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Supplemental Road Sampling and Surface Material Removal Verification Report

DeLong Mountain Regional Transportation System, Alaska

Prepared for

Teck Cominco Alaska Inc.
Anchorage, Alaska

Exponent®

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Acronyms and Abbreviations

CSB	concentrate storage building
DMTS	DeLong Mountain Regional Transportation System
EPA	U.S. Environmental Protection Agency
the port	DMTS Port facility
Teck Cominco	Teck Cominco Alaska Inc.
TUB	truck unloading building
XRF	x-ray fluorescence

Supplemental Road Sampling and Surface Material Removal Verification Report

Introduction and Background

The purpose of this report is to present the results of sampling work done in 2002 by Teck Cominco Alaska Inc. (Teck Cominco), as called for in the *Supplemental Road Surface Sampling and Analysis Plan* (Exponent 2002a). The sampling efforts were focused on characterizing the metals concentrations in the areas of the DeLong Mountain Regional Transportation System (DMTS) road planned for test paving. This report also documents the condition of the road after road surface material containing residual concentrates was removed and recycled prior to paving, as called for in the *Concentrate Recovery and Recycling Plan* (Exponent 2002b).

The Red Dog Mine is located approximately 50 miles east of the Chukchi Sea, in the western end of the Brooks Range of northern Alaska (Figure 1). Ore containing zinc and lead is milled at the Red Dog Mine to produce zinc and lead concentrates in a powder form. These concentrates are hauled year-round from Red Dog Mine via the DMTS road to concentrate storage buildings (CSBs) at the DMTS Port facility (the port), where they are stored for later loading onto ships during the summer months.

The DMTS road is a 52-mile long, 30-ft wide all weather gravel-surface overland road connecting the Red Dog Mine with the port. The road was constructed in 1987–1988 using a 6-ft-thick gravel bed laid over a geotextile mat placed directly on the original ground surface. The DMTS road includes nine bridges spanning drainages along the way between the port and Red Dog Mine. The DMTS is owned by Alaska Industrial Development and Export Authority, which has contracted with Teck Cominco for its use, operation, and maintenance.

Although fugitive dust control has been a high priority at Red Dog Mine, the port, and along the DMTS road over the years, a moss study done in the year 2000 by the National Park Service (Ford and Hasselbach 2001) indicated that there were some impacts from fugitive dust along the DMTS road and near the port. A fugitive dust study completed in 2001 by Teck Cominco characterized the nature and extent of fugitive dust releases from the DMTS road corridor and provided baseline data from which to monitor the performance of new equipment and dust management practices.

One of the dust management approaches being evaluated is hard surfacing (paving) of the DMTS road. Teck Cominco laid down a test section of pavement on several miles of DMTS road in summer 2002. The purpose of the test is to evaluate the durability of the pavement under site-specific conditions, and to evaluate the suitability of the paving system for minimizing fugitive dust emissions from the DMTS road into the environment while reducing road maintenance requirements for the road surface. The test pavement area also included the "racetrack", a single lane road loop where trucks pull off the main road to unload ore concentrates into CSBs at the port. The extent of the DMTS road surface that was paved in 2002 is shown in Figure 1.

Sampling Program

The *Supplemental Road Surface Sampling and Analysis Plan* (Exponent 2002a) called for characterization of lead, zinc, and cadmium concentrations on the road surface (*in situ*) using a combination of field-portable x-ray fluorescence (XRF) detector sampling and laboratory sampling, for both surface samples and core samples. *In situ* XRF readings were collected at a total of 417 sample points at 135 stations. At a subset of these sample stations, 59 samples of road surface material were collected for *ex situ* XRF measurement, and 43 for offsite laboratory analysis. Approximately 15 percent of road surface measurements were submitted for offsite laboratory analysis. Samples submitted to the laboratory were analyzed for lead by graphite furnace atomic absorption spectrometry using U.S. Environmental Protection Agency's (EPA) Method 7421, and zinc and cadmium by inductively coupled plasma using EPA Method 6010B. Core samples were also taken from 3 depth intervals (0–4, 4–8, and 8–12 in.) at 14 stations—9 on the racetrack loop and 5 on the main road—to characterize the vertical distribution of metals within the material that makes up the road.

Sampling Results (Initial Conditions)

This section summarizes the findings of the supplemental sampling called for in the *Supplemental Road Surface Sampling and Analysis Plan* (Exponent 2002a). This work was intended to further characterize the road surface prior to the paving work.

Table 1 provides a summary of the maximum measured *in situ* and *ex situ* XRF values from sampling points A, B, and C at each road surface sampling station. Figure 2 illustrates road surface sample station locations, and the maximum concentrations (by *in situ* XRF) at each station. As expected, the highest concentrations were observed in the port area, especially on the racetrack adjacent to the truck unloading building (TUB). Concentrations generally decreased with distance away from the TUB, and away from the port site in general.

For a complete listing of the sample results for all sampling points at all stations, refer to Table A-1 in Appendix A. Table A-1 presents the *in situ* and *ex situ* XRF field measurement (EPA Method 6200) results and the laboratory results for lead, zinc, and cadmium. Left, middle, and right side samples are designated by the suffixes A, B, and C, respectively, on the sample names.

Table 2 shows the analytical results for lead, zinc, and cadmium for all road surface samples submitted for offsite laboratory analysis.

Table 3 provides a summary comparison of the *in situ*, *ex situ*, and laboratory results for each road surface sampling point where all three types of analyses were performed.

Table 4 presents analytical results for lead, zinc, and cadmium for all of the road core samples submitted for offsite laboratory analysis. XRF measurements were not made on these samples. The locations of the core samples are illustrated in Figure 3. Samples were collected from 0–4, 4–8, and 8–12 in. depths. The analytical results indicate a typical decrease in concentration with depth at each sample location. The maximum lead, zinc, and cadmium concentrations observed were 509, 2,280, and 17 mg/kg, respectively. These maximums occurred in shallow 0–4 in. samples.

Identification of Areas for Recovery and Recycling

After the additional road surface characterization work was completed, data were reviewed to identify areas for metals recovery and recycling, with the goal of, at a minimum, recovering metals so as to reduce concentrations to acceptable levels in the road surface areas to be paved. Because site-specific cleanup standards had not yet been established, the supplemental characterization data were compared with Method 2 "arctic zone" cleanup standards in order to identify areas for removal and recycling of road material. Method 2 "arctic zone" cleanup levels for lead, zinc, and cadmium are 1,000, 41,000, and 140 mg/kg, respectively.

Exceedance ratios were calculated by dividing the laboratory results by the corresponding cleanup level for the analyte. Table 2 shows exceedance ratios for each of the analytes at each road surface sampling station, and Table 4 shows exceedance ratios for the road core sample results. The maximum exceedance ratio among the analytes for a given station is indicated with a box around the value. As Tables 2 and 4 show, the maximum exceedance ratio was invariably for lead for all road surface and road core samples. This finding indicates that, based on the cleanup levels used here for comparison, the focus can be placed on lead concentrations when considering actions to be taken based on the available data.

Both *in situ* and *ex situ* XRF data were correlated with the lab results so as to establish threshold XRF concentrations that could be used to define areas for removal and recycling. Figures 4 and 5 show correlation plots for lead for the *in situ* and *ex situ* XRF data in comparison with the offsite laboratory data (shown in Table 3). The *in situ* correlation plot has more scatter than the *ex situ* correlation plot. This is as expected, because the *ex situ* measurement is made on a homogenized sample, and the sample submitted to the laboratory includes the same material from which the *ex situ* XRF measurement was taken. As a result, *ex situ* measurements are more closely correlated with the laboratory results. Based on Figure 5, the value estimated statistically for the *ex situ* XRF value that is equivalent to an analytical laboratory result of 1,000 mg/kg for lead (the assumed cleanup level) is 1,128 mg/kg. Lower confidence limits are also listed on each correlation plot for the XRF equivalent of the 1,000 mg/kg laboratory value for lead.

The *in situ* XRF results provided the most comprehensive coverage of the road surface areas that were to be paved. Figure 2 illustrates road surface concentrations based on *in situ* XRF results. The breakpoint between the bluish and reddish colored symbols (729 ppm) indicates the *in situ* XRF concentration below which there would be a 95 percent confidence that there would be no exceedance of the arctic zone standards for lead of 1,000 mg/kg, based on the correlation relationship in Figure 4. A review of the comparison in Table 3 indicated that with a few exceptions, the *in situ* exceedance locations shown in Figure 2 were inclusive of the *ex situ* exceedance locations, and were also inclusive of locations with lab results exceeding 1,000 mg/kg.

The results shown on Figure 2, along with the threshold XRF values estimated from Figures 4 and 5, were used to help guide the recovery and recycling effort.

Overview of Recovery and Recycling

After areas of the road surface with concentrations above the default cleanup standards were identified, the road surface material in those areas was removed and recycled into the mill at the mine, prior to paving the test section of the DMTS road. This section provides an overview of the removal and recycling process, as defined in the *Concentrate Recovery and Recycling Plan* (Exponent 2002b).

Areas having road surface or road core sample concentrations exceeding the arctic zone soil cleanup levels were identified through sampling work described in the *Supplemental Road Surface Sampling and Analysis Plan* (Exponent 2002a) and summarized above. The sampling effort defined areas of exceedance within 100-ft segments of road. In areas where sampling stations were spaced at 500-ft intervals, the sampling procedure is designed to go to 100-ft intervals where exceedances are detected. The stations where exceedances occurred were marked. Specifically, if the average XRF reading at any one or more of the three sampling points at a station exceeded the default arctic zone cleanup levels, or if a laboratory confirmation sample indicated an exceedance at that station, an area 50 ft on either side of the station was demarcated using lath stakes and/or flagging along the road shoulder. Once the area for removal was identified, the removal was implemented.

Areas that were marked for removal were wetted down by spraying them with water trucks, using water acquired from the nearest normal road watering sources (MS-2 and/or MS-3), in order to facilitate removal of the roadbed materials and to minimize dust generation. Water was applied at rates that avoided generating runoff from the road surface.

Using graders, approximately 1 to 2 in. of road surface material was scraped from the road surface. The road surface material was graded into furrowed windrows. When it was necessary, in order to grade to a desired depth, additional water was applied to the road prior to additional passes with the grader. The furrowed material was promptly loaded into truck-trailers using front-end loaders. Loads were securely covered with tarps and transported to the mine, to be recycled in accordance with the *Concentrate Recovery and Recycling Plan* (Exponent 2002b). Approximately 15,000 tons of materials were removed and transported to the mine for recycling. The material was stockpiled at the crusher, and is being recycled at the rate of 200 to 300 tons/day.

Once the road was graded to the desired depth in the removal areas (50 ft on either side of stations with exceedances of cleanup levels), the surface in that area was be re-sampled by *in situ* XRF measurements at the same station locations sampled during the supplemental sampling (illustrated in Figure 2). In addition, *in situ* XRF measurements were also taken at the ends of excavations. For example, where multiple sequential road segments were graded for recovery, then these additional XRF measurements were taken at each end of the complete removal area, to confirm that the removal continued far enough toward the next measurement station where there was no exceedance measured in the original sampling.

Where XRF verification measurements indicated remaining road surface material concentrations in exceedance of the cleanup levels, the recovery procedure described above was repeated until additional recovery was no longer warranted. Once there were no concentrations in exceedance of soil cleanup levels at a station, a verification sample of road surface material was collected at that station for *ex situ* XRF analysis. If the *ex situ* XRF measurement was also below the cleanup level, the recovery was considered complete, and the sample was submitted for laboratory confirmation analysis. If the *ex situ* XRF measurement was still above the cleanup level, the recovery and verification sampling procedures described above were repeated again.

Verification Sampling Results (Current Conditions)

This section summarizes verification data documenting the condition of the road surface after removal and recycling, and prior to paving.

Table 5 presents the analytical results of the verification samples sent to the offsite laboratory. The sample stations listed in Table 5 are the stations where material was removed for recovery and recycling prior to paving. Note that these stations correspond to the stations highlighted in Tables 1, 2, and 3. Table 5 shows measurement results for lead, zinc, and cadmium at each of these stations. These samples were the final confirmation samples following material removal from the road surface. Left, middle, and right side samples are designated by the suffixes A, B, and C, respectively. Field replicates are designated as 1 and 2 for the parent and duplicate sample, respectively.

Figure 6 illustrates sample station locations and concentrations of the laboratory verification samples, along with the approximate extent of the test paving. Lead concentrations were generally below the arctic zone cleanup level (1,000 mg/kg), and for the most part were below 250 mg/kg. Prior to removal, the port area and especially the racetrack had lead concentrations exceeding 1,000 mg/kg (see Figure 2). Following recovery and recycling of road surface material, those areas are now well below the arctic zone standard, with the exception of three locations.

The three laboratory samples that had concentrations greater than the cleanup level for lead (i.e., Stations 136, 138, and 181) are shown with reddish colored symbols and labels on Figure 6. These portions of the road are the on-ramp and exit from the TUB, which had historically been repeatedly filled and covered. These older road surfaces contained metal concentrations that were greater than the cleanup levels. Although material was removed to a depth of 1−5 ft, the field team was unable to remove all of the material with metals concentrations above the arctic zone levels. Because the depth of this excavation was endangering the safety of the field team and affecting trucking operations, no further removal was performed. However, these areas were covered with clean fill and paved such that there are no exposure pathways for the metals that were left in place.

Summary

The road surface samples collected at stations prior to removal characterized the DMTS road surface areas that were to be paved (see Figure 1). Stations with lead concentration greater than the arctic zone standard of 1,000 mg/kg were subjected to a recovery process that continued until there was *in situ* and *ex situ* evidence that the road surface concentrations were below that level. Laboratory verification samples were collected for all stations (see Figure 6). For a few stations near the TUB where the material with elevated concentrations could not be fully removed for logistical reasons, the material was covered with clean fill and capped with pavement, likely eliminating any exposure pathways.

Pavement was placed as planned over most of the area sampled. The only stations that were not paved over were Station 101, which is on the racetrack just north of the TUB, and Stations 145 through 148, which are near the refueling station. Figure 6 illustrates the approximate extent of the paving.

References

Exponent. 2002a. Supplemental road surface sampling and analysis plan, DeLong Mountain Regional Transportation System, Alaska. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2002b. Concentrate recovery and recycling plan, DeLong Mountain Regional Transportation System, Alaska. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Ford, S., and L. Hasselbach. 2001. Heavy metals in mosses and soils on six transects along the Red Dog Mine haul road, Alaska. NPS/AR/NRTR-2001/38. National Park Service, Western Arctic National Parklands.

Figures

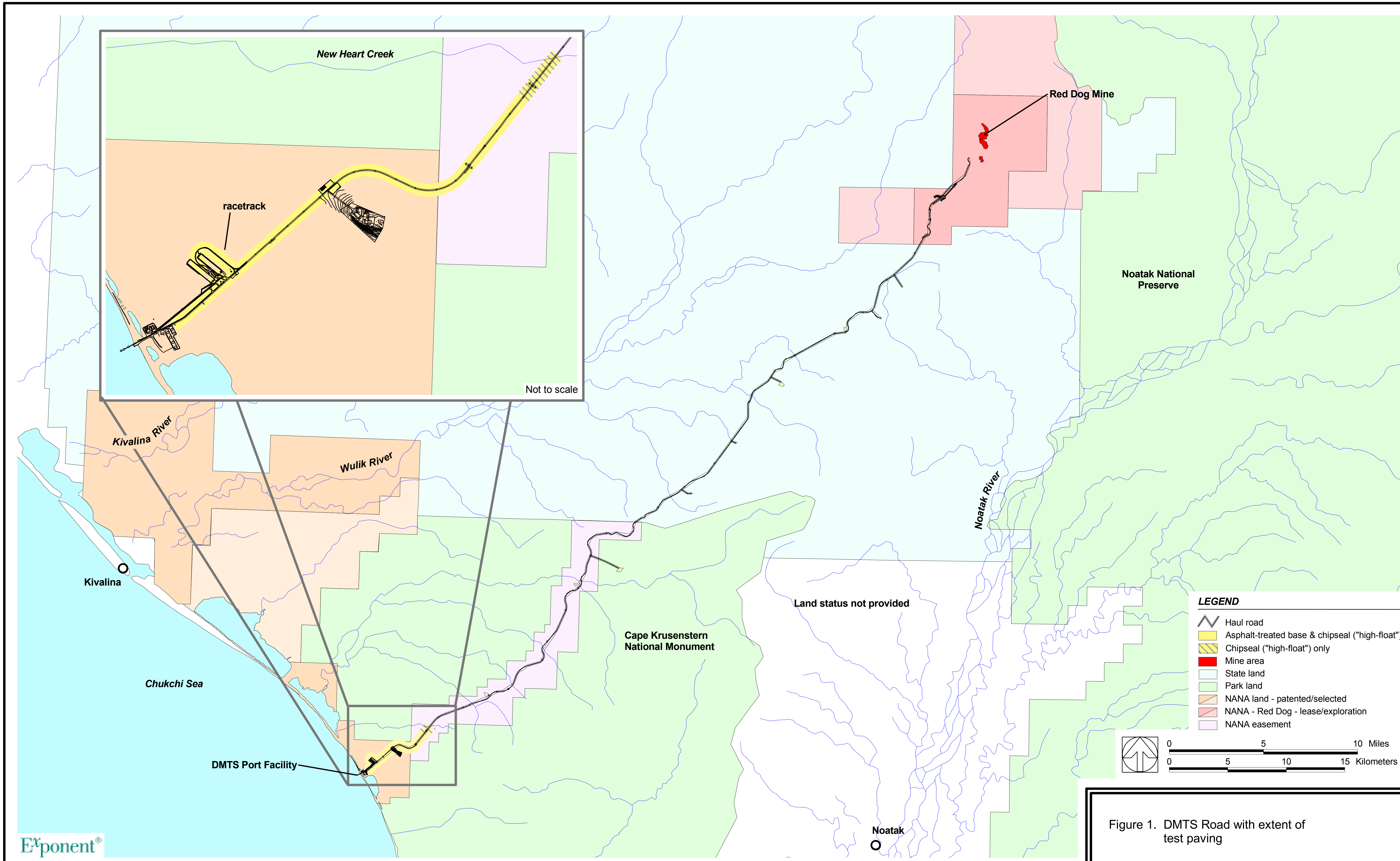

Figure 1. DMTS Road with extent of test paving

8601997.001 1700 | Oct 31, 2002 | Fig 1 paving dock close-up view | Fig 1 extent of paving layout | j:/red_dog/projects/paving_data.apr

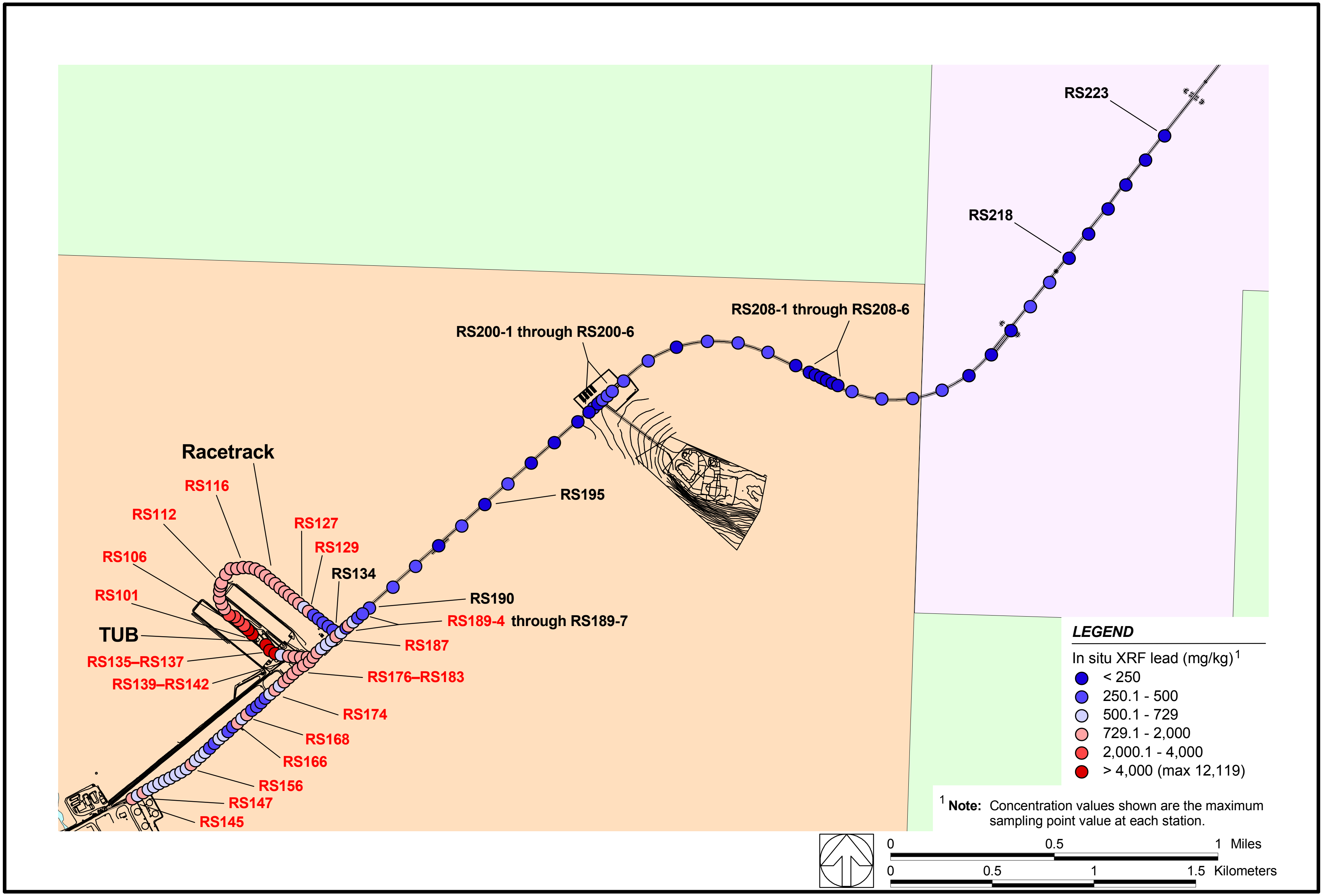

Figure 2. Road surface lead concentrations before recovery and recycling

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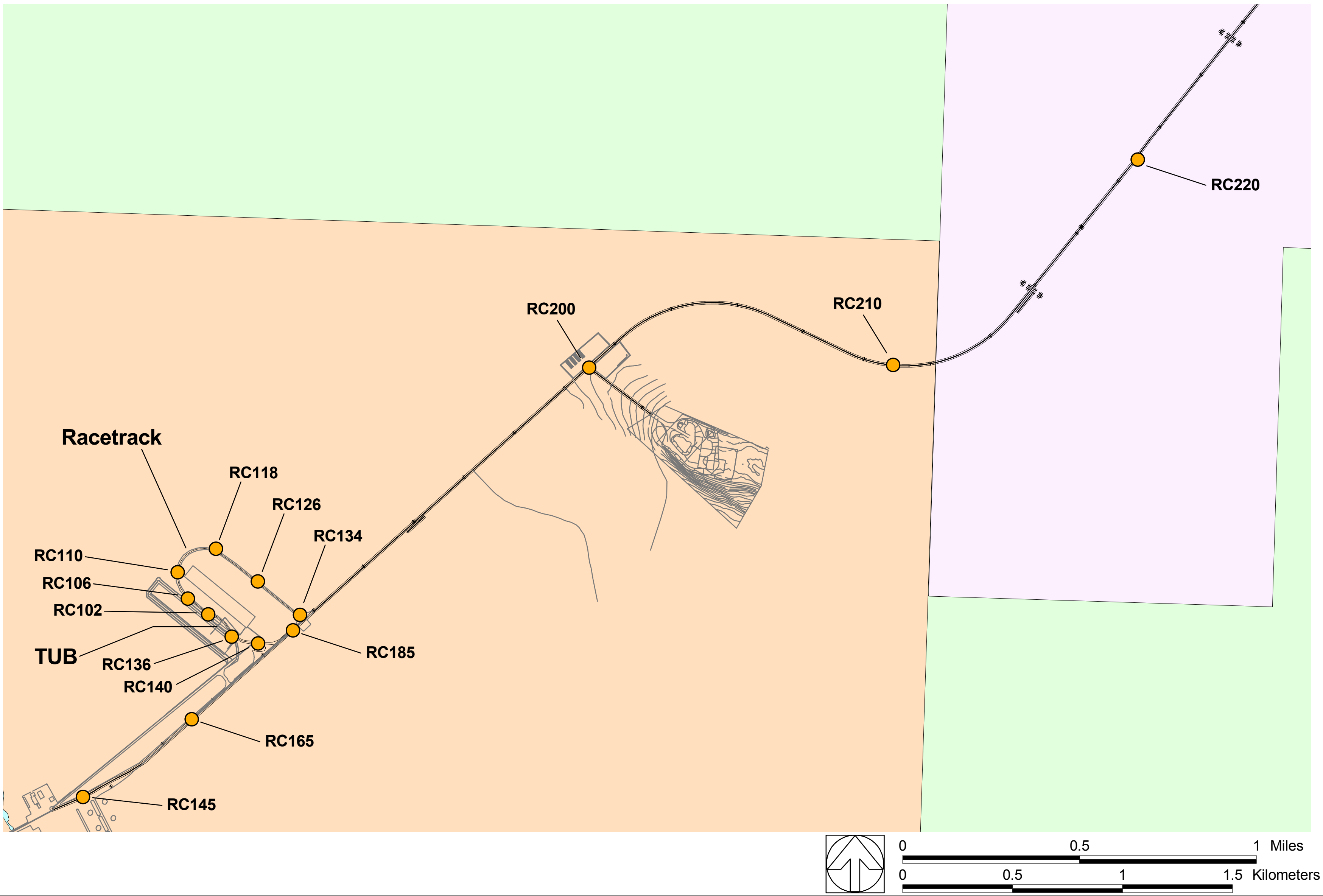

Figure 3. DMTS road core sample locations

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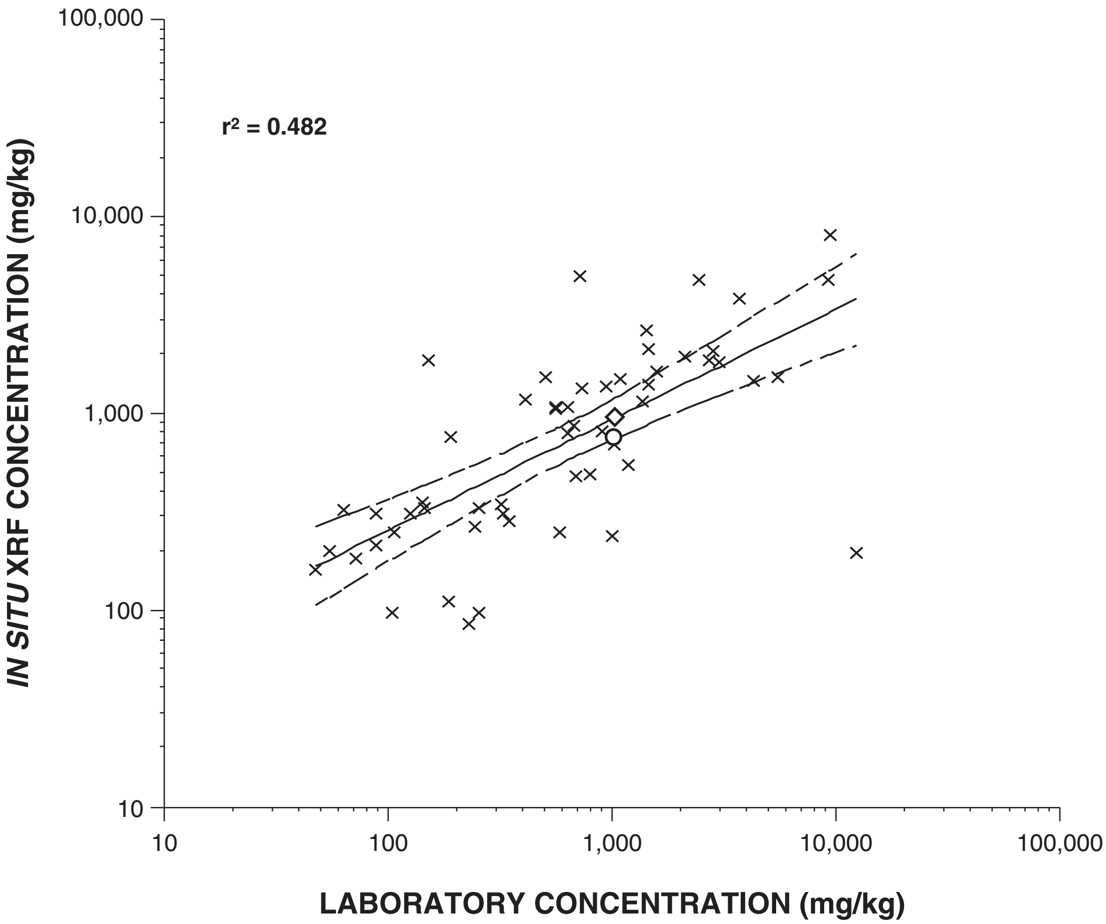
8601997.001 1700 | Oct 31, 2002 | Fig 3 core sample view | Fig 3 Road surface core layout | j:/red_dog/projects/paving_data.apr



LEGEND

For an analytical laboratory concentration of 1,000:

◇ Estimated *in situ* concentration = 922

○ Estimated *in situ* LCL concentration = 729

—— Best-fit line (Lab conc. = $10^{(0.3362 + 0.8593 \times \log_{10} \textit{in situ} \text{ conc.})}$)

— — Confidence limits (95% confidence)

Note:

LCL = lower confidence limit (95% confidence)

Figure 4. Comparison of laboratory and *in situ* XRF lead concentrations

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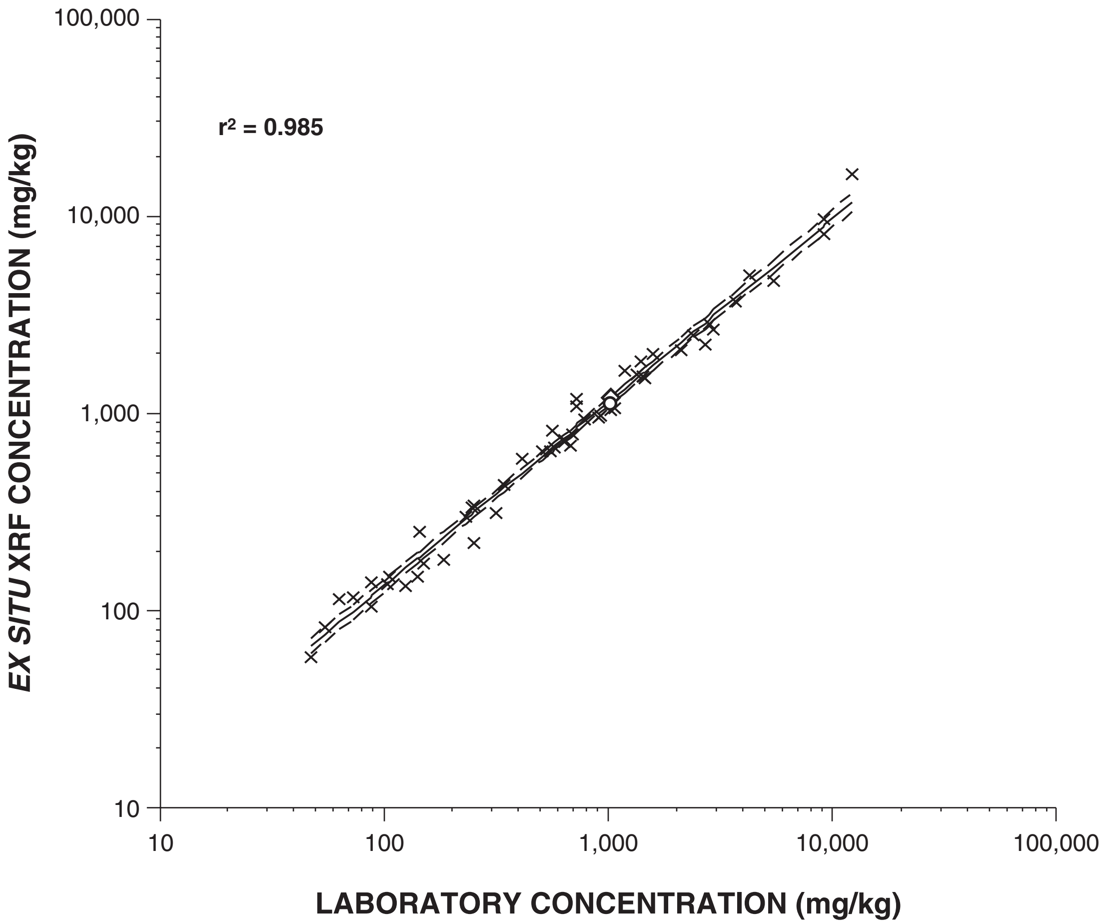

LEGEND

For an analytical laboratory concentration of 1,000:

◇ Estimated *ex situ* concentration = 1,128

○ Estimated *ex situ* LCL concentration = 1,075

—— Best-fit line (Lab conc. = $10^{(-0.2315 + 1.0577 \times \log_{10} \textit{ex situ} \text{ conc.})}$)

— — Confidence limits (95% confidence)

Note:

LCL = lower confidence limit (95% confidence)

Figure 5. Comparison of laboratory and *ex situ* XRF lead concentrations

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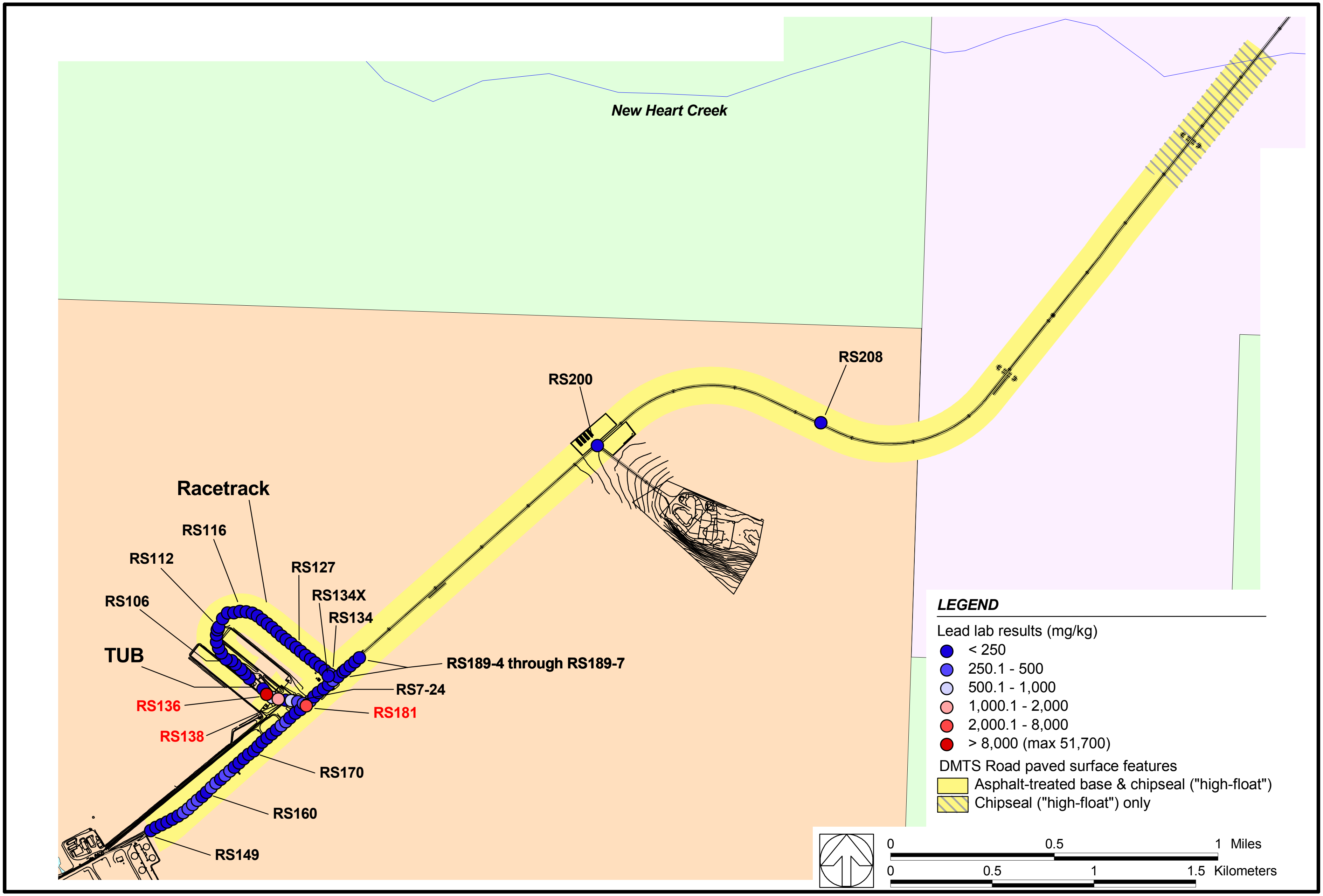

Figure 6. Road surface lead concentrations after recovery and recycling

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8601997.001 1700 | Oct 31, 2002 | Fig 6 GPS paving lab view | Fig 6 Road surface lab layout | j:/red_dog/projects/paving_data.apr

Tables

Table 1. Summary of station maximums for pre-removal road surface XRF results

	Lead (mg/kg)		Zinc (mg/kg)		Cadmium (mg/kg)	
Station	*In situ* XRF[a]	*Ex situ* *XRF*[a]	*In situ* XRF[a]	*Ex situ* *XRF*[a]	*In situ* XRF[a]	*Ex situ* *XRF*[a]
101	7,900	9,677	54,364	75,776	196	242
102	4,760	2,949	21,590	17,894	70	92
103	3,770	3,658	15,000	19,098	60	102
104	2,620	1,829	11,700	9,734	60	50 *U*
105	2,060	2,800	12,510	14,093	60 *U*	86
106	2,080	1,520	11,900	7,667	60 *U*	50 *U*
107	1,380	1,180	8,980	5,498	60 *U*	50 *U*
108	1,810	2,659	9,630	11,296	70	50 *U*
109	1,400	1,510	6,910	8,454	60 *U*	50 *U*
110	1,860	2,229	9,070	13,696	80	105
111	1,520	4,669	7,327	47,283	60	207
112	1,480	1,060	7,437	5,779	60 *U*	50 *U*
113	1,510	640	6,431	2,850	60 *U*	50 *U*
114	1,000		5,262		60 *U*	
115	1,160	590	4,910	2,490	60 *U*	50 *U*
116	950		4,860		60 *U*	
117	1,070	735	5,390	2,930	60 *U*	50 *U*
118	1,000	507	5,040	2,419	60 *U*	50 *U*
119	801		4,336		60 *U*	
120	1,070	819	4,130	3,728	60 *U*	50 *U*
121	1,040	633	4,582	2,600	60 *U*	50 *U*
122	769		3,900		60 *U*	
123	770		4,040		60 *U*	
124	820		4,140		60 *U*	
125	782		3,950		60 *U*	
126	863	796	4,222	4,029	60 *U*	50 *U*
127	800		3,470		60 *U*	
128	598		4,350		60 *U*	
129	787		4,054		60 *U*	
130	360		2,650		60 *U*	
131	364		8,560		60 *U*	
132	404		3,070		60 *U*	
133	397	593	2,270	2,280	60 *U*	50 *U*
134	305		1,870		60 *U*	
135	4,660	8,038	29,300	51,994	60 *U*	231
136	12,119	4,960	86,139	31,898	252	161
137	4,908	1,070	25,667	5,398	60 *U*	50 *U*
138	523	137	3,827	558	60 *U*	50 *U*
139	1,830	171	9,331	881	60 *U*	50 *U*
140	1,920	2,080	10,510	11,898	60 *U*	50 *U*
141	1,600	1,989	8,369	12,000	60 *U*	50 *U*
142	891		4,682		60 *U*	
145	798	950	3,970	4,768	60	50 *U*
146	714		3,910		60 *U*	
147	736		3,300		60 *U*	
148	611		3,160		60 *U*	
149	569		2,963		60 *U*	
150	550		2,279		60 *U*	
151	551		2,200		60 *U*	
152	570		2,279		60 *U*	

Table 1. (cont.)

Station	Lead (mg/kg) In situ XRF[a]	Lead (mg/kg) *Ex situ XRF*[a]	Zinc (mg/kg) In situ XRF[a]	Zinc (mg/kg) *Ex situ XRF*[a]	Cadmium (mg/kg) In situ XRF[a]	Cadmium (mg/kg) *Ex situ XRF*[a]
153	688		3,230		60 *U*	
154	502		2,590		60 *U*	
155	653	662	3,210	3,219	60 *U*	50 *U*
156	830		3,120		60 *U*	
157	522		2,350		60 *U*	
158	505		2,087		60 *U*	
159	566		3,011		60 *U*	
160	342		1,810		60 *U*	
161	482		2,627		60 *U*	
162	598	248	2,531	1,150	60 *U*	50 *U*
163	549		2,620		60 *U*	
164	482	927	2,675	5,130	60 *U*	50 *U*
165	487	1,410	2,600	7,174	60 *U*	50 *U*
166	865		3,736		60 *U*	
167	658		3,430		60 *U*	
168	821		5,040		60 *U*	
169	430		2,740		60 *U*	
170	400		2,210		60 *U*	
171	362		2,350		60 *U*	
172	392	331	2,510	1,260	60 *U*	50 *U*
173	650		3,700		60 *U*	
174	824		4,260		60 *U*	
175	696	1,030	4,090	5,898	60 *U*	50 *U*
176	1,000		5,374		60 *U*	
177	892		5,572		60 *U*	
178	832	338	4,618	1,020	60 *U*	50 *U*
179	1,130	1,560	7,493	7,885	60 *U*	50 *U*
180	1,360	977	7,380	5,238	65	50 *U*
181	900		5,270		60 *U*	
182	754	257	3,160	1,080	60 *U*	50 *U*
183	880		3,020		60 *U*	
184	720		3,964		60 *U*	
185	540	1,650	3,059	6,970	60 *U*	50 *U*
186	632		2,339		60 *U*	
187	792	706	3,050	3,210	60 *U*	50 *U*
188	520		2,231		60 *U*	
189	463		1,760		60 *U*	
189-4	1,800	795	7,312	4,000	55 *U*	50 *U*
189-5	607		2,860		55 *U*	
189-6	403		2,330		55 *U*	
189-7	329	275	1,760	1,200	55 *U*	50 *U*
190	379		1,570		60 *U*	
191	268		1,180		60 *U*	
192	260		1,660		60 *U*	
193	224		1,170		60 *U*	
194	350	133	1,460	561	60 *U*	50 *U*
195	235		858		60 *U*	
196	380		1,110		60 *U*	
197	197	81	815	261	60 *U*	50 *U*
198	182		636		60 *U*	

Table 1. (cont.)

Station	Lead (mg/kg)		Zinc (mg/kg)		Cadmium (mg/kg)	
	In situ XRF[a]	*Ex situ XRF*[a]	*In situ* XRF[a]	*Ex situ XRF*[a]	*In situ* XRF[a]	*Ex situ XRF*[a]
199	220		1,340		60 *U*	
200	340	16,096	1,220	74,778	60 *U*	252
200-1	239		950		60 *U*	
200-2	352		1,210		60 *U*	
200-3	226		1,130		60 *U*	
200-4	323		1,250		60 *U*	
200-5	383		973		60 *U*	
200-6	275		1,190		60 *U*	
201	306	105	2,360	477	60 *U*	50 *U*
202	295		1,050		60 *U*	
203	250	146	1,390	538	60 *U*	50 *U*
204	353	147	1,170	571	60 *U*	50 *U*
205	328		1,960		60 *U*	
206	320	296	5,000	1,240	60 *U*	50 *U*
207	232		2,771		60 *U*	
208	247	661	1,050	3,099	60 *U*	50 *U*
208-1	222		1,060		55 *U*	
208-2	136		4,430		55 *U*	
208-3	193		1,360		55 *U*	
208-4	170		1,200		55 *U*	
208-5	146		755		55 *U*	
208-6	190		1,490		55 *U*	
209	257		1,300		60 *U*	
210	342	307	1,110	1,030	60 *U*	50 *U*
211	284		2,500		60 *U*	
212	265	181	1,850	727	60 *U*	50 *U*
213	217		884		60 *U*	
214	217		983		60 *U*	
215	247	221	3,170	934	60 *U*	50 *U*
216	283	322	934	1,770	60 *U*	50 *U*
217	299		989		60 *U*	
218	230		1,640		60 *U*	
219	170	136	2,519	497	60 *U*	50 *U*
220	182	143	1,010	590	60 *U*	50 *U*
221	182		914		60 *U*	
222	145		682		60 *U*	
223	174	57	740	141	60 *U*	50 *U*
224	111		583		55 *U*	
225	111		624		55 *U*	

Note: Station numbers 143 and 144 were not used.

(grey shading) - indicates stations where material was removed for recovery and recycling prior to paving

In situ XRF - x-ray fluorescence field measurement on the road surface

Ex situ XRF - x-ray fluorescence field measurement on a sample of material collected from the road surface

[a] The XRF value shown is the maximum measured value of three sampling points (left, middle, right) at that station. Measurements by EPA Method 6200.

Table 2. Pre-removal road surface laboratory results with exceedance ratios

		Concentration (mg/kg)[a]			Exceedance Ratios[b]		
Station	Sample ID	Lead	Zinc	Cadmium	Lead	Zinc	Cadmium
101	RS-101-A	9,300	48,300	271	9.3	1.18	1.94
102	RS-102-A	2,430	11,700	71	2.4	0.29	0.51
103	RS-103-A	3,720	16,300	101	3.7	0.40	0.72
104	RS-104-A	1,410	6,050	38	1.4	0.15	0.27
105	RS-105-A	2,820	12,500	75	2.8	0.30	0.54
106	RS-106-A	1,440	6,840	41	1.4	0.17	0.30
107	RS-107-A	729	3,240	21	0.7	0.08	0.15
108	RS-108-A	2,990	10,400	73	3.0	0.25	0.52
109	RS-109-A	1,460	6,890	46	1.5	0.17	0.33
110	RS-110-A	2,710	12,300	104	2.7	0.30	0.74
111	RS-111-A	5,470	40,300	254	5.5	0.98	1.81
112	RS-112-A	1,080	4,860	31	1.1	0.12	0.22
113	RS-113-C	508	2,290	16	0.5	0.06	0.12
115	RS-115-A	414	1,720	11	0.4	0.04	0.08
117	RS-117-A	637	2,500	16	0.6	0.06	0.12
118	RS-118-B	123	478	3.0	0.1	0.01	0.02
120	RS-120-A	563	2,270	15	0.6	0.06	0.11
121	RS-121-A	558	2,410	15	0.6	0.06	0.11
126	RS-126-C	680	2,830	18	0.7	0.07	0.13
133	RS-133-B	345	1,370	8.5	0.3	0.03	0.06
135	RS-135-A	9,180	46,100	267	9.2	1.12	1.91
136	RS-136-C	4,310	22,700	133	4.3	0.55	0.95
137	RS-137-A	720	3,210	19	0.7	0.08	0.14
138	RS-138-A	88	307	1.8	0.1	0.01	0.01
139	RS-139-C	151	581	3.4	0.2	0.01	0.02
140	RS-140-C	2,130	9,940	54	2.1	0.24	0.39
141	RS-141-A	1,590	7,600	41	1.6	0.19	0.29
145	RS-145-A	910	4,380 *J*	26 *J*	0.9	0.11	0.19
155	RS-155-B	64	211	1.7	0.1	0.01	0.01
162	RS-162-B	144	623	3.5	0.1	0.02	0.03
164	RS-164-A	789	4,510 *J*	24	0.8	0.11	0.17
164	RS-164-C	692	3,580	19	0.7	0.09	0.14
172	RS-172-B	246	772	4.4	0.2	0.02	0.03
175	RS-175-A	1,030	5,110	32	1.0	0.12	0.23
178	RS-178-C	255	634	6.2	0.3	0.02	0.04
179	RS-179-A	1,360	6,110	40	1.4	0.15	0.28
180	RS-180-A	936	4,210	27	0.9	0.10	0.19
182	RS-182-A	189	709	5.1	0.2	0.02	0.04
185	RS-185-C	1,190	4,460	26	1.2	0.11	0.19
187	RS-187-B	638	2,720	17	0.6	0.07	0.12
189-4	RS-189-4-C	1,010	4,290	24	1.0	0.10	0.17
189-7	RS-189-7-A	323	1,600	8.8	0.3	0.04	0.06
194	RS-194-C	126	438	3.2	0.1	0.01	0.02
197	RS-197-B	55	176	1.5	0.1	0.00	0.01
200	RS-200-A	12,300	43,600	229	12.3	1.06	1.64
201	RS-201-B	88	324 *J*	1.8	0.1	0.01	0.01
203	RS-203-C	106	454 *J*	2.7	0.1	0.01	0.02
204	RS-204-B	142	570 *J*	3.7	0.1	0.01	0.03

Table 2. (cont.)

Station	Sample ID	Concentration (mg/kg)[a] Lead	Zinc	Cadmium	Exceedance Ratios[b] Lead	Zinc	Cadmium
206	RS-206-B	231	1,000	5.7	0.2	0.02	0.04
208	RS-208-C	579	2,670 *J*	12	0.6	0.07	0.08
210	RS-210-C	317	1,100 *J*	6.1	0.3	0.03	0.04
212	RS-212-A	185	632 *J*	3.8	0.2	0.02	0.03
215	RS-215-B	255	1,020 *J*	5.3	0.3	0.02	0.04
219	RS-219-C	104	430 *J*	2	0.1	0.01	0.01
220	RS-220-A	73	260 *J*	1	0.1	0.01	0.01
223	RS-223-A	47	138 *J*	1 *U*	0.0	0.00	0.01 *U*

Note: Station numbers 143 and 144 were not used.

- indicates stations where material was removed for recovery and recycling prior to paving

[a] Results from analysis by EPA Method 6010B.

[b] Exceedance ratios are calculated by dividing the laboratory results by the arctic zone cleanup levels. Cleanup levels for lead, zinc, and cadmium are 1,000, 41,000, and 140 mg/kg, respectively. The maximum exceedance ratio among the analytes for a given station is indicated with a box around the value.

Table 3. Pre-removal road surface XRF and laboratory results comparison

		Lead (mg/kg)			Zinc (mg/kg)			Cadmium (mg/kg)		
Station	Sample ID	*In situ* XRF[a]	*Ex situ* XRF[a]	Lab[b]	*In situ* XRF[a]	*Ex situ* XRF[a]	Lab[b]	*In situ* XRF[a]	*Ex situ* XRF[a]	Lab[b]
101	RS-101-A	7,900	9,677	9,300	54,364	75,776	48,300	196	242	271
102	RS-102-A	4,760	2,499	2,430	21,590	14,490	11,700	70	50 *U*	71
103	RS-103-A	3,770	3,658	3,720	15,000	19,098	16,300	60	102	101
104	RS-104-A	2,620	1,829	1,410	11,700	9,734	6,050	60	50 *U*	38
105	RS-105-A	2,060	2,800	2,820	12,510	14,093	12,500	60 *U*	86	75
106	RS-106-A	2,080	1,520	1,440	11,900	7,667	6,840	60 *U*	50 *U*	41
107	RS-107-A	1,340	1,180	729	8,980	5,498	3,240	60 *U*	50 *U*	21
108	RS-108-A	1,810	2,659	2,990	9,630	11,296	10,400	70	50 *U*	73
109	RS-109-A	1,400	1,510	1,460	6,910	8,454	6,890	60 *U*	50 *U*	46
110	RS-110-A	1,860	2,229	2,710	9,070	13,696	12,300	80	105	104
111	RS-111-A	1,520	4,669	5,470	7,327	47,283	40,300	60	207	254
112	RS-112-A	1,480	1,060	1,080	7,437	5,779	4,860	60 *U*	50 *U*	31
113	RS-113-C	1,510	640	508	5,413	2,850	2,290	60 *U*	50 *U*	16
115	RS-115-A	1,160	590	414	4,910	2,490	1,720	60 *U*	50 *U*	11
117	RS-117-A	1,070	735	637	5,390	2,930	2,500	60 *U*	50 *U*	16
118	RS-118-B	296	187	123	1,170	833	478	60 *U*	50 *U*	3.0
120	RS-120-A	1,070	819	563	4,130	3,728	2,270	60 *U*	50 *U*	15
121	RS-121-A	1,040	633	558	4,582	2,600	2,410	60 *U*	50 *U*	15
126	RS-126-C	863	678	680	4,222	3,259	2,830	60 *U*	50 *U*	18
133	RS-133-B	282	432	345	1,300	1,890	1,370	60 *U*	50 *U*	8.5
135	RS-135-A	4,660	8,038	9,180	29,300	51,994	46,100	60 *U*	231	267
136	RS-136-C	1,450	4,960	4,310	11,500	31,898	22,700	60 *U*	154	133
137	RS-137-A	4,908	1,070	720	25,667	5,398	3,210	60 *U*	50 *U*	19
138	RS-138-A	213	137	88	1,220	558	307	60 *U*	50 *U*	1.8
139	RS-139-C	1,830	171	151	9,331	881	581	60 *U*	50 *U*	3.4
140	RS-140-C	1,920	2,080	2,130	10,510	11,898	9,940	60 *U*	50 *U*	54
141	RS-141-A	1,600	1,989	1,590	8,369	12,000	7,600	60 *U*	50 *U*	41
145	RS-145-A	798	950	910	3,970	4,768	4,380 *J*	60	50 *U*	26 *J*
155	RS-155-B	319	114	64	1,430	347	211	60 *U*	50 *U*	1.7
162	RS-162-B	332	248	144	1,400	1,150	623	60 *U*	50 *U*	3.5
164	RS-164A	482	927	789	2,675	5,130	4,510 *J*	60 *U*	50 *U*	24
164	RS-164-C	473	785	692	2,339	3,619	3,580	60 *U*	50 *U*	19
172	RS-172-B	263	331	246	1,280	1,260	772	60 *U*	50 *U*	4.4
175	RS-175-A	696	1,030	1,030	4,090	5,898	5,110	60 *U*	50 *U*	32
178	RS-178-C	326	338	255	1,380	1,020	634	60 *U*	50 *U*	6.2
179	RS-179-A	1,130	1,560	1,360	7,493	7,885	6,110	60 *U*	50 *U*	40
180	RS-180-A	1,360	977	936	7,380	5,238	4,210	65	50 *U*	27
182	RS-182-A	754		189	3,160		709	60 *U*		5.1
185	RS-185-C	540	1,650	1,190	3,059	6,970	4,460	60 *U*	50 *U*	26
187	RS-187-B	792	706	638	3,050	3,210	2,720	60 *U*	50 *U*	17
189-4	RS-189-4-C	1,800		1,010	7,312		4,290	55 *U*		24
189-7	RS-189-7-A	298		323	1,520		1,600	55 *U*		8.8
194	RS-194-C	310	133	126	1,460	561	438	60 *U*	50 *U*	3.2
197	RS-197-B	197	81	55	815	261	176	60 *U*	50 *U*	1.5
200	RS-200-A	196	16,096	12,300	1,070	74,778	43,600	60 *U*	252	229
201	RS-201-B	306	105	88	1,270	477	324 *J*	60 *U*	50 *U*	1.8
203	RS-203-C	250	146	106	1,010	538	454	60 *U*	50 *U*	2.7
204	RS-204-B	353	147	142	1,150	571	570 *J*	60 *U*	50 *U*	3.7
206	RS-206-B	84	296	231	5,000	1,240	1,000 *J*	60 *U*	50 *U*	5.7
208	RS-208-C	247	661	579	1,030	3,099	2,670 *J*	60 *U*	50 *U*	12
210	RS-210-C	342	307	317	1,110	1,030	1,100 *J*	60 *U*	50 *U*	6.1
212	RS-212-A	110	181	185	1,850	727	632 *J*	60 *U*	50 *U*	3.8
215	RS-215-B	97	221	255	3,170	934	1,020 *J*	60 *U*	50 *U*	5.3

Table 3. (cont.)

		Lead (mg/kg)			Zinc (mg/kg)			Cadmium (mg/kg)		
		In situ	*Ex situ*		*In situ*	*Ex situ*		*In situ*	*Ex situ*	
Station	Sample ID	XRF[a]	XRF[a]	Lab[b]	XRF[a]	XRF[a]	Lab[b]	XRF[a]	XRF[a]	Lab[b]
219	RS-219-C	96	136	104	2,519	497	430 *J*	60 *U*	50 *U*	2
220	RS-220-A	182	115	73	830	370	260 *J*	60 *U*	50 *U*	1
223	RS-223-A	160	57	47	715	141	138 *J*	60 *U*	50 *U*	1 *U*

Note: Station numbers 143 and 144 were not used.
(grey shading) - indicates stations where material was removed for recovery and recycling prior to paving
In situ XRF - x-ray fluorescence field measurement on the road surface
Ex situ XRF - x-ray fluorescence field measurement on a sample of material collected from the road surface

[a] Measurements by EPA Method 6200.

[b] Results from analysis by EPA Method 6010B.

Table 4. Pre-removal road core laboratory results with exceedance ratios

Station	Sample ID	Depth Interval (in.)	Concentration (mg/kg)[a] Lead	Zinc	Cadmium	Enrichment Ratios[b] Lead	Zinc	Cadmium
102	RC-102-A	0–4	91	381	1.9	0.09	0.009	0.014
102	RC-102-B	4–8	21	104	1 *U*	0.02	0.003	0.007 *U*
102	RC-102-C	8–12	23	116	1 *U*	0.02	0.003	0.007 *U*
106	RC-106-A	0–4	231	761	4.6	0.23	0.019	0.033
106	RC-106-B	4–8	24	93	1 *U*	0.02	0.002	0.007 *U*
106	RC-106-C	8–12	20 *U*	100	1 *U*	0.02 *U*	0.002	0.007 *U*
110	RC-110-A	0–4	155	654	3.9	0.16	0.016	0.028
110	RC-110-B	4–8	35	149	1 *U*	0.03	0.004	0.007 *U*
110	RC-110-C	8–12	99	358	1.6	0.10	0.009	0.011
118	RC-118-A	0–4	27	121	1 *U*	0.03	0.003	0.007 *U*
118	RC-118-B	4–8	20 *U*	85	1 *U*	0.02 *U*	0.002	0.007 *U*
118	RC-118-C	8–12	20 *U*	80	1 *U*	0.02 *U*	0.002	0.007 *U*
126	RC-126-A	0–4	138	560	3.4	0.14	0.014	0.024
126	RC-126-B	4–8	22	91	1 *U*	0.02	0.002	0.007 *U*
126	RC-126-C	8–12	24	87	1 *U*	0.02	0.002	0.007 *U*
134	RC-134-A	0–4	167	690	3.8	0.17	0.017	0.027
134	RC-134-B	4–8	57	231	1.6	0.06	0.006	0.011
134	RC-134-C	8–12	47	171	1 *U*	0.05	0.004	0.007 *U*
136	RC-136-A	0–4	449	2,280	17	0.45	0.056	0.121
136	RC-136-B	4–8	42	217	1.2	0.04	0.005	0.009
136	RC-136-C	8–12	41	222 *J*	1	0.04	0.005	0.007
140	RC-140-A	0–4	365	1,940 *J*	11	0.37	0.047	0.080
140	RC-140-B	4–8	252	1,210 *J*	8.1	0.25	0.030	0.058
140	RC-140-C	8–12	31	117 *J*	1 *U*	0.03	0.003	0.007 *U*
145	RC-145-A	0–4	509	1,660	10	0.51	0.040	0.072
145	RC-145-B	4–8	54	147	2.0	0.05	0.004	0.014
145	RC-145-C	8–12	21 *U*	70	1.0 *U*	0.02 *U*	0.002	0.007 *U*
165	RC-165-A	0–4	154	527	3.4	0.15	0.013	0.024
165	RC-165-B	4–8	23	82	1.0 *U*	0.02	0.002	0.007 *U*
165	RC-165-C	8–12	49	142	1.0 *U*	0.05	0.003	0.007 *U*
185	RC-185-A	0–4	316	1,390	7.9	0.32	0.034	0.056
185	RC-185-B	4–8	250	1,130	7.1	0.25	0.028	0.051
185	RC-185-C	8–12	29	124	1 *U*	0.03	0.003	0.007 *U*
200	RC-200-A	0–4	20 *U*	94	1 *U*	0.02 *U*	0.002	0.007 *U*
200	RC-200-B	4–8	20 *U*	87	1 *U*	0.02 *U*	0.002	0.007 *U*
200	RC-200-C	8–12	21	72	1 *U*	0.02	0.002	0.007 *U*
210	RC-210-A	0–4	56	171	1.2	0.06	0.004	0.009
210	RC-210-B	4–8	17	57	1 *U*	0.02	0.001	0.007 *U*
210	RC-210-C	8–12	12	50	1 *U*	0.01	0.001	0.007 *U*
220	RC-220-A	0–4	68	186	1.0	0.07	0.005	0.007
220	RC-220-B	4–8	47	178	1.1	0.05	0.004	0.008
220	RC-220-C	8–12	99	319	1.7	0.10	0.008	0.012

Note: Station numbers 143 and 144 were not used.

[a] Results from analysis by EPA Method 6010B.

[b] Exceedance ratios are calculated by dividing the laboratory results by the cleanup levels. Cleanup levels for lead, zinc, and cadmium are 1,000, 41,000, and 140 mg/kg, respectively. The maximum exceedance ratio among the analytes for a given station is indicated with a box around the value.

Table 5. Verification sample results for post-removal samples

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
101	A		21 *U*	66	1 *U*
101	B		21 *U*	39	1.1 *U*
101	C		21 *U*	37	1.1 *U*
102	A	1	34	126	1 *U*
102	A	2	48	156	1.1 *U*
102	B	1	24	88	1 *U*
102	C	1	22	88	1.1 *U*
103	A		23	88	1 *U*
103	B		31	134	1 *U*
103	C		21 *U*	73	1 *U*
104	A		53	244	1.4
104	B		129	655	3.9
104	C		42	169	1 *U*
105	A	1	21 *U*	96	1 *U*
105	A	2	21 *U*	71	1 *U*
105	B		110	245	1.6
105	C		63	258	2.3
106	A	1	31	139	1 *U*
106	A	2	23	119	1 *U*
106	B		21 *U*	82	1 *U*
106	C		23	109	1 *U*
107	A	1	71	340	2.1
107	A	2	83	414	2.5
107	B		25	108	1 *U*
107	C		21 *U*	87	1 *U*
108	A		20 *U*	82	1 *U*
108	B		70	154	1 *U*
108	C		35	150	1 *U*
109	A	1	21 *U*	100	1 *U*
109	A	2	21 *U*	96	1 *U*
109	B		164	459	2.6
109	C		51	226	1 *U*
110	A		41 [b]		
110	B		50 [b]		
110	C		47 [b]		
111	A		39 [b]		
111	B		28 [b]		
111	C		37 [b]		
112	A		42 *J*	234	1.4
112	B		20 *UJ*	75	1 *U*
112	C		20 *U*	85	1 *U*
113	A		24 *J*	82	1 *U*
113	B		22 *J*	89	1 *U*
113	C		85 *J*	424	4.7
114	A		31 [b]		
114	B	1	33 *J*	149	1 *U*
114	B	2	30	140	1 *U*
114	C		44 *J*	227	1.5

Table 5. (cont.)

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
115	A		21	100	1 *U*
115	B		59 *J*	221	1 *U*
115	C		69 *J*	278	2.6
116	A		24 *J*	87	1 *U*
116	B		77 *J*	299	1.9
116	C		59 *J*	307	2
117	A		31 *J*	148	1 *U*
117	B		73	310	2
117	C	1	65	254	1.7
117	C	2	44	204	1.8
118	A		21 *U*	79	1 *U*
118	B		42	127	1 *U*
118	A		17 [b]		
119	A		21 *U*	73	1 *U*
119	B		28	111	1 *U*
119	A		18 *U* [b]		
120	A		204 [b]		
120	B		67 [b]		
120	C	1	53	190	1 *U*
120	C	2	37	158	1 *U*
121	A		194	837	5.3
121	B		31	125	1 *U*
121	C		85	259	2.1
122	A		65	182	1.5
122	B		40	90	1 *U*
122	C		36	65	1 *U*
123	A		21 *U*	54	1 *U*
123	B		57	219	1 *U*
123	C		44	170	1 *U*
124	A		54	203	1 *U*
124	B	1	100	336	2.2
124	B	2	89	305	2
124	C		27	113	1 *U*
125	A		37	97	1.2
125	B		42	139	1.5
125	C		27	73	1 *U*
126	A		87	249	2.2
126	B		62	162	1 *U*
126	C	1	49	117	1 *U*
126	C	2	45	116	1 *U*
127	A		27	75	3.1
127	B		80	208	2.6
127	C		72	206	2.8
128	A	1	38	62	1 *U*
128	A	2	61	76	1 *U*
128	B		80	212	1
128	C		58	103	1 *U*
129	A		196	669	5

Table 5. (cont.)

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
129	B		44	133	1.9
129	C		221	615	3.9
130	A	1	96	349	2.9
130	A	2	115	399	2.9
130	B		68	230	2.6
130	C		124	373	4.5
131	A		56	169	2.1
131	B		101	338	3.5
131	C		106	385	3.4
132	A		67	124	1 *U*
132	B		105	258	2.2
132	C	1	111	398	2.9
132	C	2	92	276	1 *U*
133	A	1	56	164	1 *U*
133	A	2	49	183	1 *U*
133	B		50	66	1 *U*
133	C		77	81	2.3
134	A		47	119	1 *U*
134	B		46	189	1.9
134	C		264	1,040	6.3
134X	A		56	118	1 *U*
134X	B		150	591	3.4
134X	C		46	151	1 *U*
135	A		22	78	1 *U*
135	B		25	91	1 *U*
135	C		21 *U*	94	1 *U*
136	A		51,700	182,000	1,040
136	B	1	2,920	11,300	64
136	B	2	2,830 *J*	11,100	68
136	C		277	1,060	6.4
137	A		39	164	1 *U*
137	B		514	1,760	11
137	C		456	1,920	12
138	A	1	1,000	4,100	26
138	A	2	1,220 *J*	5,000	31
138	B		329	1,420	8.7
138	C		378	1,560	9.8
139	A		169	626	4.3
139	B		143	710	4.5
139	C		197	727	4.4
140	A		70	318	2.2
140	B		249	1,030	6.3
140	C		740	3,390	21
141	A	1	324 *J*	1,360	8.9
141	A	2	200	1,100	8.2
141	B		78	373	2.7
141	C		21 *U*	106	1 *U*
142	A		491 [b]		
142	B		354 [b]		
142	C		743 [b]		

Table 5. (cont.)

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
149	A		121	462	2.8
149	B		33	112	1 *U*
149	C		85	259	1.9
150	A	1	21 *U*	54	1 *U*
150	A	2	25	74	1
150	B		21 *U*	69	1 *U*
150	C		21 *U*	57	1 *U*
151	A	1	20 *U*	60	1 *U*
151	A	2	21	77	1 *U*
151	B		57	166	1.9
151	C		105	215	2.8
152	A		21 *U*	54	1 *U*
152	B		92	282	2.1
152	C		27	71	1 *U*
153	A		45	61	1.5
153	B		20 *U*	33	1 *U*
153	C		20 *U*	47	1 *U*
154	A		63	234	3.0
154	B		20 *U*	29	1 *U*
154	C		43	48	1 *U*
155	A		225	789	5.4
155	B		292	1,120	7.3
155	C		69	163	3.2
156	A		347	1,310	8.5
156	B		329	1,200	7.6
156	C		288	1,040	7
157	A	1	241	917	6.1
157	A	2	314	1,160	7.3
157	B		118	450	3
157	C		84	267	2.5
158	A		73	249	1 *U*
158	B		232	714	4.9
158	C		331	1,150	7.4
159	A	1	25	63	1 *U*
159	A	2	33	80	2.2
159	B		53	182	1 *U*
159	C		144	410	2.6
160	A		67	226	1.7
160	B		79	262	1 *U*
160	C		29	104	1 *U*
161	A		406	1,510	12
161	B		298	633	6.2
161	C		125	409	4.6
162	A		271	716	6
162	B	1	66	156	1.7
162	B	2	57	176	1 *U*
162	C		42	138	1.8
163	A		71	331	4.5

Table 5. (cont.)

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
163	B		53	162	3
163	C		120	411	4
164	A		37	168	1.7
164	B		40	123	2.1
164	C		303	985	6.1
165	A	1	93	259	1.9
165	A	2	100	269	1 *U*
165	B		43	135	1 *U*
165	C		453	1,340	8
166	A		21 *U*	34	1 *U*
166	B		68	184	1.7
166	C	1	131	394	2.6
166	C	2	105	327	2.1
167	A		47	97	1 *U*
167	B		95	310	3.1
167	C	1	33	112	1 *U*
167	C	2	39	119	1 *U*
168	A		107	358	3.6
168	B		126	393	5.2
168	C		186	850	7.6
169	A		31	135	1 *U*
169	B	1	214	664	5.9
169	B	2	198	606	5.2
169	C		46	156	2.4
170	B		57	194	1.8
170	A		69	227	4.1
170	C		55	191	1.6
171	A		33	133	1 *U*
171	B		68	247	2
171	C	1	26	84	1 *U*
171	C	2	27	92	1.5
172	A		28	54	1 *U*
172	B		24	96	1 *U*
172	C		51	163	1 *U*
173	A		46	131	1 *U*
173	B		21 *U*	39	1 *U*
173	C		83	312	2.7
174	A		63	162	3.3
174	B		143	458	2.8
174	C		51	172	1 *U*
175	A		33	116	1 *U*
175	B	1	89	267	1.8
175	B	2	60	208	1 *U*
175	C		39	90	1 *U*
176	A		120	431	2.2
176	B		258	990	5
176	C		28	41	1 *U*
177	A		412	1,560	8.7
177	B		21 *U*	77	1.1

Table 5. (cont.)

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
177	C	1	20 *U*	67	1.0 *U*
177	C	2	21 *U*	63	1 *U*
178	A		21 *U*	77	1.0 *U*
178	B		21 *U*	51	1.0 *U*
178	C		21 *U*	48	2.2
179	A	1	21 *U*	58	1.0 *U*
179	A	2	21 *U*	76	1.1 *U*
179	B		21 *U*	70	1.0 *U*
179	C		21 *U*	56	1.1 *U*
180	C		21 *U*	83	1.1 *U*
180	A		21 *U*	56	1.1 *U*
180	B		33	119	1.2
181	F		27	131	1 *U*
181	A		72	272	1.8
181	B	1	136	485	3.2
181	B	2	167	573	3.8
181	C		104	454	2.9
181	E		2,910	13,600	84
182	A		58	212	3.5
182	B		52	170	3.4
182	C		52	165	2.1
182	D		69 *J*	231	2.3
182	D		210 *J*	753	5.5
182	F		277 *J*	926	6
183	A	1	21 *U*	63	1.0 *U*
183	A	2	21 *U*	52	1.0 *U*
183	B		21 *U*	52	1.0 *U*
183	C		24	93	1.1 *U*
183	D		58 *J*	210	1.5
183	E		135 *J*	522	3.1
183	F		136 *J*	598	4.1
184	A		60	262	1.8
184	B		96	368	2.6
184	C	1	31	108	1.3
184	C	2	29	99	1.3
184	D	1	148 *J*	623	4.3
184	E	2	162	640	4.3
184	F		96	382	2.9
185	A		81	317	2.6
185	B		21 *U*	59	1.1 *U*
185	C		72	203	1.8
185	D		126 *J*	536	4.4
186	A		167	722	4.5
186	B		76	340	2.5
186	C		52	242	1.7
187	A	1	250	9,690	5.7
187	A	2	383	1,200	6.9
187	B		62	187	1.1 *U*

Table 5. (cont.)

Station	Sample Point	Field Replicate	Laboratory Verification[a] (mg/kg) Lead	Zinc	Cadmium
187	C		21 *U*	45	1.0 *U*
188	A	1	21 *U*	39	1.7
188	A	2	21 *U*	39	1.0 *U*
188	B		21 *U*	53	1.1 *U*
188	C		78	64	1.1 *U*
189	A		21 *U*	55	1.0 *U*
189	C		123	648	5.8
189	B		207	860	6.2
189-4	A		117	366	2.2
189-4	B		27	77	1.0 *U*
189-4	C		39	73	1.1 *U*
189-5	A		21 *U*	54	1.0 *U*
189-5	B		21 *U*	45	1.1 *U*
189-5	C		48	114	1.2
189-6	A		21 *U*	44	1.2
189-6	B		21 *U*	54	1.0 *U*
189-6	C		20 *U*	69	1.0 *U*
189-7	A		21 *U*	31	1.1 *U*
189-7	B		21 *U*	40	1.0 *U*
189-7	C		21 *U*	64	1.0 *U*
200	A	1	43	157	2.4
200	A	2	59	294	4.1
200	B		22	86	1.0 *U*
200	C		21 *U*	81	1.0 *U*
208	A		40	156	1.1 *U*
208	A		160 [b]		
208	C		24	95	1.0 *U*
7-24	A		425 [b]		
7-24	A		66 [b]		

Note: Station numbers 143 and 144 were not used.

- indicates samples from stations with concentrations exceeding the arctic zone standards that were left in place due to logistical constraints

[a] Results from analysis by EPA Method 6010B.

[b] Results were analyzed by *ex situ* XRF and converted to an equivalent laboratory value using the correlation in Figure 5.

Appendix A

Additional Data Tables

Table A-1. Complete list of road surface *in situ and ex situ* XRF results and laboratory results (pre-removal)

			In situ XRF Measurement[a]			*Ex situ* XRF Measurement[a]			Lab Measurement[b]		
Station	Transect Point	Field Replicate	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
101	A		7,900	54,364	196	9,677	75,776	242.4	9,300	48,300	271
101	B		830	5,760	60 *U*						
101	C		742	4,260	60 *U*						
102	A		4,760	21,590	70	2,499	14,490	50 *U*	2,430	11,700	71.0
102	B		1,600	7,964	60 *U*	794	4,067	50 *U*			
102	C		2,100	10,830	60 *U*	2,949	17,894	92.3			
103	A		3,770	15,000	60	3,658	19,098	102.1	3,720	16,300	101
103	B		1,250	6,274	60 *U*						
103	C		1,770	9,920	60 *U*						
104	A		2,620	11,700	60	1,829	9,734	50 *U*	1,410	6,050	37.6
104	B		2,080	11,000	60						
104	C		1,140	5,460	60 *U*						
105	A		2,060	12,510	60 *U*	2,800	14,093	85.6	2,820	12,500	75.2
105	B		1,340	5,800	60 *U*						
105	C		1,200	6,760	60 *U*						
106	A		2,080	11,900	60 *U*	1,520	7,667	50 *U*	1,440	6,840	41.4
106	B		1,840	10,100	60 *U*	1,060	5,258	50 *U*			
106	C		1,400	6,800	60 *U*	1,380	7,219	50 *U*			
107	A		1,340	8,980	60 *U*	1,180	5,498	50 *U*	729	3,240	21.1
107	B		1,380	7,485	60 *U*						
107	C		1,260	5,386	60 *U*						
108	A		1,810	9,630	70	2,659	11,296	50 *U*	2,990	10,400	73.4
108	B		1,600	7,101	60 *U*						
108	C		1,300	4,930	60 *U*						
109	A		1,400	6,910	60 *U*	1,510	8,454	50 *U*	1,460	6,890	45.7
109	B		898	4,706	60 *U*						
109	C		1,140	5,042	60 *U*						
110	A		1,860	9,070	80	2,229	13,696	104.8	2,710	12,300	104
110	B		1,000	4,602	60 *U*	566	1,680	50 *U*			
110	C		1,130	5,402	60 *U*	433	2,090	50 *U*			
111	A	1	1,520	7,327	60	4,669	47,283	207.2	5,520	35,400	230
111	A	2							5,420	45,100	278
111	B		1,270	6,286	60 *U*						
111	C		1,120	4,535	60 *U*						
112	A		1,480	7,437	60 *U*	1,060	5,779	50 *U*	1,080	4,860	31.0
112	B		839	4,066	60 *U*						
112	C		1,120	4,462	60 *U*						
113	A		1,280	6,431	60 *U*						
113	B		930	4,422	60 *U*						

Table A-1. (cont.)

			In situ XRF Measurement[a]			*Ex situ* XRF Measurement[a]			Lab Measurement[b]		
Station	Transect Point	Field Replicate	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
113	C		1,510	5,413	60 *U*	640	2,850	50 *U*	508	2,290	16.4
114	A		1,000	5,262	60 *U*						
114	B	1	781	3,260	60 *U*						
114	B	2									
114	C		990	4,802	60 *U*						
115	A		1,160	4,910	60 *U*	590	2,490	50 *U*	414	1,720	11.4
115	B		550	1,855	60 *U*						
115	C		771	3,660	60 *U*						
116	A		950	4,860	60 *U*						
116	B		298	1,060	60 *U*						
116	C		644	3,293	60 *U*						
117	A		1,070	5,390	60 *U*	735	2,930	50 *U*	637	2,500	16.2
117	B		532	2,063	60 *U*						
117	C		623	3,149	60 *U*						
118	A		1,000	5,040	60 *U*	507	2,419	50 *U*			
118	B		296	1,170	60 *U*	187	833	50 *U*	123	478	3.0
118	C		669	3,350	60 *U*	417	1,920	50 *U*			
119	A		801	4,336	60 *U*						
119	B		514	2,903	60 *U*						
119	C		546	3,040	60 *U*						
120	A		1,070	4,130	60 *U*	819	3,728	50 *U*	563	2,270	15.0
120	B		359	2,000	60 *U*						
120	C		641	2,990	60 *U*						
121	A		1,040	4,582	60 *U*	633	2,600	50 *U*	558	2,410	15.3
121	B		367	1,720	60 *U*						
121	C		660	3,671	60 *U*						
122	A		769	3,830	60 *U*						
122	B		668	3,900	60 *U*						
122	C		647	2,951	60 *U*						
123	A		710	3,880	60 *U*						
123	B		382	1,960	60 *U*						
123	C		770	4,040	60 *U*						
124	A		820	4,140	60 *U*						
124	B		375	1,610	60 *U*						
124	C		427	1,800	60 *U*						
125	A		782	3,950	60 *U*						
125	B		600	3,119	60 *U*						
125	C		755	3,650	60 *U*						
126	A		755	3,910	60 *U*	796	4,029	50 *U*			

Table A-1. (cont.)

			In situ XRF Measurement[a]			*Ex situ* XRF Measurement[a]			Lab Measurement[b]		
Station	Transect Point	Field Replicate	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
126	B		265	1,070	60 *U*	223	782	50 *U*			
126	C	1	863	4,222	60 *U*	678	3,259	50 *U*	683	2,820	17.8
126	C	2							670	2,830	18.2
127	A		800	3,470	60 *U*						
127	B		476	2,135	60 *U*						
127	C		361	2,170	60 *U*						
128	A		538	2,963	60 *U*						
128	B		380	2,060	60 *U*						
128	C		598	4,350	60 *U*						
129	A		540	3,623	60 *U*						
129	B		350	2,135	60 *U*						
129	C		787	4,054	60 *U*						
130	A		350	2,650	60 *U*						
130	B		251	2,060	60 *U*						
130	C		360	1,800	60 *U*						
131	A		364	3,710	60 *U*						
131	B		102	8,560	60 *U*						
131	C		190	5,180	60 *U*						
132	A		404	3,070	60 *U*						
132	B		358	2,150	60 *U*						
132	C		295	1,210	60 *U*						
133	A		397	2,270	60 *U*	462	2,280	50 *U*			
133	B		282	1,300	60 *U*	432	1,890	50 *U*	345	1,370	8.5
133	C		332	1,870	60 *U*	593	1,720	50 *U*			
134	A		304	1,760	60 *U*						
134	B		274	1,160	60 *U*						
134	C		305	1,870	60 *U*						
135	A		4,660	29,300	60 *U*	8,038.4	51,993.6	231	9,180	46,100	267
135	B		2,380	12,600	60 *U*						
135	C		3,660	24,070	60 *U*						
136	A		12,119.0	86,138.9	252.2	4,259.2	24,998.4	160.8			
136	B		1,070	6,210	60 *U*	3,868.8	18,188.8	89.9			
136	C		1,450	11,500	60 *U*	4,960	31,897.6	153.7	4,310	22,700	133
137	A		4,907.5	25,666.6	60 *U*	1,069.6	5,398.4	50 *U*	720	3,210	19.4
137	B		534.2	3,179.5	60 *U*						
137	C		1,280	8,850	60 *U*						
138	A		212.5	1,220	60 *U*	136.6	557.6	50 *U*	88.2	307	1.8
138	B		299.5	1,523.5	60 *U*						
138	C		523	3,826.6	60 *U*						

Table A-1. (cont.)

Station	Transect Point	Field Replicate	*In situ* XRF Measurement[a] Lead (mg/kg)	*In situ* XRF Zinc (mg/kg)	*In situ* XRF Cadmium (mg/kg)	*Ex situ* XRF Measurement[a] Lead (mg/kg)	*Ex situ* XRF Zinc (mg/kg)	*Ex situ* XRF Cadmium (mg/kg)	Lab Measurement[b] Lead (mg/kg)	Lab Zinc (mg/kg)	Lab Cadmium (mg/kg)
139	A		773.0	3,470	60 *U*						
139	B		65	247.4	60 *U*						
139	C		1,830	9,331	60 *U*	171.4	880.8	50 *U*	151	581	3.4
140	A		920	4,073.3	60 *U*	971.2	4,848	50 *U*			
140	B		746	4,650	60 *U*	143.7	608.4	50 *U*			
140	C		1,920	10,510	60 *U*	2,080	11,897.6	50 *U*	2,130	9,940	53.9
141	A		1,600	8,369.3	60 *U*	1,988.8	12,000	50 *U*	1,590	7,600	40.7
141	B		590	2,489.3	60 *U*						
141	C		514	2,603.5	60 *U*						
142	A		550.1	2,177.3	60 *U*						
142	B		375.8	1,739.5	60 *U*						
142	C		890.7	4,682.2	60 *U*						
145	A		798	3,970	60	950	4,768	50 *U*	910	4,380	26.3
145	B		560	2,480	60 *U*	648	2,690	50 *U*			
145	C		590	2,840	60 *U*	584	2,290	50 *U*			
146	A		714	3,910	60 *U*						
146	B		466	2,210	60 *U*						
146	C		630	2,783	60 *U*						
147	A		736	3,300	60 *U*						
147	B		454	2,140	60 *U*						
147	C		570	2,900	60 *U*						
148	A		611	3,160	60 *U*						
148	B		504	2,100	60 *U*						
148	C		554	2,885	60 *U*						
149	A		569	2,963	60 *U*						
149	B		281	1,500	60 *U*						
149	C		460	2,099	60 *U*						
150	A		462	2,260	60 *U*						
150	B		388	1,620	60 *U*						
150	C		550	2,279	60 *U*						
151	A		551	2,200	60 *U*						
151	B		314	1,340	60 *U*						
151	C		550	2,060	60 *U*						
152	A		497	2,279	60 *U*						
152	B		326	1,330	60 *U*						
152	C		570	2,135	60 *U*						
153	A		475	2,435	60 *U*						
153	B		236	1,380	60 *U*						
153	C		688	3,230	60 *U*						

Table A-1. (cont.)

Station	Transect Point	Field Replicate	*In situ* XRF Measurement[a] Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	*Ex situ* XRF Measurement[a] Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lab Measurement[b] Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
154	A		502	2,590	60 *U*						
154	B		318	1,510	60 *U*						
154	C		430	2,003	60 *U*						
155	A		600	3,210	60 *U*	635	3,160	50 *U*			
155	B		319	1,430	60 *U*	114	347	50 *U*	63.5	211	1.7
155	C		653	3,200	60 *U*	662	3,219	50 *U*			
156	A		540	2,900	60 *U*						
156	B		366	1,550	60 *U*						
156	C		830	3,120	60 *U*						
157	A		508	2,350	60 *U*						
157	B		304	1,540	60 *U*						
157	C		522	2,300	60 *U*						
158	A		462	1,930	60 *U*						
158	B		343	1,420	60 *U*						
158	C		505	2,087	60 *U*						
159	A		566	3,011	60 *U*						
159	B		306	1,540	60 *U*						
159	C		350	1,550	60 *U*						
160	A		334	1,810	60 *U*						
160	B		210	863	60 *U*						
160	C		342	1,670	60 *U*						
161	A		482	2,627	60 *U*						
161	B		274	1,330	60 *U*						
161	C		451	2,560	60 *U*						
162	A		397	1,991	60 *U*						
162	B		332	1,400	60 *U*	248	1,150	50 *U*	144	623	3.5
162	C		598	2,531	60 *U*						
163	A		452	2,519	60 *U*						
163	B		342	1,610	60 *U*						
163	C		549	2,620	60 *U*						
164	A		482	2,675	60 *U*	927	5,130	50 *U*	789	4,510	24.4
164	B		222	1,000	60 *U*	147	541	50 *U*			
164	C		473	2,339	60 *U*	785	3,619	50 *U*	692	3,580	18.9
165	A		487	2,600	60 *U*						
165	B		280	1,280	60 *U*						
165	C		479	2,243	60 *U*	1,410	7,174	50 *U*			
166	A		589	3,736	60 *U*						
166	B		290	1,570	60 *U*						
166	C		865	3,630	60 *U*						

Table A-1. (cont.)

			In situ XRF Measurement[a]			*Ex situ* XRF Measurement[a]			Lab Measurement[b]		
Station	Transect Point	Field Replicate	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
167	A		658	3,430	60 *U*						
167	B		200	929	60 *U*						
167	C		568	2,147	60 *U*						
168	A		821	5,040	60 *U*						
168	B		271	1,090	60 *U*						
168	C		569	2,195	60 *U*						
169	A		430	2,740	60 *U*						
169	B		307	1,200	60 *U*						
169	C		328	1,570	60 *U*						
170	A		400	2,210	60 *U*						
170	B		241	1,000	60 *U*						
170	C		290	1,160	60 *U*						
171	A		362	2,350	60 *U*						
171	B		196	1,040	60 *U*						
171	C		283	1,250	60 *U*						
172	A		392	2,510	60 *U*						
172	B		263	1,280	60 *U*	331	1,260	50 *U*	246	772	4.4
172	C		365	1,910	60 *U*						
173	A		650	3,700	60 *U*						
173	B		499	2,800	60 *U*						
173	C		380	1,300	60 *U*						
174	A		824	4,260	60 *U*						
174	B		478	2,519	60 *U*						
174	C		578	1,200	60 *U*						
175	A		696	4,090	60 *U*	1,030	5,898	50 *U*	1,030	5,110	32.4
175	B		510	2,483	60 *U*	385	880	50 *U*			
175	C		502	1,570	60 *U*	277	678	50 *U*			
176	A		1,000	5,374	60 *U*						
176	B		404	2,120	60 *U*						
176	C		320	1,480	60 *U*						
177	A		892	5,572	60 *U*						
177	B		677	3,590	60 *U*						
177	C		342	1,460	60 *U*						
178	A		832	4,618	60 *U*						
178	B		517	3,011	60 *U*						
178	C	1	326	1,380	60 *U*	338	1,020	50 *U*	271	706	6.7
178	C	2							239	562	5.6
179	A		1,130	7,493	60 *U*	1,560	7,885	50 *U*	1,360	6,110	39.7
179	B		445	2,570	60 *U*						

Table A-1. (cont.)

Station	Transect Point	Field Replicate	*In situ* XRF Measurement[a] Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	*Ex situ* XRF Measurement[a] Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lab Measurement[b] Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
179	C		378	1,580	60 *U*						
180	A		1,360	7,380	65	977	5,238	50 *U*	936	4,210	26.5
180	B		551	2,990	60 *U*						
180	C		407	1,700	60 *U*						
181	A		900	5,270	60 *U*						
181	B		520	3,020	60 *U*						
181	C		424	1,820	60 *U*						
182	A		754	3,160	60 *U*				189	709	5.1
182	B		594	2,951	60 *U*	257	1,080	50 *U*			
182	C		640	3,107	60 *U*						
183	A		535	2,600	60 *U*						
183	B		880	3,020	60 *U*						
183	C		394	1,810	60 *U*						
184	A		720	3,964	60 *U*						
184	B		480	2,435	60 *U*						
184	C		655	2,663	60 *U*						
185	A		505	2,531	60 *U*	741	3,347	50 *U*			
185	B		475	2,400	60 *U*	768	3,869	50 *U*			
185	C		540	3,059	60 *U*	1,650	6,970	50 *U*	1,190	4,460	26
186	A		632	1,780	60 *U*						
186	B		482	2,220	60 *U*						
186	C		443	2,339	60 *U*						
187	A		497	2,327	60 *U*						
187	B		792	3,050	60 *U*	706	3,210	50 *U*	638	2,720	17.1
187	C		491	2,500	60 *U*						
188	A		383	1,700	60 *U*						
188	B		520	2,231	60 *U*						
188	C		246	1,240	60 *U*						
189	A		445	1,510	60 *U*						
189	B		463	1,460	60 *U*						
189	C		354	1,760	60 *U*						
189-4	A		239	1,290	55 *U*				1,010	4,290	24.1
189-4	B		244	1,760	55 *U*						
189-4	C		1,800	7,312	55 *U*	795	4,000	50 *U*			
189-5	A		360	1,620	55 *U*						
189-5	B		304	1,810	55 *U*						
189-5	C		607	2,860	55 *U*						
189-6	A		403	2,253	55 *U*						
189-6	B		306	1,680	55 *U*				323	1,600	8.80
189-6	C		402	2,330	55 *U*						

Table A-1. (cont.)

			In situ XRF Measurement[a]			*Ex situ* XRF Measurement[a]			Lab Measurement[b]		
Station	Transect Point	Field Replicate	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
189-7	A		298	1,520	55 *U*	275	1,200	50 *U*			
189-7	B		329	1,640	55 *U*						
189-7	C		300	1,760	55 *U*						
190	A		209	946	60 *U*						
190	B		254	1,510	60 *U*						
190	C		379	1,570	60 *U*						
191	A		178	880	60 *U*						
191	B		235	1,180	60 *U*						
191	C		268	1,120	60 *U*						
192	A		160	737	60 *U*						
192	B		260	1,660	60 *U*						
192	C		239	1,210	60 *U*						
193	A		199	880	60 *U*						
193	B		224	1,090	60 *U*						
193	C		215	1,170	60 *U*						
194	A		174	869	60 *U*						
194	B		350	890	60 *U*						
194	C		310	1,460	60 *U*	133	561	50 *U*	126	438	3.2
195	A		235	824	60 *U*						
195	B		110	461	60 *U*						
195	C		217	858	60 *U*						
196	A		198	845	60 *U*						
196	B		380	980	60 *U*						
196	C		266	1,110	60 *U*						
197	A		110	616	60 *U*						
197	B		197	815	60 *U*	81	261	50 *U*	54.6	176	1.5
197	C		190	674	60 *U*						
198	A		100	410	60 *U*						
198	B		160	539	60 *U*						
198	C		182	636	60 *U*						
199	A		170	841	60 *U*						
199	B		181	902	60 *U*						
199	C		220	1,340	60 *U*						
200	A		196	1,070	60 *U*	16,096	74,778	252	12,300	43,600	229
200	B		340	1,220	60 *U*	123	318	50 *U*			
200	C		307	1,130	60 *U*	168	448	50 *U*			
200-1	A		239	950	60 *U*						
200-1	B		234	887	60 *U*						
200-1	C		196	880	60 *U*						

Table A-1. (cont.)

			In situ XRF Measurement[a]			*Ex situ* XRF Measurement[a]			Lab Measurement[b]		
Station	Transect Point	Field Replicate	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
200-2	A		352	1,210	60 *U*						
200-2	B		244	1,010	60 *U*						
200-2	C		230	980	60 *U*						
200-3	A		226	1,130	60 *U*						
200-3	B		180	916	60 *U*						
200-3	C		222	970	60 *U*						
200-4	A		197	1,070	60 *U*						
200-4	B		323	1,250	60 *U*						
200-4	C		251	1,070	60 *U*						
200-5	A		383	973	60 *U*						
200-5	B		218	874	60 *U*						
200-5	C		259	941	60 *U*						
200-6	A		188	952	60 *U*						
200-6	B		275	1,190	60 *U*						
200-6	C		188	821	60 *U*						
201	A		169	2,360	60 *U*						
201	B		306	1,270	60 *U*	105	477	50 *U*	87.5	324	1.8
201	C		196	1,040	60 *U*						
202	A		221	814	60 *U*						
202	B		223	934	60 *U*						
202	C		295	1,050	60 *U*						
203	A		199	966	60 *U*						
203	B		242	1,390	60 *U*						
203	C		250	1,010	60 *U*	146	538	50 *U*	106	454	2.7
204	A		257	1,100	60 *U*						
204	B		353	1,150	60 *U*	147	571	50 *U*	142	570	3.7
204	C		338	1,170	60 *U*						
205	A		320	1,240	60 *U*						
205	B		328	1,200	60 *U*						
205	C		283	1,960	60 *U*						
206	A		154	3,840	60 *U*						
206	B	1	84	5,000	60 *U*	296	1,240	50 *U*	225	1,020	5.8
206	B	2							236	983	5.5
206	C		320	1,120	60 *U*						
207	A		127	2,771	60 *U*						
207	B		232	914	60 *U*						
207	C		212	896	60 *U*						
208	A		185	1,050	60 *U*						
208	B		206	806	60 *U*						
208	C		247	1,030	60 *U*	661	3,099	50 *U*	579	2,670	11.8

Table A-1. (cont.)

Station	Transect Point	Field Replicate	*In situ* XRF Measurement[a] Lead (mg/kg)	*In situ* XRF Measurement[a] Zinc (mg/kg)	*In situ* XRF Measurement[a] Cadmium (mg/kg)	*Ex situ* XRF Measurement[a] Lead (mg/kg)	*Ex situ* XRF Measurement[a] Zinc (mg/kg)	*Ex situ* XRF Measurement[a] Cadmium (mg/kg)	Lab Measurement[b] Lead (mg/kg)	Lab Measurement[b] Zinc (mg/kg)	Lab Measurement[b] Cadmium (mg/kg)
208-1	A		126	600	55 *U*						
208-1	B		150	830	55 *U*						
208-1	C		222	1,060	55 *U*						
208-2	A		117	530	55 *U*						
208-2	B		136	771	55 *U*						
208-2	C		49.6 *U*	4,430	55 *U*						
208-3	A		100	1,360	55 *U*						
208-3	B		55	770	55 *U*						
208-3	C		193	938	55 *U*						
208-4	A		110	598	55 *U*						
208-4	B		41	1,200	55 *U*						
208-4	C		170	750	55 *U*						
208-5	A		140	561	55 *U*						
208-5	B		146	738	55 *U*						
208-5	C		140	755	55 *U*						
208-6	A		139	1,490	55 *U*						
208-6	B		120	617	55 *U*						
208-6	C		190	760	55 *U*						
209	A		140	676	60 *U*						
209	B		224	1,020	60 *U*						
209	C		257	1,300	60 *U*						
210	A		126	529	60 *U*	108	404	50 *U*			
210	B		203	820	60 *U*	187	796	50 *U*			
210	C		342	1,110	60 *U*	307	1,030	50 *U*	317	1,100	6.1
211	A		137	773	60 *U*						
211	B		203	822	60 *U*						
211	C		284	2,500	60 *U*						
212	A		110	1,850	60 *U*	181	727	50 *U*	185	632	3.8
212	B		265	830	60 *U*						
212	C		218	830	60 *U*						
213	A		97	626	60 *U*						
213	B		173	790	60 *U*						
213	C		217	884	60 *U*						
214	A		126	545	60 *U*						
214	B		205	893	60 *U*						
214	C		217	983	60 *U*						
215	A		232	820	60 *U*						
215	B		97	3,170	60 *U*	221	934	50 *U*	255	1,020	5.3
215	C		247	913	60 *U*						

Table A-1. (cont.)

Station	Transect Point	Field Replicate	In situ XRF Measurement[a] Lead (mg/kg)	In situ Zinc (mg/kg)	In situ Cadmium (mg/kg)	Ex situ XRF Measurement[a] Lead (mg/kg)	Ex situ Zinc (mg/kg)	Ex situ Cadmium (mg/kg)	Lab Measurement[b] Lead (mg/kg)	Lab Zinc (mg/kg)	Lab Cadmium (mg/kg)
216	A		283	923	60 *U*	322	1,770	50 *U*			
216	B		227	934	60 *U*						
216	C		229	839	60 *U*						
217	A		263	882	60 *U*						
217	B		299	938	60 *U*						
217	C		260	989	60 *U*						
218	A		170	797	60 *U*						
218	B		230	1,020	60 *U*						
218	C		179	1,640	60 *U*						
219	A		100	668	60 *U*						
219	B		170	748	60 *U*						
219	C	1	96	2,519	60 *U*	136	497	50 *U*	111	453	2.4
219	C	2							96	400	2
220	A	1	182	830	60 *U*	115	370	50 *U*	83.8	316	1.7
220	A	2							61.2	210	1
220	B		176	1,010	60 *U*	143	590	50 *U*			
220	C		152	880	60 *U*	125	496	50 *U*			
221	A		122	575	60 *U*						
221	B		182	904	60 *U*						
221	C		126	914	60 *U*						
222	A		124	463	60 *U*						
222	B		145	682	60 *U*						
222	C		130	661	60 *U*						
223	A		160	715	60 *U*	57	141	50 *U*	47.4	138	1 *U*
223	B		166	670	60 *U*						
223	C		174	740	60 *U*						
224	A		81	540	55 *U*						
224	B		51	323	55 *U*						
224	C		111	583	55 *U*						
225	A		90	460	55 *U*						
225	B		111	482	55 *U*						
225	C		96	624	55 *U*						

Note: *In situ* XRF - x-ray fluorescence field measurement on the road surface
Ex situ XRF - x-ray fluorescence field measurement on a sample of material collected from the road surface

[a] Measurements by EPA Method 6200.

[b] Measurements by EPA Method 6010B.

Table A-2. Sample station locations

Station ID	Latitude	Longitude	State Plane Coordinates X	Y
101	67.586339	-164.036112	415704.753608	4970902.239538
102	67.586538	-164.036622	415635.957906	4970977.358297
103	67.586726	-164.037110	415570.101952	4971048.353688
104	67.586935	-164.037791	415477.560526	4971127.915835
105	67.587090	-164.038215	415420.243111	4971186.549704
106	67.587149	-164.038853	415331.901042	4971211.057611
107	67.587423	-164.039422	415255.778919	4971313.879628
108	67.587637	-164.039744	415213.411594	4971393.623826
109	67.587895	-164.040023	415177.576743	4971489.262370
110	67.588206	-164.040033	415179.926413	4971603.047894
111	67.588431	-164.039969	415191.568754	4971685.041215
112	67.588555	-164.039840	415211.066790	4971729.797897
113	67.588936	-164.039389	415278.600572	4971867.065646
114	67.589188	-164.038853	415356.442870	4971956.765299
115	67.589209	-164.038140	415456.207434	4971961.171004
116	67.589274	-164.037437	415555.105404	4971981.715552
117	67.589268	-164.036713	415656.080094	4971976.198561
118	67.589215	-164.036021	415752.023784	4971953.640561
119	67.589102	-164.035398	415837.616776	4971909.456653
120	67.588936	-164.034819	415916.432916	4971846.091987
121	67.588769	-164.034240	415995.238205	4971782.362324
122	67.588608	-164.033671	416072.720976	4971720.873542
123	67.588426	-164.033092	416151.348529	4971651.659469
124	67.588254	-164.032539	416226.468421	4971586.222411
125	67.588099	-164.032008	416298.722740	4971527.104027
126	67.587938	-164.031429	416377.605726	4971465.572223
127	67.587766	-164.030850	416456.357958	4971400.018187
128	67.587605	-164.030281	416533.847453	4971338.533578
129	67.587433	-164.029723	416609.670880	4971273.077012
130	67.587273	-164.029117	416692.339037	4971211.790359
131	67.587117	-164.028548	416769.891778	4971152.136504
132	67.586951	-164.027980	416847.186288	4971088.830680
133	67.586795	-164.027395	416926.974524	4971029.105140
134	67.586639	-164.026816	417005.926359	4970969.407743
134X	67.586564	-164.027001	416979.219612	4970942.656570
135	67.585899	-164.034487	415926.294529	4970733.869586
136	67.585663	-164.034047	415984.879248	4970645.542224
137	67.585529	-164.033398	416073.863982	4970593.561405
138	67.585470	-164.032690	416171.985586	4970568.740517
139	67.585433	-164.031837	416290.612226	4970551.302805
140	67.585422	-164.031193	416380.376585	4970544.332006
141	67.585384	-164.030437	416485.451578	4970526.975194
142	67.585411	-164.029675	416592.143307	4970533.364257
145	67.578931	-164.049331	413769.968285	4968253.823633
146	67.579071	-164.048725	413856.275824	4968302.226024
147	67.579210	-164.048102	413944.943941	4968350.185082
148	67.579355	-164.047502	414030.472197	4968400.445497
149	67.579495	-164.046901	414116.078659	4968448.873536
150	67.579640	-164.046295	414202.442668	4968499.107963

Table A-2. (cont.)

Station ID	Latitude	Longitude	State Plane Coordinates X	Y
151	67.579768	-164.045672	414290.973966	4968543.047618
152	67.579897	-164.045039	414380.912644	4968587.307808
153	67.580036	-164.044422	414468.737122	4968635.299856
154	67.580176	-164.043795	414557.968885	4968683.612452
155	67.580331	-164.043210	414641.516518	4968737.605172
156	67.580514	-164.042668	414719.397113	4968802.036831
157	67.580702	-164.042159	414792.729448	4968868.449662
158	67.580895	-164.041622	414870.030198	4968936.562891
159	67.581077	-164.041107	414944.125666	4969000.755059
160	67.581270	-164.040592	415018.352551	4969068.970796
161	67.581485	-164.040077	415092.843226	4969145.233044
162	67.581689	-164.039551	415168.735908	4969217.422428
163	67.581860	-164.039026	415244.090522	4969277.548242
164	67.582032	-164.038543	415313.592506	4969338.233366
165	67.582241	-164.038001	415391.775598	4969412.179800
166	67.582407	-164.037481	415466.368818	4969470.501887
167	67.582606	-164.036976	415539.263747	4969540.962300
168	67.582799	-164.036429	415617.948817	4969609.036253
169	67.582997	-164.035887	415695.994731	4969678.962465
170	67.583164	-164.035319	415777.296627	4969737.432730
171	67.583351	-164.034847	415845.435812	4969803.658379
172	67.583555	-164.034374	415913.917732	4969876.097264
173	67.583738	-164.033838	415990.941213	4969940.567778
174	67.583925	-164.033302	416068.011568	4970006.501864
175	67.584108	-164.032781	416142.938788	4970071.042446
176	67.584301	-164.032261	416217.845274	4970139.245481
177	67.584489	-164.031730	416294.226182	4970205.570186
178	67.584666	-164.031263	416361.539953	4970268.165522
179	67.584875	-164.030673	416446.406430	4970341.901713
180	67.585041	-164.030088	416530.058193	4970399.935488
181	67.585213	-164.029423	416624.948068	4970459.798584
182	67.585427	-164.028999	416686.698282	4970536.124833
183	67.585626	-164.028581	416747.430272	4970606.993086
184	67.585813	-164.028076	416820.161813	4970673.075511
185	67.585996	-164.027513	416900.940449	4970737.430682
186	67.586178	-164.026950	416981.705924	4970801.420878
187	67.586366	-164.026440	417055.143968	4970867.848152
188	67.586543	-164.025893	417133.613958	4970930.084188
189	67.586757	-164.025319	417216.293953	4971005.729523
190	67.587669	-164.022701	417592.612513	4971327.331760
191	67.588613	-164.020067	417971.518148	4971660.580628
192	67.589568	-164.017519	418338.523182	4971998.259817
193	67.590507	-164.014933	418710.612973	4972329.930334
194	67.591413	-164.012353	419081.445199	4972649.574946
195	67.592390	-164.009762	419454.627769	4972995.152152
196	67.593334	-164.007197	419823.761727	4973328.793868
197	67.594283	-164.004569	420201.717756	4973663.995381
198	67.595211	-164.001983	420573.536187	4973991.722369
199	67.596161	-163.999365	420950.051381	4974327.367144

Table A-2. (cont.)

Station ID	Latitude	Longitude	State Plane Coordinates X	Y
200	67.597088	-163.996828	421314.965141	4974654.980685
200-1	67.596600	-163.998094	421132.571480	4974482.200391
200-2	67.596799	-163.997584	421206.076912	4974552.685625
200-3	67.596981	-163.997123	421272.544035	4974617.174484
200-4	67.597164	-163.996602	421347.393370	4974681.759762
200-5	67.597351	-163.996071	421423.683959	4974747.763644
200-6	67.597555	-163.995524	421502.406016	4974819.913685
201	67.598022	-163.994220	421689.839822	4974984.850715
202	67.598944	-163.991452	422086.867227	4975309.630475
203	67.599583	-163.988260	422539.694362	4975529.027782
204	67.599883	-163.984709	423038.608440	4975622.861026
205	67.599862	-163.981158	423533.756080	4975599.323062
206	67.599491	-163.977698	424012.123402	4975448.212411
207	67.598944	-163.974426	424462.226541	4975233.595257
208	67.598402	-163.971148	424913.246767	4975020.803696
208-1	67.598666	-163.972818	424683.393735	4975124.851385
208-2	67.598561	-163.972150	424775.324416	4975083.482579
208-3	67.598456	-163.971499	424864.956830	4975042.113772
208-4	67.598336	-163.970813	424959.185778	4974994.999298
208-5	67.598230	-163.970146	425051.116460	4974953.630492
208-6	67.598125	-163.969494	425140.748874	4974912.261685
209	67.597876	-163.967855	425366.567337	4974813.821054
210	67.597597	-163.964368	425849.841245	4974696.340361
211	67.597662	-163.960811	426346.876335	4974704.390442
212	67.598059	-163.957453	426819.981259	4974834.770553
213	67.598740	-163.954412	427252.120812	4975070.440720
214	67.599695	-163.951901	427613.452316	4975408.673645
215	67.600784	-163.949717	427930.680123	4975797.365937
216	67.601867	-163.947561	428243.905281	4976183.998127
217	67.602956	-163.945442	428552.010945	4976572.998064
218	67.604045	-163.943264	428868.319392	4976961.750701
219	67.605145	-163.941113	429180.960329	4977354.655924
220	67.606271	-163.938961	429494.010822	4977757.077183
221	67.607355	-163.936987	429781.727717	4978144.924853
222	67.608476	-163.934820	430096.758213	4978545.473607
223	67.609570	-163.932685	430406.989781	4978936.297985
7-24	67.585311	-164.029770	416577.705943	4970497.334680

Note: All coordinates are in the NAD27 datum.
Latitude and longitude are in decimal degrees.
State plane coordinates are in Alaska Zone VII.

Appendix B

Changes and Additions to the Sampling Plan

Changes and Additions to the Sampling Plan

The procedures and methods for the additional characterization sampling for the road surface and for the post-removal verification sampling were described in the *Supplemental Road Surface Sampling and Analysis Plan* (Exponent 2002a) and in the *Concentrate Recovery and Recycling Plan* (Exponent 2002b), respectively. Changes or modifications to the procedures in these sampling and analysis plans (SAPs) are outlined below.

Sample Collection

- The number of stations that were sampled changed from the original number planned in the SAP: 143 stations (instead of 107) were analyzed by *in situ* x-ray fluorescence (XRF) and of these, 7 stations were chosen for field duplicate sample collection (instead of 8). Fourteen stations were chosen for soil core collection (instead of 8).
- Exact coordinates of sampling locations differed slightly from the planned coordinates identified in the SAP (Exponent 2002a). For example, samples at stations that were not safe for field personnel or samples that were inaccessible were either shifted to another location or an alternate location was chosen.
- At various times throughout the sampling effort, the XRF instrument was modified or repaired for different reasons. For example, the transparent film covering the XRF window was replaced with transparency film for laser printers as an emergency solution until a replacement could be delivered to the field team. Other changes to the XRF instrument included the use of a makeshift bracket to activate the shutter trigger when taking *in situ* measurements, and the enclosure of the instrument in a transparent plastic bag for protection from the elements (e.g., moisture, dust). Based on data from tests with the modified XRF instrument, using standards of known concentrations, corrections were made to the XRF data accordingly.
- Additional samples were collected at each station that were not required according to the SAP. These road shoulder samples were taken approximately 1 ft above the tundra and the same procedures for measuring metals concentrations with the XRF instrument and in the laboratory were employed.
- *In situ* XRF reading procedures were modified in the field. As described in the SAP, three measurements at each sampling point were to be taken, and the mean XRF concentration was to be reported. However, the actual procedure used in the field was as follows. If the sampler took a first reading and it was below 50 percent of the any of the Method 2 “under 40-inch zone” criteria (i.e., 50 percent would be 500 mg/kg for lead, 15,000 mg/kg for zinc, or 50 mg/kg for cadmium), then it was recorded as the reading. If the reading exceeded 50 percent of the cleanup criteria, a second reading was taken. If the average of the two readings was below 75 percent of the cleanup criteria (e.g., 750 mg/kg for lead, 22,500 mg/kg for zinc, or 75 mg/kg or cadmium), this average was recorded as the reading. If it was not, then a third reading was taken, and the three readings were averaged and

recorded. Then, as described in the SAP, a soil sample was collected, an *ex situ* XRF measurement taken, and these were subsequently submitted to the laboratory. Note that the reason for using this modified approach was to reduce the field effort, while maintaining the increased precision of the averaged measurement if the concentration at that sample point location was elevated.

- Changes in procedure were made for the collection of soil cores. The SAP describes the soil core to be collected with a split-spoon sampler driven by a hand-operated power hammer to a depth of 12 in. In the field, personnel used a small pick and shovel as an alternative to the corer. Samplers carefully dug down 4 in. into the road material and placed the sample in a bowl. The same procedures were performed for the next two samples at 4-in. intervals. Then, as described in the SAP, the samples were homogenized and submitted to an analytical laboratory.

- The SAP describes the *ex situ* samples to be taken at the location where the *in situ* sample was taken. However, road traffic and road surface conditions made it difficult for the field crew to ensure that both sample types were at the same location. Distance between the two sample locations ranged up to 5 ft.

- In the field, *ex situ* samples were not analyzed by the XRF instrument immediately after collection, as it was described in the SAP. To facilitate a more efficient operation, the *ex situ* sample was transferred from the mixing bowl to a plastic Ziploc® bag for temporary storage until an *ex situ* XRF measurement could be made. To make a measurement, soil was taken from the bag and placed in the sample cup according to the procedures described in EPA Method 6200. Once a reading was taken, the soil was placed back into the bag. The bag was then shaken to remix the sample, and a representative subsample was collected from the bag, transferred to a sample jar, and submitted for laboratory analysis. The Ziploc® bag provided extra protection from potential dust exposure. Rinsate samples from the Ziploc® bags were also collected.

Reference

Exponent. 2002a. Sampling and analysis plan, DeLong Mountain Regional Transportation System, Alaska. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2002b. Concentrate recovery and recycling plan, DeLong Mountain Regional Transportation System, Alaska. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Appendix C

Quality Assurance Review

Quality Assurance Review

Introduction

A quality assurance review was completed by Exponent for total solids and metals analyses in soil samples collected during the Supplemental Road and Surface Material Removal Verification Study at the Red Dog Mine. Samples were collected from May 25 to July 25, 2002. A modified U.S. Environmental Protection Agency (EPA) Level 3 data validation was completed.

Analyses of metals and total solids in soil were performed by Columbia Analytical Services, Inc., Kelso, Washington.

Completeness

Results reported by the laboratory were 100-percent complete, with 12 exceptions: Requested analyses on 12 samples could not be completed because the sample containers were received broken at the laboratory. The affected samples were: RS-310B-VS, RS-118C-VS, RS-119C-VS, RS-120A-VS, RS-120B-VS, RS-110C-VS, RS-111A-VS, RS-111B-VS, RS-111C-VS, RS-114A-VS, RS-110A-VS, and RS-110B-VS.

Holding Times and Sample Preservation

Holding time constraints were met for all samples.

Instrument Performance

The performance of the analytical instruments, as documented by the laboratory, was acceptable.

Initial and Continuing Calibration

Initial and continuing calibrations, as documented by the laboratory, were completed for all applicable target analytes and met the laboratory criteria for acceptable performance and frequency of analysis.

Initial and Continuing Calibration Blanks

The initial and continuing calibration blank analyses, as documented by the laboratory, met the laboratory criteria for acceptable performance.

Laboratory Blank Analyses

No analytes were detected in the laboratory blanks.

Instrument-Specific Quality Control Procedures

The results of the instrument-specific quality control procedures for metals analyses (interference check sample [ICS] and inductively coupled plasma [ICP] serial dilution) met applicable control limits for acceptable performance and frequency of analysis requirements, with one exception: The percent difference of zinc in SDG K2204718 was above the control limit. Associated sample results were qualified as estimated (assigned a *J* qualifier).

Accuracy

The accuracy of the analytical results is evaluated in the following sections in terms of analytical bias (matrix spike and laboratory control sample [LCS] recoveries) and precision (duplicate sample analyses).

Matrix Spike Recoveries

The recoveries reported by the laboratory for matrix spike analyses, and the frequency of analysis, met the laboratory's criteria for acceptable performance, with the following exceptions:

- The recovery of cadmium in sample delivery group (SDG) K2203716 was not within the applicable control limits. All associated cadmium results were qualified as estimated (assigned a *J* qualifier).
- The recovery of lead in SDG K2204716 was not within the applicable control limits. All associated lead results were qualified as estimated (assigned a *J* qualifier).
- The recovery of lead in SDG K2205084 was not within the applicable control limits. All associated lead results were qualified as estimated (assigned a *J* qualifier).
- The recovery of lead in SDG K2204713 was not within the applicable control limits. All associated lead results were qualified as estimated (assigned a *J* qualifier).
- The recoveries of lead and zinc in SDG K2204718 were not within the applicable control limits. All associated lead and zinc results were qualified as estimated (assigned a *J* qualifier).

Laboratory Control Sample Recoveries

The recoveries reported by the laboratory for all LCS recoveries, and the frequency of analysis, met the laboratory's criteria for acceptable performance.

Precision

Results for all duplicate sample analyses, and the frequency of analysis, met the laboratory's criteria for acceptable performance, with the following exceptions:

- The duplicate relative percent difference (RPD) for zinc in SDG K2203859 exceeded the control limit. All associated zinc results were qualified as estimated (assigned a *J* qualifier).
- The duplicate RPD for cadmium and zinc in SDG K2203716 exceeded the control limit. All associated cadmium and lead results were qualified as estimated (assigned a *J* qualifier).
- The duplicate RPD for lead in SDG K2204713 exceeded the control limit. All associated lead results were qualified as estimated (assigned a *J* qualifier).
- The duplicate RPD for lead and zinc in SDG K2204718 exceeded the control limit. All associated lead and zinc results were qualified as estimated (assigned a *J* qualifier).
- The duplicate RPD for zinc in SDG K2205077 exceeded the control limit. All associated zinc results were qualified as estimated (assigned a *J* qualifier).
- The duplicate RPD for lead in SDG K2205076 exceeded the control limit. All associated lead results were qualified as estimated (assigned a *J* qualifier).

Field Quality Control Samples

Field quality control samples consisted of field duplicate samples, filter blank samples, and equipment rinsate blanks.

The precision of all target analytes detected in the field duplicates was acceptable. Metals were reported as detected in the filter and equipment rinsate blanks. No action was required because the concentrations of the metals detected in the natural samples were above the action limits.