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Chemical Data Report

Herbicide Residue Survey, Haines-Fairbanks Pipeline Alaska

Materials Section
Engineering Services Branch

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Executive Summary

Composite surface soil samples were collected from twenty-three locations along the Alaskan portions of the former Haines-Fairbanks Pipeline corridor, and from six background locations, in August, September, and October 2003. The soil samples were analyzed for selected herbicides, and for dioxins.

- The particular dioxin congener (2,3,7,8-tetrachlorodibenzodioxin) that is associated with contaminated 2,4,5-T herbicide products (e.g., "Agent Orange") was not detected in any soil sample.

- General concentrations of dioxins (as expressed by sample TEQs) were below the State of Alaska cleanup goal at all sampling locations, and within background levels at all but seven of the twenty-three corridor sampling locations.

- The distribution of dioxin congeners in all samples closely resembles the distribution that would expected of dioxins formed during general combustion processes, and not what would be expected from dioxin-contaminated 2,4,5-T.

- No target herbicides (2,4-D; 2,4,5-T; Picloram; or Fenuron) were detected in any sample.

Table of Contents

Abbreviations and Acronyms

2,4,-D:	2,4-Dichlorophenoxyacetic acid
2,4,5-T:	2,4,5-Trichlorophenoxyacetic acid
ADEC:	Alaska State Department of Environmental Conservation
CEPOA:	U.S. Army Corps of Engineers Alaska District
EMPC:	Estimated Maximum Possible Concentration
EPA:	U.S. Environmental Protection Agency
HpCDD:	Hepatchlorodibenzo-p-dioxin
HpCDF:	Hepatchlorodibenzofuran
HxCDD:	Hexachlorodibenzo-p-dioxin
HxCDF:	Hexachlorodibenzofuran
ng/kg:	nanograms-per-kilogram; equals "parts-per-trillion"
PeCDD:	Pentachlorodibenzo-p-dioxin
PeCDF:	Pentachlorodibenzofuran
QA:	Quality assurance
QC:	Quality control
OCDD:	Octachlorodibenzo-p-dioxin
OCDF:	Octachlorodibenzofuran
SAP:	Sampling and Analysis Plan
TCDD:	Tetrachlorodibenzo-p-dioxin (usually 2,3,7,8-TCDD)
TCDF:	Tetrachlorodibenzofuran
TEF:	Toxicity Equivalence Factor
TEQ:	Toxicity Equivalence Quotient
UCL:	Upper Confidence Limit
USACE:	U.S. Army Corps of Engineers

Chemical Data Report

1. Introduction

This Chemical Data Report was prepared by the U.S. Army Corps of Engineers Alaska District Engineering Services Branch, Materials Section (CEPOA-EN-ES-M), at the request of the Alaska District Project Management Division (CEPOA-PM-P). It presents the results of chemical analyses performed on soil samples collected from multiple locations along the corridor of the former Haines-Fairbanks Pipeline.

2. Site Background Information

2.1 Location

The Haines-Fairbanks Pipeline extends a total of 626 miles from Haines, Alaska, through the Canadian provinces of British Columbia and the Yukon Territory, and on to Fairbanks, Alaska (see maps in Appendix A). The pipeline right-of-way extended 25 feet on either side of the centerline of the 8-inch diameter pipeline. The pipeline route generally parallels the Haines Highway from Haines, Alaska to Haines Junction, Yukon Territory, then follows the Alaska Highway to Delta Junction, Alaska, and then follows the Richardson Highway to Fort Wainwright, Alaska.

Sampling was limited to the approximately 326 miles that lie within United States territory. At total of 23 locations were sampled within the pipeline corridor, and six background locations were sampled within one mile of the pipeline corridor; see Appendix A for maps of sampling locations.

2.2 Summary of Pipeline History

The Haines-Fairbanks Pipeline was built in 1953 and 1954 by the U.S. military, to transport fuels from the port at Haines to military bases in interior Alaska. The pipeline was supported by a number of pumping stations and bulk storage terminals along its route. Much of the pipeline was laid on the ground surface, although approximately 96 miles near Delta Junction, and most of the 42 miles between the Haines Fuel Terminal and the Canadian border, were buried. The pipeline remained in use from 1954 until 1973 (ADEC 2003 b). The above-ground pipeline (particularly the Canadian portion, which was built with a lower grade of steel pipe) was plagued with leaks from corrosion, ice damage, and vandalism (e.g., bullet holes). To improve visibility of the pipeline route to aerial inspections, a program of spraying the pipeline corridor with herbicides was enacted in approximately 1955 (MDA, 1999; Hudson, 1994).

In 2002, the pipeline right-of-way was determined by the U.S. Army Corps of Engineers to be eligible for investigation under the Formerly Used Defense Sites (FUDS) Program. The USACE Inventory Project Report (INPR) focused on petroleum products as

the primary potential contaminant along the pipeline corridor, and the initial investigation of the pipeline right-of-way was scheduled for 2005 (USACE 2002; ADEC 2003b).

2.3 Documentation of Herbicide Use

The 2003 sampling effort was spurred by historical documentation brought to light in recent years. A 1994 report prepared for the Champagne and Aishihik First Nations of Canada presented correspondence and other specific information on types of herbicides used at the pipeline (Hudson, 1994). The correspondence included exchanges between U.S. Army representatives and Canadian officials requesting permission to use or substitute certain herbicides for application on the Canadian portions of the pipeline. The herbicide products mentioned in the correspondence include -

- "Esteron" or "Esteron Brush Killer": a mixture of 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid);
- "Tordon 101": a mixture of 2,4-D and picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid);
- "Fenuron" (1,1-dimethyl-3-phenylurea).

The reported use of "Esteron Brush Killer" caused particular concern, as this product contained the same ingredients as the military defoliant "Agent Orange", and potentially contained similar dioxin (polychlorinated dibenzo-p-dioxin and dibenzofuran) by-products as were associated with "Agent Orange" and other 2,4,5-T-containing products (MDA, 1999; Hudson, 1994; Gochfeld, 2001; National Academy Press, 2000).

The correspondence trail documented in the Champagne and Aishihik First Nations report appeared to indicate that spraying of herbicides began in Canada in June 1966. Esteron was the first herbicide proposed for use, but by 1968 the U.S. Army requested to substitute Tordon 101 and Fenuron for the Esteron, due to the unavailability of "Esteron Brush Killer". The last documented herbicide application was to have occurred in the summer of 1969. By the end of 1973, maintenance of the pipeline had ceased (Hudson, 1994).

The Champagne and Aishihik First Nations report was brought to the attention of the Army Corps of Engineers and ADEC by the Tanana Chiefs Conference in 2002. The Army Corps of Engineers began an archive search in early 2003 to attempt to find more information on herbicide use and application patterns; in particular, information that would show whether or not the herbicide usage in Canada documented in the Champagne and Aishihik First Nations report was also typical of usage in U.S. territory. Archival record searches were conducted at National Archives facilities in Washington, D.C., Seattle, and Anchorage, and at the University of Alaska at Anchorage. The documentation obtained from these searches has been largely fragmentary and unenlightening; however, two documents were found that provided some specific information on the use of herbicides by the U.S. Army on the pipeline right-of-way:

- A Department of the Army memorandum dated December 1970, entitled "USARAL Experience in the Use of Herbicides for Brush and Weed Control" (Department of the Army, 1970). The document describes in general terms its program of chemical and mechanical control of vegetation along the Haines-Alaska Pipeline. It specifically lists the herbicides Tordon 101, 2,4-D, 2,4,5-T, and Fenuron as having been "used with a great degree of success".

- A technical specification for contract brush control along the pipeline, dated March 1968 (Department of the Army, 1968). This document mentions only the herbicides 2,4-D and picloram, but was written around the same period that the U.S. Army proposed switching from Esteron to a 2,4-D/picloram product (Tordon 101) product in Canada. The technical specification details specific areas to be sprayed, as well as restrictions on application. The clearances for aerial spraying (i.e., a fifty-foot right-of-way; no application within 500 feet of streams and lakes, etc.) are very similar to those stated in the correspondence between U.S. Army and Canadian authorities (Hudson, 1994).

Taken together, these two documents suggested that the same herbicide products and similar application patterns might have been used on the both the Canadian and Alaskan portions of the pipeline.

2.4 Overview of Herbicides and Dioxins

The herbicide compounds reported to have been applied to the pipeline right-of-way include (in various combinations): 2,4-D; 2,4,5-T; picloram; and fenuron. The compounds 2,4-D and 2,4,5-T both belong to the same class of phenoxyacetate herbicides, and were developed as selective herbicides against broadleaf weeds. Both are readily biodegraded, and typically persist in the environment for a matter of weeks or months. The acute toxicity to humans of these compounds, in of themselves, is considered to be rather low, and they are not considered to be carcinogenic (EPA, 2002a; EPA Region 9, 2002; Spectrum)

Picloram belongs to a different chemical class of herbicides, but is also a broad-leaf selective, systemic herbicide. It is more persistent in the environment than the phenoxyacetate herbicides, but is subject to biodegradation and photolysis, with a reported half-life of 100 days or less. Picloram is considered less toxic to mammals than the phenoxyacetate herbicides, and is not regarded as a carcinogen (Spectrum; EPA 2002b).

Fenuron is a non-specific weed and brush herbicide. Little toxicological information appears to be available for fenuron, but animal studies suggest that it is far less toxic than picloram or the phenoxyacetate herbicides. A degradation half-life of up to 4.5 months has been measured for fenuron (Spectrum).

The primary toxicological concern with 2,4,5-T is not the herbicide compound itself, but the formation of dioxins during its manufacture and storage. Two molecules of 2,4,5-T (or its 2,4,5-trichlorophenol precursor) can undergo a specific condensation reaction to form a single molecule of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most toxic of the dioxin congeners. Studies of military "Agent Orange" stocks found 2,3,7,8-TCDD

concentrations ranging from less than 0.05 ppm to almost 50 ppm; manufacturing standards established in 1974 for domestic use of 2,4,5-T required a limit of 0.05 ppm TCDD (National Academy Press, 2000).

"Dioxins" (in this report this term is used in its common sense to refer to the entire class of polychlorinated dibenzo-p-dioxins and dibenzofurans) tend to be found throughout the environment, and can be formed by many processes, particularly the burning of wastes containing a source of the element chlorine. Dioxins are considered to be carcinogenic and to cause other acute and chronic health effects, and are noted for their persistence in the environment. Dioxins formed during combustion typically include a large number of different congeners, but predominately the more heavily-chlorinated compounds such as the "octochloro" and "heptachloro" congeners. Octochlorodibenzo-p-dioxin (OCDD) has been found to be the dominant congener in total dioxins from:

- "Mass-burn" (i.e., no segregation of wastes) municipal solid waste incinerators;
- Industrial oil-fired boilers;
- Industrial wood-fired boilers;
- Diesel and unleaded gasoline combustion in vehicles; and
- Sewage sludge incinerators (Cleverly, 1997).

The burning of household garbage in open barrels has also been found to emit significant amounts of dioxins. The congener distribution of dioxins from small-scale open burning is similar to that seen from mass-burn solid waste incinerators (EPA, 1997; EPA, 1998).

Dioxins generated by combustion generally contain only 0.1 to 1.0 percent 2,3,7,8-TCDD, although up to 7 percent TCDD has been detected in stack emissions from industrial oil-fired burners (Cleverly, 1997). By contrast, the dioxin created during the manufacture of 2,4,5-T was almost exclusively 2,3,7,8-TCDD, due to the specificity of the chemical reaction involved. In principle, this allows herbicide-generated dioxin to be distinguished from the ubiquitous combustion-generated dioxins in environmental samples (Gochfeld, 2001; MDA, 1999; National Academy Press, 2000; Schecter, 2001).

The definitive analytical method for dioxins is currently U.S. EPA Method 8290. This method quantifies seventeen separate polychlorinated dibenzo-p-dioxin and dibenzofuran congeners. The relative toxicity of these different compounds varies greatly, with 2,3,7,8-TCDD being the most toxic, and the octochlorodibenzo dioxins and furans considered to be less toxic by several orders-of-magnitude. Each congener is assigned a "Toxicity Equivalence Factor" (TEF, see Table 2-1), which expresses that congeners toxicity relative to that of 2,3,7,8-TCDD. The measured concentration of each congener in a sample is multiplied by its respective TEF, and these adjusted concentrations added together to calculate a "Toxicity Equivalence Quotient", or TEQ, for that sample. The TEQ expresses the total aggregate toxicity of the dioxin congeners in terms of an equivalent concentration of 2,3,7,8-TCDD alone.

Table 2-1 Dioxin and Furan TEFs	
Method 8290 Target Congener	Toxicity Equivalence Factor[1]
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	1.0
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1.0
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	0.1
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	0.1
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	0.1
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	0.01
Octachlorodibenzo-p-dioxin	0.0001
2,3,7,8-Tetrachlorodibenzofuran	0.1
1,2,3,7,8-Pentachlorodibenzofuran	0.05
2,3,4,7,8-Pentachlorodibenzofuran	0.5
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	0.1
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01
Octachlorodibenzofuran	0.0001
1. Toxicity Equivalence Factors (TEFs) cited are those currently proposed by the U.S. EPA and World Health Organization (WHO; van den Berg, et al., 1998), and favored by the State of Alaska Department of Health and Department of Environmental Conservation.	

2.5 Previous Investigations of Dioxin and Herbicide Contamination

There have been relatively few investigations for dioxins or herbicides along the pipeline corridor. In 1993, five soil samples were collected from a herbicide-treated portion of the right-of-way in the Klukshu area of Yukon Territory. Dioxin analyses of composites of these soil samples revealed notably high (up to 30 ng/kg) concentrations of the dioxin congener 2,3,7,8-TCDD. A subsurface soil composite had a much lower but still detectable concentration of TCDD (MDA, 1999). TCDD was the dominant congener in these samples, suggesting that a dioxin-contaminated 2,4,5-T preparation had indeed been applied in this area (see Section 6.2 and Table 6-1 below).

Soil collected from a DDT pesticide drum site near the Border Pump Station in British Columbia were analyzed for dioxins, as part of a 1994 site assessment by Royal Roads University. No significant concentrations of dioxins were reported (MDA, 1999).

A follow-up study was conducted in the Klukshu Camp area by Indian and Northern Affairs Canada (INAC) in 1995. Samples of soil, lake sediments, fish and animal tissue, and wood were analyzed for dioxins. The soil samples again showed patterns of congener distribution (i.e., relatively high concentrations of 2,3,78-TCDD) suggestive of 2,4,5-T application. However, little or no TCDD was detected in local lake sediments, fish tissue, or mammal tissue, suggesting that the dioxins had not migrated far from the areas sprayed. An

exception to this pattern was the detectable concentration of TCDD in tissue from voles; the MDA report speculates that the living and feeding habits of voles caused them to have an especially high incidence of exposure to any dioxins present in the surface soils (MDA, 1999).

There are no known studies in which soil samples for dioxin analysis were collected directly from Alaskan portions of the Haines-Fairbanks Pipeline right-of-way. A 2002 site assessment along the corridor of the CANOL pipeline was performed at Native Allotment FF-9632, near Northway, Alaska (Ridolfi, 2002). Three archived composite soil samples collected in September 2002 were analyzed for dioxins. All three samples contained dioxins at very low concentrations (0.33 to 2.13 ng/kg TEQ, as compared to a conservative EPA Region 9 cleanup goal of 3.9 ng/kg). Only one of the three samples contained a detectable concentration of 2,3,7,8-TCDD, making it unclear whether the dioxins reported were the result of herbicide applications (Ridolfi, 2003).

Soil samples for herbicide analysis have been collected during a number of environmental investigations along the pipeline corridor. None of these investigations have reported detectable concentrations of herbicides (Lorimer, 1995; UMA, 1995; Ridolfi, 2002) This is not unexpected, considering the low environmental persistence of these compounds, and the decades that have passed since their application.

3. Field Activities and Observations

3.1 Purpose of Sampling

The purpose of this sampling event was to determine whether certain herbicides and herbicide-generated dioxins could be detected in surface soils along Alaskan portions of the Haines-Fairbanks pipeline corridor. The goal was not to conduct a comprehensive investigation of the pipeline corridor or surrounding areas, but to first establish whether the potential contaminants-of-concern identified above and in the Sampling and Analysis Plan (USACE, 2003) could indeed be found in areas where they would have been directly applied.

3.2 Summary of Field Activities

The samples were collected 30 August through 6 September 2003, and on 21 and 22 October 2003. The CEPOA field sampling team consisted of chemist Chris Floyd (CEPOA-EN-ES-M) and environmental engineer David Westerman (CEPOA-EN-EE-A). In addition, Alaska Department of Environmental Conservation (ADEC) project manager Bob Glascott was present for all sampling activities to provide regulatory oversight.

3.3 Observations

A copy of the field notebook is provided in Appendix E, and photographs of the sampling sites are provided in Appendix D. A brief description of each sampling site is also

provided in Table 3-2. The various sampling locations varied widely with respect to how clearly-defined the pipeline corridor appeared, and how densely the vegetation had grown into the right-of-way. At some locations, the corridor was very difficult to distinguish from the surrounding vegetation; at others, the corridor was clearly defined. Vegetation growth had been affected at several locations due the corridor's obvious use as a trail (locations SU3, SU8, SU9, SU13, SU20, and SU23) or as a right-of-way for modern utilities (locations SU4, SU5, SU6, SU7, SU13, and SU23). Bare soil was observed at several locations, primarily where surface soils were sandy (e.g., locations SU12, SU14, SU16, SU17). Even where the pipeline corridor was unmistakable, the width of the zone of retarded vegetation growth was often significantly less than 50 feet.

No overt signs of chemical contamination were noted. Although much of the pipeline has been removed, remnants of the pipeline such as sections of pipe, steel mile-marker panels, and a valve pit were discovered at a number of locations.

3.4 Sampling Procedures

Sample collection and handling procedures closely followed that described in the Sampling and Analysis Plan (USACE, 2003). At each sampling location, a 50-foot by 50-foot grid was measured off and marked with survey flags at 12.5-foot intervals, to create a grid-square five subsampling points deep and five subsampling points wide (for a total of 25 equidistant subsampling points). At each subsampling point, a garden hoe was used to clear debris and loose vegetation from a small area, and then a hole 6 inches or more deep was dug with a 3-inch diameter hand-auger. A soil subsample was collected using a stainless-steel spoon to gather a representative sample of the top two inches of collectable material (whether mineral soil or loose organic material) from the sidewalls of the hole; at nearly all locations, the vegetative mat was clearly defined, and the subsample was collected from immediately below the vegetative mat. Where the soil surface was bare of vegetation, the subsample was collected from the surface to two inches below the surface. As each of the twenty-five subsamples was collected, it was added to a large stainless-steel bowl. A portable scale was used to ensure that each of the subsamples was the same mass, and contributed equally to the final composite sample. The subsamples were thoroughly homogenized in the bowl to form a single composite sample, from which the sample containers were filled.

3.5 Deviations from the Sampling and Analysis Plan

Several deviations from the procedures and objectives specified in the Sampling and Analysis Plan are noted below. These changes were minor, and either have no effect on data usability, or were implemented to improve data usability.

- The SAP stated that the analytical holding time (from collection to sample extraction) for the herbicide methods (EPA Methods 8151A and 8321) was 7 days. This holding time was obtained from a mis-reading of a table in a USACE guidance document (Table B-1, EM 200-1-3 *Requirements for the Preparation of Sampling and Analysis Plans*). The correct holding time for these methods is 14 days, as shown in EM 200-1-3 and in Chapter 4 of the U.S. EPA *Test Methods for Evaluating Solid Waste,*

Physical/Chemical Methods (SW846). This is documented here as a deviation because not all herbicide samples were extracted within the erroneously-cited 7-day holding time, but all were extracted within the correct 14-day holding time.

- The primary laboratory for herbicide analyses, Severn Trent Laboratories, Inc., of Tacoma, WA, analyzed the samples using a modification of Method 8151A, in which mass spectroscopy is used to verify the identity of a gas chromatography peak, instead of second-column confirmation. This change in methodology has no effect on data-usability, particularly since there were no herbicide peaks to confirm.

- The SAP stated, "If for some reason a subsampling point cannot be sampled, that point will be omitted from the sampling unit composite." In practice, the sampling sites contained far more obstructions (such as trees, stumps, boulders, brush piles, etc.) than was anticipated, and it was feared that omitting all obstructed subsampling points would result in composite samples that were not truly comparable to one another. Instead, an obstructed subsampling point was relocated off that grid-point to the nearest accessible location.

- The SAP stated that, "At each subsampling point, any vegetation mat will be carefully removed from an area approximately 6 inches in diameter, and set aside". It quickly became apparent that attempting to pry up an intact vegetation mat caused far more damage to the area vegetation than simply clearing loose surface vegetation and debris from a small (3-6 inch diameter) patch of ground and punching through the mat with a small hand auger, so the latter technique was adopted. Prying up the vegetation mat also tended to obscure the horizon between the vegetative layer and mineral soil, making the proper sampling interval more difficult to discern.

- The mass of soil collected from each subsampling point was reduced to 50 grams from 100 grams, once it became clear that 100 grams resulted in an unnecessarily large composite sample.

3.6 Scope of Analytical Methods

The composite soil sample from each pipeline corridor and background location was analyzed by for the following compounds, by the analytical methods cited.

Table 3-1 Analytical Methods

Parameter	Method	Target Contaminants
Dioxins & Furans	EPA SW846 8290	Method list of seventeen target polychlorinated dibenzo-p-dioxin and dibenzofuran congeners
Selected Chlorinated Herbicides	EPA SW846 8151A	2,4-D 2,4,5-T Picloram
Selected Carbamate Herbicide	EPA SW846 8321	Fenuron

3.7 Scope of Sampling Locations

Surface soil composite samples were collected from a total of 29 locations, as summarized in Table 3-2 and shown on maps in Appendix A.

- 23 composite samples collected directly from the pipeline right-of-way.
- 6 composite samples were collected from background locations.

The sampling locations were selected on a judgmental (non-statistical) basis, based on documentary evidence of where herbicides were supposed to have been applied, and on recommendations from private citizens, land-holders, and government agencies. The intent was to maximize the probability of sampling in areas where any herbicide and dioxin residues would most likely still be present in surface soils (e.g., areas where surface soils are undisturbed or minimally-disturbed since the period of herbicide application), and to sample the entire U.S. portion of the pipeline corridor in a reasonably representative fashion. Relative ease of access, and whether rights-of-entry could be obtained, were also important considerations in the final selection of sampling sites. The spacing between the eighteen sampling locations along the Fairbanks-Yukon portion of the corridor ranged from 5 to 26 miles, for an average of 15 miles between sampling locations. Along the Haines Highway portion, the spacing between the five corridor sampling locations ranged from approximately 1 to 22 miles, for an average of 11 miles between sampling locations.

A probabilistic (statistically-based) sampling design was considered, but not pursued. The lack of information on the variability of potential contamination concentrations made a statistical design difficult to devise. A few preliminary calculations were made using the Klukshu area data, but the standard deviation of that small data set is very high, and predicted that a prohibitively large number of samples (i.e., several hundred) would be required to determine a mean concentration for the Haines-Fairbanks pipeline corridor. In addition, trying to adhere to a purely random or systematic sampling-point distribution (required for most probabilistic designs) on a project of this unusual scale would have severely increased the access and logistical difficulties.

3.8 Investigation Derived Waste

All waste was disposed of as described in the Sampling and Analysis Plan.

Table 3-2 Summary of Sampling Locations

ID	General Location	Description	Approximate Coordinates (NAD 27)
SU1	Near Richardson Hwy MP 329, south of Eielson AFB	Discontinuous grassy corridor in agricultural area off Johnson Road, 1.6 miles east of Richardson Hwy	64 32' 59" N 146 58' 12" W
SU2	Salcha Elementary School Richardson Hwy MP 322	Ill-defined corridor in dense woodlands just off ski trail approx 1 mile east of school	64 28' 57" N 146 56' 47" W
SU3	Near Richardson Hwy MP 315	Woodlands between Harding and Birch Lake; along dirt trail near pipeline mile-marker "577"	64 21' 35" N 146 50' 37" W
SU4	Near Richardson Hwy MP 310	Broad marshy utility corridor in woodlands 3 miles east of Birch Lake; deep water-filled trench in corridor	64 18' 45"N 146 31' 44"W
SU5	J. Fowler Cabin Road, near Richardson Hwy MP 290	Broad grassy corridor near intersection with cabin road; evidence of brush clearing	64 15' 59" N 146 11' 19" W
SU6	Near Richardson Hwy MP 281	Broad grassy utility corridor off pipeline access road,1.5 miles west of Timber Pump Station	64 12' 51" N 145 57' 23" W
SU7	Near Alaska Hwy MP 1413	Rocky, sparsely-vegetated corridor 10 miles east of Delta Junction; near private residence	63 58' 06" N 145 28' 51" W
SU8	Near Alaska Hwy MP 1402	Sandy trail at pipeline marker "513", near Greenbelt of Delta Agriculture Project	63 53' 23" N 145 11' 32" W
SU9	Near Alaska Hwy MP 1384	Grassy corridor in woodlands west of large gravel pit	63 45' 37" N 144 42' 17"W
SU10	Near Alaska Hwy MP 1360, Dot Lake area	Partially-overgrown corridor in birch forest near private residence; pipeline visible on surface	63 38' 47" N 144 02' 12" W
SU11	Near Alaska Hwy MP 1343, 4.3 mi S of Robertson R.	Grassy corridor in spruce bog on west side of highway	63 26' 19" N 143 49' 35" W
SU12	Near Alaska Hwy MP 1328.5, Tanacross area	Partially regrown corridor in birch forest, at pipeline mile-marker "436"	63 21' 39" N 143 19' 48" W
SU13	Near Alaska Hwy MP 1303, south bank of Tanana River	At pipeline marker "414", approx 600 ft south of river bluff; utilities, campsites, many trails in area	63 19' 05" N 142 38' 19" W
SU14	Near Alaska Hwy MP 1285	Open corridor near borrow area	63 13' 24" N 142 13' 18"W
SU15	Near Alaska Hwy MP 1262	Sparsely vegetated "bench" on hillside, approx 1/4-mile from highway, just north of pipeline valve pit "47"	63 00' 30"N 141 44' 03" W
SU16	Near Alaska Hwy MP 1249	Sandy, sparsely-vegetated area off Deadman Lake Rd; pipeline visible on surface where it intersects road	62 53' 08" N 141 30' 29" W
SU17	Near Alaska Hwy MP 1234	Open muskeg area; pipeline visible on surface nearby. Old telephone poles paralleling highway cross corridor approx. 50 yards north of sampling location	62 44' 30" N 141 12' 05" W
SU18	Near Alaska Hwy MP 1222, near U.S. border station	Corridor on wooded hillside; corridor cleared for use as a firebreak; pipeline sections visible	62 37' 04" N 141 00' 40" W

continued

Table 3-2 Summary of Sampling Locations (continued)			
ID	**General Location**	**Description**	**Approximate Coordinates (NAD 27)**
SU19	Near Haines Hwy MP 40, Dalton Cache/border area	Adjacent to Canadian border on Haines side	59 26' 50" N 136 20' 36" W
SU20	Near Haines Hwy MP 27.3, Mosquito Lake Rd junction	Grassy corridor near private residence, approx 200 feet NW of pipeline mile-marker "29"	59 25' 26" N 136 00' 53" W
SU21	Near Haines Hwy MP 19.2, across hwy from Council Grounds pullout	Lane of small growth amongst large cottonwoods; identified as berry-picking area by Klukwan representative	59 23' 37" N 135 51' 53" W
SU22	Northwest Haines	Private residence in Comstock Rd area; heavy brush along foot trail, upgradient from yard	59 14' 37" N 135 28' 16" W
SU23	End of Skyline Drive, northeast Haines	Grassy area just downslope from gate ending Skyline Drive; rocky pathway with utilities, partially buried pipeline visible downslope of sampling location	59 14' 58" N 135 26' 01" W
	Background Locations		
BK5	Near SU5	On J. Fowler Cabin Rd, approx. 0.3 mile east of corridor	64 16' 13" N 146 11' 29" W
BK8	Near SU8	Dense spruce forest several hundred feet from highway, on opposite side of hwy from SU8	63 53' 16" N 145 11' 33" W
BK12	Near SU12	Open birch woodland several hundred feet north of SU12	63 21' 46" N 143 19' 47" W
BK16	Near SU16	Clearing in spruce/birch woodland off Deadman Lake Rd, approx 0.3 mile west of SU16	62 53' 08" N 141 30' 52" W
BK20	Approx 2.5 miles north of SU20	Clearing at terminus of Mosquito Lake Rd	59 27' 37" N 136 01' 29" W
BK23	Near SU23	Approx 300 ft up Mt Ripinsky Trail from trail-head at terminus of Skyline Drive; dense coastal rainforest	59 14' 59" N 135 26' 05" W

4. Results of Chemical Analyses

Comprehensive tables of extracted chemical data are presented in Appendix B. The data are discussed in the sections below.

Five laboratories were used for this project, as shown in Table 4-1. Field triplicate samples were collected at SU6 and SU16; one fraction of each triplicate was sent to a quality assurance (QA) laboratory as a check on the primary laboratories. No QA laboratory was procured for Method 8321, as no second qualified laboratory could be found to perform this method. An additional field duplicate sample was collected at SU22.

Table 4-1 Project Laboratories	
Analysis	Laboratory
Method 8290 (Primary Lab)	Paradigm Analytical Laboratories (Wilmington, NC)
Method 8151A (Primary Lab)	Severn Trent Laboratories - Seattle (Tacoma, WA)
Method 8321 (Primary Lab)	CalTest Analytical Laboratory (Napa, CA)
Method 8290 (QA Lab)	Severn Trent Laboratories - Sacramento (Sacramento, CA)
Method 8151A (QA Lab)	Severn Trent Laboratories - Burlington (Colchester, VT)

4.1 Dioxins and Furans

The results of the Method 8290 analyses are presented in Table 1 of Appendix B. The significant results are summarized in Table 4-2 below.

Some individual congener results of the Method 8290 analyses were reported as "EMPC", or "Estimated Maximum Possible Concentration". This occurs when an instrument response meets some but not all of the criteria detailed in the methodology for definitively identifying a particular congener (e.g., retention time, signal-to-noise ratio, ion abundance ratios, and the absence of certain interferences). That instrument response therefore cannot be confirmed to be a targeted dioxin congener, but in the interest of being maximally conservative, that response is presented in the sample data as an estimated concentration of the congener to which it is most similar, and flagged "EMPC".

Dioxin data is typically expressed as a Toxicity Equivalence Quotient, or TEQ, calculated as described in Section 2.4. These calculations are straight-forward, but several different conventions exist where the data contains "non-detect" results or EMPCs. Non-detect results are typically included in the TEQ calculation with a value of either zero, or of one-half the reported detection limit for that congener. EMPC results are either included at face value, or discarded (given a value of zero). All four possible combinations of these TEQ calculations are presented in the Appendix B data table. The most conservative TEQ (one-half detection limit for "non-detect"; EMPCs included) is shown in Table 4-2.

The Sampling and Analysis Plan cited an U.S. EPA Region 9 risk-based "preliminary remediation goal" (PRG) of 3.9 ng/kg 2,3,7,8-TCDD as a "data quality objective", a benchmark on which to base laboratory contract performance requirements. This PRG is a highly conservative concentration calculated for residential soils, and represents a cancer risk of "10^{-6}" (one-in-one-million) over a continuous exposure period of 70 years (U.S. EPA Region 9, 2002). The Alaska Department of Environmental Conservation has not published a specific cleanup level for dioxins, but has established a general risk-based cleanup goal of "10^{-5}" (one-in-one hundred thousand) (ADEC, 2003a). Using this level of risk, the ADEC cleanup goal for dioxins would be 39 ng/kg, or ten times higher than the EPA PRG described above.

- All sampling location TEQ values are below the ADEC risk-based cleanup goal of 39 ng/kg.
- Samples from only four sites have TEQ values between the ADEC cleanup goal and the EPA "10^{-6}" PRG: SU4, SU13, SU22, and SU23.
- Seventeen of the twenty-three corridor sampling locations have TEQ values of less than 1.0 ng/kg.
- The congener 2,3,7,8-TCDD cannot be confirmed in any sample. Most samples were "non-detect" for 2,3,7,8-TCDD; EMPCs at extremely low concentrations were reported for 2,3,7,8-TCDD at seven sites, including two background locations.

Table 4-2 Summary of Dioxin Results

Location	Sample TEQ[1] (ng/kg)	reported 2,3,7,8-TCDD (ng/kg)
SU1	1.32	EMPC [0.196]
SU2	0.555	ND (0.132)
SU3	0.430	ND (O.125)
SU4	11.9	EMPC [0.382]
SU5	0.397	EMPC [0.111]
BK5	0.312	EMPC [0.177]
SU6	0.704 - 1.781[2]	EMPC [0.173]
SU7	0.259	ND (0.128)
SU8	0.246	ND (0.121)
BK8	0.453	ND (0.153)
SU9	0.698	ND (0.191)
SU10	0.317	ND (0.108)
SU11	0.528	ND (0.176)
SU12	0.474	ND (0.118)
BK12	0.365	ND (0.112)
SU13	20.0	EMPC [0.199]
SU14	0.434	ND (0.118)
SU15	0.393	ND (0.110)
SU16	0.425 - 0.628[2]	ND (0.28)
BK16	0.471	ND (0.134)
SU17	0.751	ND (0.231)
SU18	0.391	ND (0.168)
SU19	0.487	ND (0.212
SU20	0.448	ND (0.260)
BK20	0.704	EMPC [0.326]
SU21	0.461	ND (0.304)
SU22	2.6 - 4.8[2]	ND (0.287)
SU23	7.8	ND (0.450)
BK23	0.878	ND (0.358)

1. TEQ calculated using WHO 1998 proposed TEFs (see Table 2-1), with EMPCs and one-half detection limits for ND congeners included.
2. Duplicate/triplicate sample results presented as a range of reported concentrations.
ND: Not detected (value in parentheses is the estimated detection limit).
EMPC: Estimated Maximum Possible Concentration (value in brackets is the estimated concentration).

As is addressed further in Section 5, laboratory contamination, as revealed by the analysis of method blanks, can contribute to the concentrations of dioxins reported in the sample results. If the concentration of a dioxin congener detected in the method blank is within a factor of five of the concentration of that congener detected in an associated sample, then that congener in the sample should be regarded as non-detected. These results are flagged "BU" in the Appendix B data tables, and in the Appendix C data review report. The results in Table 4-2 are presented at "face-value", and do not account for blank

contamination. However, Table 4-3 shows that when the four highest sample TEQs are adjusted for blank contamination (by regarding the "BU"-flagged data as non-detected and the reported concentration as the detection limit, then recalculating the TEQ as before using one-half the new detection limit), the results do not change significantly.

Table 4-3 Adjustment of Selected Dioxin Results for Blank Contamination

Location	Original sample TEQ [fromTable 4-2] (ng/kg)	TEQ adjusted for method blank contamination (ng/kg)
SU4	11.9	10.9
SU13	20.0	19.9
SU22	2.6 - 4.8	2.3 - 4.1
SU23	7.8	7.1

4.2 Herbicides

The results of the analyses by Methods 8151 and 8321 are presented together in Table 2 of Appendix B.

No targeted herbicide (2,4-D; 2,4,5-T; picloram; or fenuron) was detected in any sample. The reporting limits achieved by the laboratories were well below the requested reporting limits of 10 mg/kg, and far below the available screening criteria (see Table 4-4 below).

Table 4-4 Herbicide Reporting Limits

Compound	Analytical Method	Reporting Limit Achieved (mg/kg)	Screening Criterion[1] (mg/kg)
2,4-D	EPA SW846 Method 8151A	0.3 or less	690
2,4,5-T	EPA SW846 Method 8151A	0.038 or less	610
Picloram	EPA SW846 Method 8151A	0.038 or less	4,300
Fenuron	EPA SW846 Method 8321	1.0	none available

1. U.S. EPA Region 9 Preliminary Remediation Goals for residential soils.

5. Data Quality Review

All chemical data generated by the analytical laboratories were subjected to a data quality review performed by an independent data review firm contracted by CEPOA. The data quality review was conducted by Ajmal Ilias, Ph.D., of Kismet Scientific Services, Portland, Oregon. The data review included evaluation of sample holding times, laboratory blanks (to assess potential cross-contamination of the samples), sample duplicates (to assess laboratory precision), laboratory control samples (to assess accuracy), and matrix spike and

surrogate recoveries (to assess matrix effects). A copy of the data review report is provided in Appendix C.

No significant discrepancies were found in the analytical data, and the data are usable for project purposes. The few issues highlighted by the data review report are discussed below.

The data review report points out that the dioxin QA laboratory reported many "Rep Limit" results that were lower than the associated "Det Limit" results, where as reporting limits are typically three to ten times higher than method detection limits. The laboratory explained that the default column headings "Rep Limit" and "Det Limit" that were used in its data submittal were not really appropriate to the Method 8290 data; the values reported under "Rep Limit" were actually the sample-specific "estimated detection limits" (unique to Method 8290), and the "Det Limit" values were the pre-established method detection limits (MDL) developed by the laboratory for this method.

Dioxin and furan congeners were detected in the laboratory method blanks at concentrations ranging from 0.084 to 17.2 parts-per-trillion. This level of reported laboratory contamination is not unusual, given the extreme sensitivity of this method. According to general EPA guidelines, if a compound detected in a sample at a concentration within a factor of five of the concentration of the same compounds detected in the associated method blank, then the compound concentration in the sample should be regarded as being due to laboratory contamination. If a compound is detected in a sample at concentration of between five and ten times the concentration of the same compound in the associated method blank, then the compound concentration in the sample should be regarded as "estimated". The dioxin data is flagged accordingly in Appendix B, and in Table I of the data review report (Appendix C). The effect of blank contamination on data interpretation is discussed in Section 4.1 above.

The data review report states that the laboratory performing the analysis for fenuron used "high method reporting limits (MRLs) of 1-2 ppm" as if this were a discrepancy; however, these reporting limits were well within the requested MRL of 10 mg/kg. The missing MDL and sample data reported by the data reviewer has since been provided.

The herbicide QA laboratory (STL - Burlington) has provided the MDL data missing from its original submittals. The MRL for 2,4,-D described by the data reviewer as "high", while possibly anomolous, was still well below the requested project MRL.

The primary herbicide laboratory has confirmed that it used a modification of Method 8151A, in which mass spectroscopy is used to verify the identity of a gas chromatography peak, instead of second-column confirmation. This change in methodology has no effect on data-usability.

The analytical results for field duplicate samples agree within USACE criteria, showing good intralaboratory precision, and adequate field technique in the preparation of the composite samples. Only one duplicate disagreement was noted, that between the reported "total TCDF" values reported for primary samples -06SO/-07SO, and QA sample -08SO;. However, since the "total TCDF" value will not be used for this project, and since

the individual TCDF congeners are in agreement, the disagreement is not considered significant.

6. Discussion and Conclusions

6.1 Qualitative Overview of Results

The results of the chemical analyses of these soil samples reveal no detectable remnant of herbicides or herbicide-generated dioxins in the areas tested.

- As discussed in Section 2.4, the dioxin contaminant generated during the manufacture of 2,4,5-T was primarily, if not exclusively, the congener 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

- A dioxin analysis of soil from an area treated with a significant amount of contaminated 2,4,5-T would be expected to show detectable concentrations of 2,3,7,8-TCDD, perhaps in combination with other dioxin congeners from other sources; this is what was seen in the 1993 and 1995 Klukshu area soil samples.

- However, no 2,3,7,8-TCDD was detected in any soil sample collected along Alaskan portions of the corridor in this 2003 sampling effort. The "Estimated Maximum Possible Concentration" values reported for 2,3,7,8-TCDD in a small number of samples are not considered to be detections of this congener (see Section 4.1). The values reported as EMPC were included in TEQ calculations in the interest of being maximally conservative, but an EMPC, by definition, cannot be regarded as a qualitative identification of a given congener.

These results do not prove that herbicides were never applied along Alaskan portions of the Haines-Fairbanks pipeline, but simply that no trace of such application can be detected in the present day in those areas that were sampled. The absence of detectable herbicide compounds (2,4-D; 2,4,5-T; picloram; and fenuron) was expected, and is entirely consistent with the known low persistence of these chemicals in the environment. The absence of detectable 2,3,7,8-TCDD is consistent with the following scenarios:

a) No 2,4,5-T (in the form of "Agent Orange", "Esteron Brushkiller", etc.) was ever applied to Alaskan portions of the pipeline, or

b) 2,4,5-T was applied, but the particular lots or batches of herbicide used had particularly low concentrations of dioxin contamination, or

c) Dioxin-contaminated 2,4,5-T was applied, but in such minimal quantities that no detectable residue remains, or

d) Dioxin-contaminated 2,4,5-T was applied, but in such a localized or discontinuous pattern that not one of the twenty-three 2003 sampling locations happened to be placed in a treated area. (It should be noted that this scenario is not consistent with

what is known from documentary or anecdotal information about how herbicides were supposed to have been applied along the pipeline corridor).

6.2 Comparison of Alaskan and Klukshu Dioxin Data

While dioxins were detected in both the 2003 CEPOA Alaskan corridor soil samples and in the 1993/1995 Klukshu area soil samples, the data are qualitatively very different. Table 6-1 compares the dioxin results for the four 2003 CEPOA samples with the highest TEQs, against the most comparable surface soil results from the 1993 and 1995 Klukshu samples (MDA Consulting Limited, 1999). The 1993 subsurface soil composite sample and 1995 river bed sample in the Klukshu report were omitted from the table. The TEQs in the Klukshu report were calculated using an older set of TEFs, but converting them to the 1998 WHO TEFs used for the 2003 data would not change the Klukshu TEQ values to any significant degree, as the TEF for 2,3,7,8-TCDD is the same (1.0) in the two sets of TEFs.

The table makes clear that the 2003 CEPOA samples contain predominantly the less-toxic heptachloro- (HpCDD) and octochlorodibenzodioxins (OCDD), and no detectable 2,3,7,8-TCDD above a detection limit or EMPC of 0.38 ng/kg or less. In the Klukshu samples, by contrast, 2,3,7,8-TCDD is the dominant congener, always higher in concentration than HpCDD or OCDD, or any other detected congener.

As discussed in Section 2.4, the distribution of congeners in the 2003 CEPOA samples resembles what one would expect to be generated during the combustion of chlorine-containing materials. The distribution of congeners seen in the Klukshu samples is consistent with the application of a 2,3,7,8-TCDD-contaminated herbicide in a relatively pristine (i.e., little exposure to combustion products) area.

6.3 Quantitative Evaluation of Dioxin Results

Six background samples were collected. The range of TEQ values reported for the background samples was 0.312 to 0.878 ng/kg; further statistics are provided in Table 6-3.

Table 6-3 Background Sample Statistics

Background Range (TEQs)	0.312 - 0.878 ng/kg
Mean[1]	0.53 ng/kg
Standard Deviation[1]	0.22
Coefficient of Variation[1]	0.41
Normality[1]	Data are considered normally distributed at 5% significance level via Shapiro-Wilk Test
95% Upper Confidence Limit (UCL)[1] (via Student's *t*)	0.71 ng/kg

1. Determined using U.S. EPA-distributed software *proUCL*, version 2.1.

Using the calculated 95% UCL of 0.71 ng/kg as the upper-bound of background dioxin TEQs, we see that the TEQs for 16 of the 23 corridor sampling locations (70%) are within background concentrations (see summary of site TEQs in Table 4-2).

TEQs above the background 95% UCL were reported at seven corridor sampling locations: SU, SU4, SU6, SU13, SU17, SU22, and SU23 (see Table 6-4).

Table 6-4 Summary of Locations with TEQs Exceeding Background Concentrations

Location	TEQ (ng/kg)	Location Description
SU1	1.32	Discontinuous grassy corridor in agricultural/homesteaded area off Johnson Road, 1.6 miles east of Richardson Hwy
SU4	11.9	Broad marshy corridor with overhead utility lines/poles in woodlands 3 miles east of Birch Lake; deep water-filled trench running along corridor
SU6	0.70 - 1.8	Broad grassy corridor with overhead utility lines/poles, off pipeline access road, 1.5 miles west of Timber Pump Station
SU13	20.0	At pipeline marker "414", approx 600 ft south of river bluff; overhead utility lines/poles, campsites, many trails in area
SU17	0.75	Open muskeg area; pipeline visible on surface nearby. Old telephone poles paralleling highway cross corridor approx. 50 yards north of sampling location
SU22	2.6 - 4.8	Private residence in Comstock Rd residential area of Haines; heavy brush along foot trail, upgradient from yard
SU23	7.8	Grassy area just downslope from gate ending Skyline Drive; rocky pathway with overhead utility lines/poles, partially buried pipeline visible downslope of sampling location

As discussed in Sections 6.1 and 6.2, the source of the dioxins detected at these sites does not appear to be the application of contaminated herbicides; however, the actual source is not clear. Six of the seven locations in Table 6-4 were either in an area with relatively high number of homes or farms nearby (SU1 and SU22), or active overhead utilities present within the corridor. Active utilities did not appear to be present at SU17, but a line of telephone poles paralleling the highway crossed the pipeline corridor about 50 yards north of the SU17 sampling location. Every location at which overhead utilities were present within the corridor (SU4, SU6, SU13, and SU23) had a TEQ above background (see Table 3-2 and photographs in Appendix A). Locations where the corridor had apparently been widened by brush-removal and even brush burning (such as SU5 and SU18), but did not have utilities present, had TEQs within background concentrations. This is a far from conclusive correlation, but it suggests that the installation and/or maintenance of the electrical lines and support structures might somehow be a source for some of the dioxins detected within the pipeline corridor soils.

The moderately elevated TEQs at SU1 and SU22 may be due in part to outdoor burning of household waste in the surrounding settled areas over many decades; there may also have been utilities nearby that were not noted during the site visit.

6.4 Conclusions

- No detectable concentrations of herbicides or herbicide-generated dioxin (i.e., 2,3,7,8-TCDD) were found in surface soils from those areas tested within the Haines-Fairbanks Pipeline corridor. The absence of even trace amounts of 2,3,7,8-TCDD in any sample strongly suggests that the widespread, systematic application of dioxin-contaminated 2,4,5-T (in the form of "Agent Orange" or "Esteron Brushkiller") did not occur along Alaskan portions of the pipeline corridor.

- General concentrations of dioxins (as expressed by sample TEQs) were below the ADEC cleanup goal at all locations, and within background levels at all but seven of twenty-three corridor sampling locations. The seven locations with elevated TEQs are geographically widely dispersed, suggesting that the elevated dioxins detected are due to localized sources, and not due to routine activities specific to the construction or maintenance of the petroleum pipeline. The elevated TEQs appear to correlate with the presence of utility structures within the corridor, and with the presence of nearby residential areas.

- Unless additional specific information concerning the application of herbicides along the pipeline corridor comes to light, no further testing for herbicides or herbicide-generated dioxins is recommended; the data simply do not provide a foundation for a more focused investigation. The locations where total dioxin concentrations exceed background levels may warrant further examination, but, because of the ambiguity as to the source of the dioxins, it is not clear that such investigations would fall under the mandate of the Formerly Used Defense Sites program.

Table 6-1 Comparison of 2003 CEPOA and 1993/1995 Klukshu Dioxin Data (all values in ng/kg)

Congener	CEPOA 2003 SU4	CEPOA 2003 SU13	CEPOA 2003 SU22	CEPOA 2003 SU23	*SU4-SU23 mean*	Klukshu 1993 surface composite	Klukshu 1993 surface composite	Klukshu 1995 "no growth area"	Klukshu 1995 "road"	Klukshu 1995 "road"	*Klukshu surface soil mean*
2,3,7,8-TCDD	*EMPC [0.382]*	*EMPC [0.199]*	*ND (0.260)*	*ND (0.358)*	*EMPC / ND*	29	30	9	7.2	7.5	*16.5*
1,2,3,7,8-PeCDD	1.71	1.37	0.664	1.10	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,34,7,8-HxCDD	3.52	5.51	0.785	2.37	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,6,7,8-HxCDD	12.6	18.7	7.78	10.9	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,7,8,9-HxCDD	8.42	10.5	2.12	7.51	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,4,6,7,8-HpCDD	251	912	143	270	394	*ND*	*ND*	*ND*	4.9	0.9	2.9
OCDD	1870	12200	994	1860	4231	2.2	1.7	2.7	4.9	6.2	3.5
2,3,7,8-TCDF	0.394	*EMPC [0.111]*	*EMPC [0.389]*	0.248	0.286	2.2	2.3	1.3	0.3	0.3	1.3
1,2,37,8-PeCDF	1.29	0.177	0.583	.0.378	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
2,3,4,7,8-PeCDF	3.40	0.265	1.06	0.692	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,4,7,8-HxCDF	8.59	5.36	1.48	2.34	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,6,7,8-HxCDF	3.45	2.07	1.06	1.43	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
2,3,4,6,7,8-HxCDF	4.36	4.96	1.99	1.83	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,7,8,9-HxCDF	2.94	1.08	1.19	0.378	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
1,2,3,4,6,7,8-HpCDF	87.1	268	22.3	54.3	108	*ND*	*ND*	*0.4*	*0.3*	*0.3*	*0.3*
1,2,3,4,7,8,9-HpCDF	4.04	19.1	1.02	4.54	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
OCDF	187	2700	16.8	360	--	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
TEQ (ND = 0, w/ EMPC)	11.9	20.0	4.67	7.68	*11.1*	29.2	30.2	9.3	7.4	7.7	*16.8*

"Klukshu" data extracted from Table 3 of Klukshu Environmental Study Follow-Up and Wolf Creek Snow Chemistry Study - Final Report, MDA Consulting Limited,1999.
CEPOA: Corps of Engineers, Alaska District.
ND: Not Detected (value in parentheses, if any, is the estimated detection limit).
EMPC: Estimated Maximum Possible Concentration (value in brackets is the estimated quantity).

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