GM SD	5.3	2.0	1.7
	Range	0.040 - 4.6	0.63 - 5.9	1.2 – 7.2
Urban	Mean	4.0	5.7	7.4
	Median	1.7	4.6	6.2
	Geometric Mean	1.9	3.7	5.0
	GM SD	4.0	2.8	2.6
	Range	0.13 - 19	0.64 - 22	1.1 - 24

GM = geometric mean
SD = standard deviation
ND = non detect
DL = detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = 1/2 DL: if congener not detected, concentration assumed = 1/2 detect limit
ND = DL: if congener not detected, concentration assumed = detect limit