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Proposed Approach to Evaluating Consumption of Wild Foods at the Red Devil Mine Site, Alaska, Version 2, and Response to Comments

Integrated Alaska Department of Environmental Conservation and U.S. EPA Region 10 Risk Assessor Comments on Proposed Approach to Evaluating Consumption of Wild Foods at the Red Devil Mine Site, AK, V2

Commenter: (ADEC) **Comments Developed: January 17, 2013**

Cmt. No.	Pg. & Line		Comment/Recommendation	Response
1.	1		Title should more broadly reflect that this document is evaluating exposure assumptions for the RDM HHRA	The approach presented in this technical memorandum is incorporated into the human health risk assessment (HHRA), Section 6.2 of the RI; therefore the memo will not need to be finalized. The draft memo and final response to comments will be included as an appendix to the HHRA.
2.	2		What about dermal exposure? Presumably skin surface area would vary as a function of climate.	Dermal exposure is addressed in the HHRA.
3.	2		Available Harvest and Consumption Data, Prior to 2012: The data analysis techniques of Wolfe and Utermohle should be applicable to any data set if relevant information is collected. It is unclear why data from 1983 or earlier would not be applicable if all relevant information was contained in the data set.	Since the ADF&G 2012 report is now available, data from previous surveys were not used in the risk assessment.
4.	3		The memo notes that Ballew et al. 2004, provided median and maximum consumption rates and implied that gram per day values would be provided for both median and maximum consumption rates, however, Table 1 only includes median consumption rates. Maximum consumption rates from Ballew et al. 2004 should be included as well.	Since the ADF&G 2012 report is now available, less emphasis is placed on the previous studies. See text in Section 6.2.3.5 of the RI.
5.	4		Clarify that the IDM values in Table 1 of the tech memo came from best fit distributions to regional harvest data as tabulated in Table 13 of the IDM 1997 report.	Since the ADF&G 2012 report is now available, less emphasis is placed on the previous studies. See text in Section 6.2.3.5 of the RI.
6.	4		Table 2. If the Wolfe and Walker fish consumption rate is a median value, then it should clearly be represented as such in Table 2 and not represented as a mean with a footnote identifying it as a median value. Fish consumption distributions are right skewed and means are always greater than medians.	Since the ADF&G 2012 report is now available, less emphasis is placed on the previous studies. See text in Section 6.2.3.5 of the RI.

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7.	6		The paragraph should reflect the 95th percentile values that are now available for use.	95th percentile values were used in the HHRA, except for large land mammal. Once these values are received from EPA, they will be incorporated.
8.	6		Harvest rates of all eight villages surveyed should be compared. Presumably ADFG computed 95th percentile harvest statistics for all eight villages, why aren't these values used in the comparisons?	See response to EPA comment #8.
9.	9		Discuss information indicating that no other types of berries were available on the site.	Berry data collection was attempted in 2011, but there were not sufficient samples for use in the HHRA. Additional sampling will be attempted again in 2012. Information on current berry sampling attempts is discussed in Section 6.2.3.7 of the RI.
10.	10		What other FIs will be presented in the RA as part of the sensitivity analysis & what is their basis?	Information is provided in Section 6.2.3.5 of the RI.
11.	11		Should include some discussion of what to do if a valid UCL cannot be calculated for an EPC.	Valid EPCs were calculated for all media in the RA.
12.	12		EPA has commented that use of a food chain multiplier is all that can be done given the current state of data analysis. While EPA has agreed to this approach for the draft risk assessment, EPA believes that it may be appropriate to collect further data to better characterize human health risks from fish consumption. EPA and ADEC have also noted that the data analysis of mercury levels in fish in the Kuskokwim is not sufficient to describe RDM impacts on fish tissue Hg concentrations in the Kuskokwim.	Mercury levels are further discussed in *Mercury in Aquatic Biota from the Middle Kuskokwim River Region, Alaska, 2010-2011*(Draft). Information from this report will be incorporated into the risk assessment, as appropriate.

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13.	12	& Table 6	The data from (from 3 composite fish) Sculpin for Methylmercury is limited for the Risk Assessment. Gray et al. 2000 data from fish samples showed that 90% of total mercury detected comprised of methlymuercury in fish sample from the Red Devil mining site. Other studies in fish have concurred that the majority of total mercury detected in fish is methylmercury in some cases 100%. However, when referring to Table 6 of the single Sculpin sample from August 2010, the methylmercury to total mercury is 0.16 to 3.7 or only 4%. Based upon the available literature, our data may grossly underestimate the methylmercury concentration in the fish. There is a great deal of uncertainty associated with the limited data we are using and we should acknowledge this uncertainty by collection of additional data to validate our assumptions or otherwise assume 100% methylmercury as a conservative estimate in addition to the site specific data proposed for use.	For the HHRA, 100% of the total mercury concentration was assumed to be in the methylated form. The methyl mercury result was not used in the HHRA due to low sample number.
14.	15		Please specify why only green alder bark sample results are going to be used for moose COPC calcs, green alder bark for beaver, and spruce needles for spruce grouse? Are these plants the primary diet of the assessment species or are we limiting ourselves to the vegetation data available at hand?	Additional information will be provided in Section 6.2.3.7 of the HHRA regarding use of vegetation to estimate concentrations in moose, beaver, and spruce grouse. Use the data is based on a combination of primary food sources and available data.
15.	16		There is a great deal of uncertainty associated with extrapolating contaminated soil data from two studies into blueberry concentrations. An attempt should be made to collect more blueberry data. Is the soil in table 9 representative of the area where the plant parts were collected in the study? If so, then why aren't they being used? How exactly is the comparison going to be made? Please provide details and what will be done if values are considered inappropriate? Are there transfer coefficients provided for steam and leave in the Baes et al (1984) for evaluation of the data in table 9. The specific numbers that are going to be used should be provided in a table format.	Berry data collection was attempted in 2011; there were not sufficient samples for use in the HHRA. Additional sampling will be attempted again in 2012. Without berry data, modeled data was used. Transfer coefficients will be added to Draft Final HHRA. As directed by DEC and EPA, blueberry data from Bailey et al. 2002 or Bailey and Gray 1997 are not used quantitatively the risk assessment.

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16.		Table 7 & 8	The notes are confusing "1- included 8 samples plus one field duplicate"? Field duplicates should not be included in calculating the EPC twice. Please specify that the most conservative of the primary and duplicate sample results will be used for statistical analysis. What EPC is going to be used for the ND in methylmercury? A foot note for J should be included.	These tables have been updated and the data presented in Table 6-41 of the risk assessment.
17.		Table 10	Table should not present average metals concentrations as averages will not be used as exposure point concentrations.	This table was included in the HHRA as Table 6-7. Ranges, including maximums, are provided in Table 6-7. Discussion of the maximum concentrations and, possibly, the 95% UCL will be added to this section.
18.	General	Tables	The 95th percentile UCL should be calculated for the tables that contain the data. In addition, for situations where a valid UCL cannot be calculated for the data set, an explanation of what will be used as the EPC should be included.	This data was not available at time of the development of the memo but was incorporated into the Draft HHRA.
19.	20		Duplicates are for quality assurance and should only be included in the data set once. Please specify that only one result of the primary and duplicate will be used for statistical analysis.	Field duplicates were not used as independent samples in the 95% calculations. Consistent with ADEC requirements (ADEC 2008), the highest concentrations between duplicate and original samples were used in the risk assessment.
20.	20		EPA is still unclear as to the correct approach for characterizing exposure units. Maps of contaminant concentration values with color coding to allow for visualization of concentration gradients should be provided. There are vast differences in the range of concentrations observed for the various contaminants present at the mine.	This issue was further discussed in the HHRA.

Proposed Approach to Evaluating Consumption of Wild Foods at the Red Devil Mine Site, Alaska, Version 2

Prepared by Ecology and Environment, Inc. for the Bureau of Land Management

March 5, 2012

Ecology and Environment, Inc. (E & E) has prepared this technical memorandum at the request of the Bureau of Land Management (BLM), Alaska State Office, Anchorage, Alaska to address comments provided by the U.S. Environmental Protection Agency (USEPA) and Alaska Department of Environmental Conservation (ADEC) on the Risk Assessment Work Plan (RAWP) for the Red Devil Mine Site, Alaska (E & E 2011). Specifically, this memorandum outlines an approach for evaluating the consumption of wild food from the site. This approach will be used in the human health risk assessment that will be included in the final Remedial Investigation (RI) report.

Per the RAWP, the following issues are addressed in this memorandum:

1) Exposure parameters for harvesting and consuming wild foods;
2) Estimating exposure point concentrations in wild foods;
3) Exposure Units

The first version of this memorandum was issued January 13, 2012, prior to release of the Alaska Department of Fish and Game (ADF&G) report, "Subsistence Harvests in 8 Communities in the Central Kuskokwim Drainage, 2009" (Brown et al. 2012). After release of the ADF&G report, representatives from E & E met with representatives from USEPA, ADEC, BLM, Alaska Department of Health and Social Services (DHSS), and the Agency for Toxic Substances and Disease Registry (ATSDR) on February 14th and February 23rd to discuss incorporation of the results from the ADF&G report into the human health risk assessment (HHRA), as well as address comments from USEPA and ADEC issued to BLM on January 31st. This revision incorporates data from the ADF&G report, as discussed in those meetings.

Exposure Parameters for Harvesting and Consuming Wild Foods

Plants harvested within the assessment area may take up contaminants of potential concern (COPCs) from soil into their leaves and roots. In addition, wildlife may take up COPCs through ingestion of soil and consumption of local vegetation and animals. People who consume local vegetation and wildlife, therefore, may indirectly take up COPCs from the RDM site. Human intake of COPCs through food ingestion is determined by the types of food ingested, the amount of each type of food ingested per day, the concentration of COPCs in the food, and the percentage of the diet constituting food within the assessment area.

Consistent with the RAWP, values for the following exposure parameters need to be determined to address recreation and subsistence use of the site and ingestion of wild and subsistence foods in the HHRA:

1) For the Recreational/Subsistence User (adult/child)
    a) Ingestion rate of subsistence food (IRsub)
    b) Exposure duration for ingesting subsistence foods (EDsub)
    c) Fractional intake for subsistence foods from the contaminated area (FI)
    d) Exposure frequency to soil during recreational/subsistence activities (EFsoil)
    e) Exposure frequency to surface water during recreational/subsistence activities (EFsw)
2) For the Resident (adult/child)
    a) Ingestion rate of subsistence food (IRsub)
    b) Exposure duration for ingesting subsistence foods (EDsub)
    c) Fractional intake for subsistence foods from the contaminated area (FI)
3) For the Mine Worker (adult)
    a) Ingestion rate of subsistence food (IRsub)
    b) Exposure duration for ingesting subsistence foods (EDsub)
    c) Fraction intake for subsistence foods from the contaminated area (FI)

It was agreed upon in the RAWP that these parameters would be developed in consultation with the ADEC and USEPA and presented in a technical memorandum prior to development of the HHRA. The conceptual framework for developing values for these parameters was presented to USEPA and ADEC during a teleconference held January 5, 2012. The first version of this memorandum, January 13, 2012, discussed that approach. The current revision of this report incorporates data from the 2012 ADF&G report, as discussed in meetings with USEPA and ADEC during meetings held February 14, 2012 and February 23, 2012.

Available Harvest and Consumption Data, Prior to 2012

Previously, there was limited subsistence harvest or consumption data available for the Red Devil area. Although harvest data can provide information on site use patterns, it does not often provide quantitative evaluation of consumption patterns. The following discussion presents harvest and/or consumption reports available and relevant to the site.

ADEC recommends wild food ingestion rates be obtained from ADF&G Community Profile Database (ADEC 2010), now incorporated in the Community Subsistence Information System (CSIS). Big game data from the Central Kuskokwim Big Game Survey for 2003, 2004 and 2005 are available for Red Devil in the CSIS (ADF&G 2011). The CSIS was also queried for harvest data for the neighboring communities of Sleetmute, Crooked Creek, and Stony River. Only big game data from the Central Kuskokwim Big Game Surveys of 2003, 2004 and 2005 are available for Crooked Creek and Stony River. In addition to the large game data, Sleetmute harvest data for other wild food resources is available in the CSIS but the data are from 1983, prior to use of the consumption adjustments for use in risk assessments, as described by Wolfe and Utermohle (2000).

ADF&G conducted household interviews in Red Devil in 1986 to determine resource use patterns (Brelsford et al. 1987). Although this report provides information on some harvest patterns, it does not provide sufficient detail to determine quantitative ingestion rates, and it is more than 20 years old.

The Alaska Department of Health and Social Services planned on conducting a consumption dietary survey in Red Devil and other communities near the site in the spring of 2011 as part of the Donlin Mine health impact assessment. These results were to be used to determine intake rates used in the HHRA. Unfortunately, this survey has not been conducted at the time of release of this memorandum.

Ballew et al. (2004) conducted a 12-month recall consumption survey in 13 villages throughout Alaska. The regional health corporation serving the village of Red Devil is Yukon–Kuskokwim Health Corporation (YKHC) (Alaska Community Database 2010). Four villages from the YKHC region are represented in the Ballew et al. report, although the names of the specific villages are not provided. The following subsistence foods were identified in the top 50 foods reported by the participants in the YKHC region:

- King salmon
- Moose muscle and organs
- Chum salmon
- Caribou muscle and organs
- Whitefish
- Silver salmon
- Crowberries
- Lowbush salmonberries
- Moose fat and marrow
- Pike
- Seal oil
- Herring
- Tomcod
- Caribou fat and marrow
- Blackfish
- Blueberries
- Goose

For each of the subsistence foods, information on the median and maximum amounts (in pounds per year) consumed in that region is provided. These values are presented in Table 1, as adjusted to grams per day based year round consumption (i.e., ED = 365 days per year), and broken up into major wild food source categories. The harvest rates were calculated by summing all food into the major categories of salmon, non-salmon fish, large land mammal, berries and avian.

IDM Consulting (1997) was contracted by the ADEC to evaluate existing subsistence information in an effort to define subsistence regions and develop subsistence consumption parameter distributions for use in human health risk assessment. IDM concluded in their report that although harvest data significantly overestimates consumption for some resources, in the absence of more extensive consumption data, harvest data may be reasonably used as a surrogate for preliminary estimation of consumption (IDM 1997). IDM provides harvest rate for the following major resource categories: salmon, non-salmon fish, large land mammals, marine mammals and marine invertebrates. Harvest rates are provided on per capita, 50th percentile, 90th percentile, 95th percentile and maximum levels. The 50th and 95th percentiles are provided in Table 1 for the Subarctic Interior region which includes Red Devil Village. Marine mammals and marine invertebrates harvest rates are not included in Table 1 due to the lack of these categories listed as subsistence foods from Ballew et al. (2004), the distance to a marine mammal or invertebrate harvest area to the Site, and the low harvest levels for marine mammals and invertebrates (IDM 1997).

For comparison, ingestion rates recommended by USEPA's Exposure Factors Handbook (2011) were included in Table 1. The berry values represent mean ingestion rates, body weight adjusted for adults, for the Native American consumers (Table 9-17 of USEPA 2011).

Table 1. Harvest Rates for Red Devil Village

Food Source	Ballew et al. (2004) – Median (g/day)	IDM (1997) - 50th Percentile Harvest (g/day)	IDM (1997) - 95th Percentile Harvest (g/day)	EFH (2011) (g/day)
Salmon	68	76.8	987.9	See Table 2
Non-Salmon Fish	16	27.8	149.6	See Table 2
Large Land Mammal	47	76.1	199.5	NA
Berries	21	NA	NA	18.2
Avian	5	NA	NA	NA

Notes:
EFH = Exposure Factors Handbook
NA = Not available

A number of Native American fish intake rates are summarized in the Exposure Factors Handbook (USEPA 2011). Of those studies, one conducted in Alaska (Wolfe and Walker 1987) and two conducted Washington (Toy et al. 1996, Duncan 2000) were chosen as the most representative for the Red Devil Mine site. In addition, the Toy et al. (1996) and Duncan (2000) were recommended for review by USEPA Region 10's Lon Kissinger (Kissinger 2011). These ingestion rates are provided in Table 2. For comparison the IDM fish ingestion rates are also provided in Table 2.

Table 2. Native American Fish Ingestion Rates

	Ingestion Rates (g/day) [1]				
	Wolfe and Walker (1987)	Toy et al. (1996) – Tulalip	Toy et al. (1996) – Squaxin	Duncan (2000) – Suquamish	IDM (1997) – Subarctic Interior[2]
95th Percentile					
Adult	NA	203	210	700	1137.5
Child	NA	10.5	31.5	109.5	NA
Mean					
Adult	81[3]	63	63	189	655.6
Child	NA	3	12	22.5	NA

Notes:
1 – Body weight adjusted, if needed, at 70 kg for adult and 15 kg for child
2 – Sum of salmon and non-salmon harvest rate for 50th (mean) and 95th percentile
3 - Represents median value

NA = Not available

Alaska Department of Fish and Game Harvest Report, 2012

Between January and December 2010, residents of Aniak, Chuathbaluk, Crooked Creek Lower, Kalskag, Red Devil, Sleetmute, Stony River, and Upper Kalskag were surveyed regarding the subsistence and harvest use of wild foods in those communities. The principal questions addressed were how many wild foods were harvested for subsistence, the harvest amounts, and how these foods were distributed within and between communities (Brown et al. 2012).

The survey represents a 12-month recall study, covering 2009, used to estimate subsistence harvests and uses of wild fish, game, and plant resources. Information was obtained on a household basis. The survey questions are provided in the ADF&G report. Maps of the area used for hunting, fishing and gathering during the study year were developed.

The population trend in Red Devil has decreased since the census count in the 1960's. During the study the estimated population of Red Devil was 32 residents. Eleven households in Red Devil were surveyed which included 27 residents. On average, residents lived in Red Devil approximately 23 years. The surveyed population was 44% female and 56% male. Eight-two percent were Alaska Native.

Of the households surveyed, 100% used some kind of wild food, and 82% reported that they harvested wild food. Of the top 10 resources comprising the majority of the wild foods harvested by edible weight, salmon species contributed 40%, whitefish species contributed 27%, other non-salmon species contributed 11%, black bears contributed 5% and beaver contributed 3% of the total subsistence harvest. Estimated uses and harvests wild foods are provided in Tables 7-1 through 7-6 of the ADF&G report (Brown et al. 2012). These tables provide percentage of households that use, attempt to harvest, harvest, receive, or give away each resource. Estimated pounds harvested are provided as a total for the community, mean per household, mean per capita, and total estimated amount harvest by the community.

Per ADEC (2011), high end user rates from ADF&G should be used to estimate ingestion rates for specific resources. The high end user is represented by the 95th percentile per capita use, which is the amount of wild food used by the consumer at the 95th percentile rank in a rural population during a survey year, expressed as a per person measure (g/day; Wolfe and Utermohle 2000). This is the value recommended for use in a HHRA.

The 95th percentile use is figured by:

1. Allocating household harvests of a resource category among three household
2. Groups based on reported use and sharing patterns during a survey year,
3. Summing a household's use levels across resource categories (this step is taken for higher-order resource categories only),
4. Ranking households by quantities used, and
5. Identifying the use level of the consumer at the 95th percentile rank.

ADF&G has agreed to share the harvest data for Red Devil with USEPA through a sharing agreement (Lon Kissinger, USEPA, e-mail dated 2/28/12). Through discussions with USEPA's Lon Kissinger, USEPA has agreed to calculate the summary statistics of 95th percentile use and provide those values to E & E for the following resource categories:

1. Non-salmon fish
2. Large land mammals
3. Small land mammals
4. Birds and eggs
5. Berries and plants

The 95th percentile use value will be calculated consistent with the methodology outlined in Wolfe and Utermohle (2000). If 95th percentile use values are not available in time for incorporation into the draft HHRA, recommended harvest rates based on the IDM study (1997), as described the first version of this memorandum, will be used until the 95th percentile use values can be obtained.

Potential Suppression Effect

A "suppression effect" occurs when a consumption rate for a given population reflects a current level of consumption that is artificially diminished from an appropriate baseline level of consumption for that population (National Environmental Justice Advisory Committee 2002). Although a suppression effect has primarily been studied as impacting fish harvests, this discussion has been expanded to include all wild food harvest. A suppression effect can be caused by a number of factors including when an environment has become contaminated to the point that humans refrain from harvesting from a particular area. A suppression effect may arise when wild food upon which humans rely are no longer available in historical quantities (and kinds), such that humans are unable to catch and consume as much wild food as they had or would.

Harvest data from nearby areas were reviewed to determine if a suppression effect was occurring in the Red Devil area, as compared to other nearby communities. Family relationships exist between current residents of Red Devil and Sleetmute who once lived along the Holitna River (Brown et al. 2012); therefore Sleetmute was included for comparison. Due to geographical location, Crooked Creek and Stony River were also included for comparison. Table 3 shows the harvest rates, on a mean per capita basis, for the primary harvest categories identified by Red Devil households.

For the categories of non-salmon fish and birds, Red Devil households showed the highest harvest rate, on a per capita basis, compared to Sleetmute, Stony River or Crooked Creek. Plants and berries were close to the highest rate with the highest rate at 8.7 pounds per year in Crooked Creek compared to 8 pounds per year for Red Devil. For small land mammals, the Red Devil harvest rates were low compared to Stony River but comparable to Sleetmute and Crooked Creek. For these resources, no suppression effect is evident when compared to harvest rates in neighboring communities. Therefore, the harvest rates for Red Devil for these resources are appropriate estimates of consumption for use in the HHRA.

For large land mammals, black bears contributed the largest harvest amount, followed by beavers and caribou. Reports from interviews conducted in 2010 concluded that severe declines in the availability of moose in the region have led to an increase in the harvest and use of black bears by village residents. While limited by the lack of historical data, a rise in black bear uses and harvests by Red Devil households may indicate an adaption to declines in the availability of other large game resources, such as moose and caribou. Several respondents reported during the harvest survey, that prior to the moose hunting closure in GMU 19A, moose were the primary subsistence resource for the village. While never heavily harvested by the Red Devil community, a reported decline in caribou harvests are, in part, explained by both a lack of hunting activity in traditional areas, where caribou have most often been found, and the general migration of the Mulchatna caribou herd away from the region (Brown et al. 2012).

Large game mammal harvest data is available for Red Devil from 2003, 2004, 2005 and the ADF&G 2012 report (harvest data from 2009). In 2006, following at least a decade of severe moose declines in SMU 19A, the majority of the game management unit including the Holitna and Hoholitna river drainages, was closed to moose hunting, the remainder limited to hunt opportunities requiring Tier II permits. In 2003, Red Devil residents harvest an estimated 36 pounds of moose per person. However, zero moose harvests were reported in 2004, 2005 and 2009. Similar declines were shown for caribou, with black bear harvests increasing (Brown et al. 2012). Based on this, it appears the moose harvest rates from 2003 would represent the harvest not impacted by a suppression effect. As with the 2009 data, ADF&G has agreed to share the harvest data for Red Devil from the 2003 survey with USEPA through a sharing agreement which USEPA is current working on (Lon Kissinger, USEPA, e-mail data 2/28/12). USEPA's Lon Kissinger has agreed to calculate the summary statistics of 95^{th} percentile use for these resources and provide the summary statistics to E & E.

Table 3. Comparison of Harvest Rates for Four Surveyed Communities

Category	Type	Red Devil		Sleetmute		Stony River		Crooked Creek	
		ADF&G 2012 - Mean per capita (lb/year)	ADF&G 2012 - Mean per capita (g/d)	ADF&G 2012 - Mean per capita (lb/year)	ADF&G 2012 - Mean per capita (g/d)	ADF&G 2012 - Mean per capita (lb/year)	ADF&G 2012 - Mean per capita (g/d)	ADF&G 2012 - Mean per capita (lb/year)	ADF&G 2012 - Mean per capita (g/d)
Fish	Dolly Varden	1.4	1.74	0.2	0.25	0	0.00	0.7	0.87
	Whitefish (all)	84.3	104.76	38.3	47.60	83.7	104.02	24.9	30.94
	Bourbot	0.4	0.50	0.2	0.25	0	0.00	0.7	0.87
	Grayling	7	8.70	6.3	7.83	1.4	1.74	0.9	1.12
	Northern Pike	26.7	33.18	8.1	10.07	7.1	8.82	1.2	1.49
Lg. Land Mammal	Black Bear	16.3	20.26	6	7.46	2.6	3.23	8.4	10.44
	Caribou	5	6.21	3.3	4.10	3.4	4.23	0	0.00
	Moose	0	0.00	34.6	43.00	14.2	17.65	17.1	21.25
Sm. Land Mammal	Beaver	7.8	9.69	13.3	16.53	38.7	48.09	6.3	7.83
	Other	1	1.24	1.8	2.24	0	0.00	0.5	0.62
Birds	Spruce Grouse	3.8	4.72	2	2.49	1.8	2.24	0.5	0.62
	Ruffed Grouse	1	1.24	0.4	0.50	1.2	1.49	0.2	0.25
	Migratory Birds	0.9	1.12	3.1	3.85	1.2	1.49	1	1.24
Plants	Blueberry	2.2	2.73	1.7	2.11	2	2.49	3.2	3.98
	Lowbush Cranberry	3	3.73	3.3	4.10	1.2	1.49	0.5	0.62
	Crowberry	2.2	2.73	1.3	1.62	1.8	2.24	4.2	5.22
	Greens	0.6	0.75	0.9	1.12	1.9	2.36	0.8	0.99

Notes:
Highlight = highest of per capita mean harvest values

Recommended Exposure Parameters

Based on the discussion above, harvest rates from Red Devil for 2009 (Brown et al. 2012) represent the most appropriate estimates of consumption for most resource categories and are recommended for use in the HHRA, with the exception of large land mammals. Harvest rates for large land mammals will be derived from the 2003 ADF&G survey results as to avoid inclusion of any potential suppression of harvest of these resources due to hunting restrictions or resource availability. Although harvest data significantly overestimates consumption for some resources (IDM 1997) and the data was obtained on a household, not individual, basis use of these harvest rates are the most applicable, site-specific values available and represent a health-protective approach for evaluating risk from consumption of subsistence resources. Uncertainties associated with this approach will be discussed in the Uncertainty Section of the HHRA.

Harvest rates for adults will be calculated as the sum of all the 95th percentile use rates for food within the following food categories. Because harvest rates are provided on an annual basis, the EFsub is equal to a full year, 365 days per year. Harvest rates for the resident, subsistence/recreational user, and mine worker receptors will be equal with differing FIs:

1. Non-salmon fish
2. Large land mammals
3. Small land mammals
4. Birds and eggs
5. Berries and plants

For each category, a representative species was chosen as the indicator for the category. For example, Red Devil households indicated they harvested the following berries and plants for consumption in 2009:

- Blueberry
- Lowbush cranberry
- Crowberry (blackberry)
- Wild rhubarb
- Hudson's Bay tea
- Stinkweed

The harvest rate for the Berries and Plant category will be set at the 95th percentile use rate for all six resources. The indicator species for the category was chosen as blueberries based on the high harvest rate compared to other resources, as well as the availability of contaminant level data. Table 4 shows the food source categories, proposed indicator species, study and statistic that will be used for the estimate of ingestion or consumption rate. Since the 95th percentile use value was not available at the time of preparing this memorandum, the mean per capita harvest rate is shown in this table, as well. As previously mentioned the raw data will be supplied to USEPA by ADF&G and USEPA will calculate the 95th percentile use value and provide the summary statistics to E & E for use in the HHRA.

Table 4. Wild Food Ingestion Rates

Food Source	Indicator Species	Key Study, Community	Ingestion Rate for use in HHRA	Mean Per Capita Harvest (g/day)
Non-Salmon Fish	Whitefish	ADF&G 2012 Red Devil	95th percentile use	149.0
Large Land Mammal	Moose	ADF&G 2003 Red Devil	95th percentile use	75.8
Small Land Mammals	Beaver	ADF&G 2012 Red Devil	95th percentile use	10.9
Birds	Grouse	ADF&G 2012 Red Devil	95th percentile use	6.0
Berries and Plants	Blueberry	ADF&G 2012	95th percentile use	9.9

Notes:
g/day = grams per day

The harvest data was collected on a household basis, and not for the individuals within the community. At the time of the survey, the age of people from households surveyed ranged from 10 to 90 years of age with an average age of 41 years old. Therefore, the values obtained from the survey are representative of an adult exposure scenario. No child rates were available.

A ratio of children to adult estimated energy requirements (EER) will be used to develop estimates of children's consumption of subsistence resources from adult consumption data based on the approach presented in "Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids" (The Institute of Medicine of the National Academies 2002). This approach assumes that caloric intake and energy requirements are directly related to each other.

For children, the EER includes both total energy expenditure in kilocalories per day (TEE) plus energy required for growth and development. For young children, ages 0 through 2 years, physical activity levels are relatively similar and gender differences were not observed. The equation used to develop EERs for young children is:

EER = TEE + energy deposition

This equation was used for children aged 0 through 35 months. EERs for boys and girls with "active" physical activity levels for the age ranges of 3-4, 4-5 and 5-6 were obtained from tables 5-20 and 5-21 in the Institute of Medicine of the National Academies (2002). The EERs for each of these age ranges were averaged across genders. The time period associated with each EER was used to develop a time weighted average (TWA).

A similar analysis was done for individuals aged 6 through 70 using tables 5-20, 5-21, and 5-22 in the Institute of Medicine of the National Academies (2002). For the adult EER analysis, data were used from the physical activity class of "active" and a body mass index (BMI) of 24.99 kg/m^2. This BMI is somewhat below the average BMI for Americans, but it was the highest BMI for which EERs were available in NAS 2003. For each age class, EERs were averaged across genders.

The ratio of the TWA EERs for children to adults was 0.48.

For this assessment, the adult consumption rates will be multiplied by 0.48 to produce estimates of children's consumption. This value is similar the value derived from the Columbia River Inter-Tribal Fish Commission (1994) study based on a ratio of adult to child consumption rates for fish of 0.4.

As requested by the ADEC, health protective estimates of risk will be calculated based on an FI=1 (all food consumed is harvested from the site) for the residential scenario. Additional FI values will also be presented in the risk assessment as part of a sensitivity analysis. The future adult and child residential scenario represents potential exposures to a person who lives at the site. It is assumed that the adults would live and work at the site and the children would live at the site and go to school at the site. This is presumably the most potentially highest exposed individual.

Recreational visitors and subsistence users would visit the site a portion of the year during harvest time and presumably camp in the area. If the RDM site is redeveloped in the future as a mine, it is assumed that industrial or mine workers would work at the site and live in nearby Red Devil. It is assumed these receptors (recreational/subsistence user and mine worker) would also harvest in other areas, outside of the Red Devil Mine site.

Based on discussions with the ADEC and USEPA, the FI for recreational visitors/subsistence users and mine workers will be calculated based on a ratio of the area of the Red Devil Mine site to the total harvest area for the food source category of interest. Harvest maps for trout and whitefish, large land mammals, small land mammals, ducks and geese, and berries and greens are available from the 2009 survey (Brown et al. 2012). This assumes the fraction of the food harvest is based on harvest area. For many resources, the Red Devil Mine site is not within the harvest areas identified by ADF&G (no wild food harvested within the mine area); therefore the FI will be health protective by assuming the mine area is within the harvest area. ADF&G has agreed to provide these harvest maps to USEPA to calculate total harvest area by category.

USEPA will either calculate harvest area from these maps and provide the area estimates to E & E or provide the maps to E & E to calculate area.

For the recreational/subsistence user, exposure frequency to soil during recreational/subsistence activities (EF_{soil}) and exposure frequency to surface water during recreational/subsistence activities (EF_{sw}) also needs to be determined. There is no site-specific information on how much time is spent in the Red Devil Mine site by recreational or subsistence users. Based on discussions with USEPA and ADEC, the EF for soil and surface water will be derived based on the maximum FI multiplied by the residential EF, 270 days per year for soil and 60 days per year for surface water. It is assumed children will accompany their parents or adults during the time on-site.

Proposed exposure parameters for the FI and exposure frequency to subsistence resources (EFsub), exposure frequency to soil (EFsoil), and exposure frequency to surface water (EFsw) are provided in Table 5. The residential values for EFsoil and EFsw were presented in the RAWP and are not further described in this memorandum.

Table 5. Proposed Additional Exposure Parameters

Exposure Parameter	Units	Future Residential		Recreational/ Subsistence User		Mine Worker
		Adult	Child	Adult	Child	Adult
FI_{sub}(non-salmon)	unitless	1	1	mine site area/harvest area	mine site area/harvest area	mine site area/harvest area
FI_{sub} (large land mammals	unitless	1	1	mine site area/harvest area	mine site area/harvest area	mine site area/harvest area
FI_{sub} (small land mammals	unitless	1	1	mine site area/harvest area	mine site area/harvest area	mine site area/harvest area
FI_{sub} (birds)	unitless	1	1	mine site area/harvest area	mine site area/harvest area	mine site area/harvest area
FI_{sub} (berries and plants)	unitless	1	1	mine site area/harvest area	mine site area/harvest area	mine site area/harvest area
EF_{sub}	d/year	365	365	365	365	365
EF_{soil}	d/year	270	270	270 x maximum FI	270 x maximum FI	250 x maximum FI
EF_{sw}	d/year	60	60	60 x maximum FI	60 x maximum FI	40 x maximum FI

Notes:
IRsub – ingestion rate for subsistence foods
EFsub – exposure frequency for ingestion of subsistence foods
FI – fractional intake from contaminated sources
EFsoil – exposure frequency to soil or sediment
EFsw – exposure frequency to surface water

Estimating Exposure Point Concentrations in Wild Foods

Exposure point concentrations (EPCs) for COPCs in wild food will be calculated consistent with the approach outlined in Section 3.3.3 of the RAWP, except as outlined below. Specifically, concentrations of COPCs to which human receptors will be exposed over time will be estimated per USEPA guidance (USEPA 1992) using the 95 percent UCL as the EPC where there are sufficient number of samples. Estimated media concentrations will be used for exposure pathway calculations and estimating COPC concentrations in food items. Uptake of COPCs from various media by plants and animals may cause exposures to ecological receptors and humans who consume local plants and animal products. The following discussion describes how COPC concentrations will be obtained for food items such as native vegetation, game, and fish. For more information on estimating EPCs for biota, see Sections 3.3.3 and 4.4.2.1 of the RAWP.

COPC Concentrations in Fish

In 2010, the BLM conducted a study of Kuskokwim River, Red Devil Creek, and other tributaries to the Kuskokwim River near the RDM site. Forage fish (e.g., slimy sculpin) were collected and analyzed for site-related chemicals. It is assumed that people are catching and consuming game fish from the Kuskokwim River near the mouth of the creek and potentially, to a lesser extent, Red Devil Creek. The BLM sculpin data will be used to estimate concentrations of chemicals in game fish using a food chain multiplier (FCM) approach, as described in Section 3.3.3.3 and 4.4.2.1 of the RAWP.

In brief, the concentration of a chemical in game fish will be estimated from the sculpin concentration times an FCM. For methylmercury, an FCM of three will be assumed to account for biomagnification (i.e., the game fish concentration of methylmercury will be set equal to three times the concentration in sculpin). This approach is supported by the fact that the biomagnification of methylmercury typically is three-fold with each trophic transfer (McGeer et al. 2004). For inorganic mercury and other metals, an FCM of one will be assumed. This approach is defensible because biomagnification of metals (other than methylmercury) in aquatic organisms is rare. In fact, an inverse relationship has been shown for the trophic transfer of metals (except methylmercury) via the diet—that is, concentrations decrease from one trophic level to the next (McGeer et al. 2004). Hence, use of an FCM of one for inorganic mercury and other metals is conservative.

Based on ADF&G. (Brown et al. 2012), non-salmon game fish ingested by people from Red Devil include Dolly Varden, sheefish, round whitefish, whitefish (other), burbot, grayling, and Northern pike. The trophic levels for slimy sculpin and the game fish of interest are provided below (FishBase 2011):

- Slimy scuplin – 3.37
- Dolly Varden – 4.23
- Sheefish – 4.15
- Round whitefish – 4.03
- Burbot – 4.03
- Grayling – 3.1
- Northern pike – 4.4

Based on these data, E & E will conservatively assume that the game fish of interest are one trophic level above the slimy scuplin, except for grayling, which feed at a slightly lower trophic level than the scuplin. No FCM will be applied to the sculpin data to estimate chemical concentrations in grayling tissues.

Using the sculpin data to estimate game fish concentrations in the Kuskokwim River is a health protective approach since sculpin are more resident than the fish taken from the Kuskokwim River. The approach may over-estimate the actual concentrations of fish people are catching from the Kuskokwim River. BLM also harvested grayling, burbot, pike and sheefish from the Kuskokwim River near Red Devil Creek (RDC). The metal concentrations from these samples will be provided in the HHRA for comparison only – they will not be used to generate estimates of risk due to questions about attributing COPC concentrations in these species' tissues to the Red Devil Mine site. If possible, data will be separated by samples from downstream of RDC and samples from upstream of RDC.

Current, available sculpin data for Red Devil Creek is presented in Table 6.

Table 6. Summary of 2010 Sculpin Data from Red Devil Creek, Red Devil Mine Site

Analyte	August 2010 Samples				June 2010 Samples			
	Number of Samples	Minimum Detected Concentration (mg/kg wet weight)	Maximum Detected Concentration (mg/kg wet weight)	Frequency of Detection	Number of Samples	Minimum Detected Concentration (mg/kg wet weight)	Maximum Detected Concentration (mg/kg wet weight)	Frequency of Detection
Aluminum	12	11.7	**72.5**	12/12	9	3.6	20.9	9/9
Antimony	12	6.51	**38.1**	12/12	9	0.40	4.04	9/9
Arsenic	12	6.86	**24.1**	12/12	9	1.10	4.49	9/9
Barium	12	2.83	**5.40**	12/12	9	2.01	4.35	9/9
Beryllium	12	ND[b]	ND[b]	0/12	9	ND[b]	ND[b]	0/9
Boron	12	0.031	0.088	5/12	9	0.142 J+	**0.843** J	9/9
Cadmium	12	0.029	0.056	5/12	9	0.027	**0.103**	6/9
Calcium	--	--	--	--	9	--	--	--
Chromium	12	0.038	0.188	12/12	9	0.028	**2.431**	9/9
Cobalt	--	--	--	--	9	--	--	--
Copper	12	0.72	1.164	12/12	9	0.27 J-	**2.263** J-	9/9
Iron	12	63.7	**184**	12/12	9	18.9 J-	61 J-	9/9
Lead	12	0.027	**0.079**	11/12	9	0.025 J	0.026	2/9
Magnesium	12	280	368	12/12	9	251	**423**	9/9
Manganese	12	6.65	**21.3**	12/12	9	8.44	16.0	9/9
Mercury	12	0.68	**3.70**	12/12	9	0.05	0.63	9/9
Methylmercury	1	0.16	0.16	1/1	1[a]	0.312	**0.312**	1/1
Molybdenum	12	0.028	**0.038**	7/12	9	0.03	0.03	1/9
Nickel	12	0.083	**0.263**	12/12	9	0.039	0.113	9/9
Potassium	--	--	--	--	9	--	--	--
Selenium	12	1.53	**2.98**	12/12	9	0.834	1.43	9/9
Silver	--	--	--	--	9	--	--	--
Sodium	--	--	--	--	9	--	--	--
Strontium	12	10.6	30.0	12/12	9	15.5 J+	**32.8** J+	9/9
Thallium	--	--	--	--	9	--	--	--
Vanadium	12	0.15	0.32	12/12	9	0.10	**0.40**	9/9
Zinc	12	20.6	**35.4**	12/12	9	17.1 J-	30.2 J-	9/9

Source: Matt Varner, BLM Anchorage Field Office, Anchorage, AK.

Key:
-- (double dash) = not analyzed.
BLM = Bureau of Land Management
Bold = maximum detected concentration across both sampling events.
J- = estimated value with low bias.
J+ = estimated value with high bias.
ND = not detected.

Notes:
a = Composite sample. In June 2010, methylmercury was measured only in a composite sample of three sculpin.
b = Beryllium method detection limits = 0.025 mg/kg wet weight.

COPC Concentrations in Large Land Mammals

No data on levels of site-related chemicals in wild game are available from the site. Based on ADF&G (Brown et al. 2012; ADF&G 2003), people in Red Devil harvest and consume black bear, moose and caribou. In lieu of actual measured concentrations, E & E will use the approach developed by Baes et al. (1984) and recommended by USEPA (2007, 2005b) to estimate metal concentrations in beef cattle, adjusted for moose, from metal concentrations in their diet. The general equation is:

$$C_M = F_f \times 27 \times C_D$$

Where:

- C_M = Metal concentration in moose tissue (mg/kg dry)
- F_f = Ingestion-to-beef transfer coefficient (days/kg) (from Baes et al. 1984)
- 27 = Constant; moose consume 27 kg/day of feed
- C_D = Diet metal concentration (mg/kg dry) based on plant sample results collected in 2011

During the fall and winter, moose consume large quantities of willow, birch, and aspen twigs; during the summer, moose feed on forbs, vegetation in shallow ponds, and the leaves of birch, willow and aspen (ADF&G 2012a, 2012b). Moose forage rates were estimated by Moen et al. (1997) as an average of 10.5 kilogram (kg) dry mass per day, with a range of 9.45 to 11.55 kg dry mass per day. In the fall a moose can eat about 50-60 pounds (22 to 27 kg) of food per day (The Wilderness Classroom Organization 2002). The equation above was adjusted to incorporate moose forage rate, or consumption of feed, at a rate of 27 kg per day, a high-end health protective estimate of year-round consumption. This approach will be used to estimate the concentrations in moose, an indicator species for large mammals.

The metal concentration in moose diet will be obtained from results from the green alder bark samples, provided in Table 7. The alder bark samples that were collected in 2011 represent the best surrogate for metals levels in alder twigs, leaves, and buds. Metal concentrations in the moose diet from the green alder bark samples will be estimated using the FCM approach described above for fish (FCM = 3 for methylmercury and 1 for all other metals).

COPC Concentrations in Small Land Mammals and Birds

Based on ADF&G (2002), within Red Devil people harvest and consume beaver, snowshoe hare, river otter, mink, muskrat, and porcupine. Beaver is consumed at the highest rate and will be used as an indicator for this resource category. Metal concentrations in small mammals will be estimated from concentration in their diet using the FCM approach described for fish (FCM = 3 for methylmercury and 1 for all other metals). Green alder bark from the site was sampled and analyzed for metals in 2011; a summary of the results are shown in Table 7. This data will be used to represent the beaver diet.

Based on ADF&G (Brown et al. 2012), within Red Devil people harvest and consume primarily spruce grouse and ruffed grouse. Metals concentrations in spruce grouse muscle will be estimated from the concentration in their diet using the FCM approach described for fish (FCM = 3 for methylmercury and 1 for all other metals). White spruce needles from the site was sampled and analyzed for metals in 2011; a summary of the results are shown in Table 8. This data will be used to represent the spruce grouse diet.

COPC Concentrations in Native Vegetation

Based on ADF&G (Brown et al. 2012), people in Red Devil harvest and consume blueberries, lowbush cranberries, crowberries (blackberries), wild rhubarb, Hudson's Bay tea, and stinkweed. Based on the amount consumed and the availability of limited concentration data, blueberries will be used to represent this wild food category.

Chemical concentrations in blueberry fruit will be modeled based on the following uptake equations from Baes et al. (1984):

$$Cv = Cs \times Br$$

Where,
Cv = Concentration in nonvegetative (reproductive) portion of food
Cs = Concentration in soil (mg/kg)
Br = Soil-to-plant elemental transfer coefficient for nonvegetative (reproductive) portions of food crops

The transfer coefficient for reproductive portions of plants will be obtained from Figure 2-2 of Baes et al. (1984).

Total mercury and methylmercury have been measured in several terrestrial plant species from the RDM site including willow, white spruce, black spruce, and blueberries (Bailey et al. 2002; Bailey and Gray 1997). A summary of the plant data is provided in Table 9. Additional sampling of alder, blueberry, white spruce, and pond plants was conducted in summer 2011, although there were not sufficient blueberry fruit samples available for analysis. Soil and vegetation mercury data from Bailey and Gray (1997) and Bailey et al. (2002) will be compared with modeled mercury concentrations in vegetation in the HHRA to judge the health-protectiveness of the modeling approach.

Table 7. Summary of Green Alder Bark Results, Red Devil Mine Site

Analtye	Minimum Detected (mg/kg – wet weight)	Maximum Detected (mg/kg – wet weight)	Frequency of Detection[1]
Aluminum	3.7	24.2	9/9
Antimony	0.165 J	3.35 J	8/9
Arsenic	0.06	0.91	8/9
Barium	2.35	203	9/9
Beryllium	0.005 J	0.015 J	4/9
Cadmium	0.014 J	0.129	7/9
Calcium	4560	10800	9/9
Chromium	0.3 J	1.4 J	3/9
Cobalt	0.064	0.528	9/9
Copper	4.33	6.64	9/9
Iron	17.6	34.9	9/9
Lead	0.06	0.113	9/9
Magnesium	539	967	9/9
Manganese	91.2	1140	9/9
Mercury	0.017 J	0.289 J	9/9
Methylmercury	ND (<0.0037)	ND (<0.004)	0/5
Nickel	0.72	4.15	9/9
Potassium	1530	2610	9/9
Selenium	0.22 J	0.22 J	1/9
Silver	0.016	0.193	2/9
Sodium	9.8 J	17 J	9/9
Thallium	0.006 J	0.03	4/9
Vanadium	0.03 J	0.07	9/9
Zinc	35.9 J	108 J	9/9

Note:
1 – Includes 8 samples plus one field duplicate
ND = not detect, minimum and maximum detection limits shown

Table 8. Summary of Spruce Needle Results, Red Devil Mine Site

Analtye	Minimum Detected (mg/kg – wet weight)	Maximum Detected (mg/kg – wet weight)	Frequency of Detection[1]
Aluminum	5.1	172	8/9
Antimony	0.199 J	15.1	8/9
Arsenic	0.11 J	11.1	8/9
Barium	4.16	85.3	9/9
Beryllium	0.008 J	0.008 J	2/9
Cadmium	0.1 J	0.191	8/9
Calcium	3320	9920	9/9
Chromium	0.4 J	1.3 J	5/9
Cobalt	0.05	0.303	9/9
Copper	0.93	4.42	9/9
Iron	20.1	206	9/9
Lead	0.009	0.466	9/9
Magnesium	548	958	9/9
Manganese	130	2990	9/9
Mercury	0.03	5.64	9/9
Methylmercury	ND (<0.0037)	ND (<0.004)	0/5
Nickel	0.67	6.35	9/9
Potassium	3450	7740	9/9
Selenium	ND (<0.03)	ND (<0.15)	0/9
Silver	0.016 J	0.114	7/9
Sodium	4.1 J	24.8 J	9/9
Thallium	0.005 J	0.021 J	2/9
Vanadium	0.03	0.47	8/9
Zinc	13.9	53.2 J	9/9

Note:
1 – Includes 8 samples plus one field duplicate
ND = not detect, minimum and maximum detection limits shown

Table 9. Summary of Mercury and Methylmercury Data for Vegetation at Red Devil Mine Site

Species	Area	Units[b]	Total Mercury Mean	Total Mercury Range	n	Methylmercury Mean	Methylmercury Range	n
Bailey et al. (2002)								
Alder leaves and stems[a]	Tailings	ng/g	226	149-374	3	0.5	0.4-0.6	3
	Retort	ng/g	310	--	1	--	--	0
	Mined Area	ng/g	211	24-900	10	0.3	0.1-0.7	7
Willow leaves and stems[a]	Tailings	ng/g	350	346-353	2	1.6	1.4-1.8	2
	Retort	ng/g	166	74-330	19	1.8	0.4-3.4	6
	Mined Area	ng/g	136	11-560	7	5	0.3-11	6
Soil	Tailings	µg/g	970	12-1578	5	0.4	0.1-0.7	5
	Retort	µg/g	8.5	0.05-120	21	3.3	0.7-8.2	8
	Mined Area	µg/g	210	6-1200	12	2.2	0.3-7.2	10
Bailey and Gray (1997)								
Alder leaves[a]	Retort	ng/g	310	--	1	0.45	--	1
	Mined Area	ng/g	169	30-900	18	0.63	0.54-0.72	2
Alder stems[a]	Retort	ng/g	30	--	1	--	--	--
	Mined Area	ng/g	21	<20-50	18	0.8	--	1
Willow leaves[a]	Retort	ng/g	183	90-330	14	--	--	--
	Mined Area	ng/g	197	40-560	9	2.7	--	1
Willow stems[a]	Retort	ng/g	53	30-90	11	--	--	--
	Mined Area	ng/g	39	<20-70	9	--	--	--
Blueberry leaves	Retort	ng/g	187	80-330	11	2.8	--	1
	Mined Area	ng/g	70	30-150	4	--	--	--
Blueberry stems	Retort	ng/g	61	30-120	11	--	--	--
	Mined Area	ng/g	30	<20-70	4	--	--	--
Blueberry fruit	Retort	ng/g	63	30-100	10	2.6	--	--
	Mined Area	ng/g	50	40-60	3	--	--	--
Soil	Retort	µg/g	121	0.2-1200	22	3.5	2.7-4.2	2
	Mined Area	µg/g	11	0.2-120	13	8.2	--	1

Notes:

[a] Current year's growth.
[b] Different units are used for vegetation (ng/g) and soil (ug/g).

Key:

-- = Not available or not relevant.
n = Number of samples.
ng/g = Nanograms per gram (parts per billion).
ug/g = Micrograms per gram (part per million).

Exposure Units

Per 3.3.2.1 of the RAWP, it was assumed the site would be handled as one exposure unit but that this issue would be evaluated and discussed with the USEPA and ADEC prior to development of the HHRA via this technical memorandum. Exposure units can be designated based on different uses of subareas within the site or the uneven distribution of contamination across the site.

For residents, soil and subsurface soil will be broken down into the Surface Mined Area (SMA), the Main Processing Area (MPA) and the Red Devil Creek Downstream Alluvial Area (DA) based on historical operations at the site resulting in differing concentrations. Figure 4-1 of the Draft Remedial Investigation Report (Ecology and Environment 2012) showing the geographic areas of the site is provided in this memorandum. Table 10 compares the antimony, arsenic and mercury level ranges and averages for the proposed exposure units and geographical areas.

The SMA exposure unit consists of 60 samples (including duplicates); this includes surface soil samples and subsurface soil sample to a depth of 15 feet below ground surface. The SMA exposure unit incorporates the following geographic areas, as depicted on Figure 4-1:

- Dolly Sluice and Delta (surface soil n=3; subsurface soil n=8)
- Rice Sluice and Delta (surface soil n=3; subsurface soil n=6)
- Surface Mined Area (surface soil n=32; subsurface soil n=8)

The MPA exposure unit consists of 232 surface and subsurface soil samples, including duplicates. The MPA exposure unit incorporates the Post-1955 Main Processing Area and Pre-1955 Main Processing Area (surface soil n=85; subsurface soil n=147), as depicted on Figure 4-1

The DA exposure unit consists of 34 surface and subsurface soil samples which incorporate the Red Devil Creek Downstream Alluvial Area and Delta (surface soil n=11; subsurface soil n=23).

For recreational/subsistence users and mine workers, it is assumed recreational and subsistence activities would be equally spread throughout the site. Therefore, for these receptors the full site area will be treated as a single operable unit.

Table 10. Comparison of Exposure Unit Metal Concentrations

Geographical Unit	Antimony Range (mg/kg)	Antimony Average (mg/kg)	Arsenic Range (mg/kg)	Arsenic Average (mg/kg)	Mercury Range (mg/kg)	Mercury Average (mg/kg)
Main Processing Exposure Unit						
Main Processing Unit (n=232)	0.343-2890	2163	7.77-9880	1789	0.28-6110	244
Red Devil Creek Downstream Alluvial Exposure Unit						
RDC Downstream Alluvial (n=34)	0.321-2710	360	3.36-3510	731	0.063-471	86.8
Surface Mined Area Exposure Unit						
Dolly Sluice (n=11)	0.0886-122	27	12-1200	302	0.168-326	70
Rice Sluice (n=9)	1.17-68.7	15	8.01-142	44	0.198-33.1	8.9
Surface Mined Area (n=40)	0.25-508	84.6	8.67-8510	1623	0.032-174	44

Ecology & Environment, Inc. GIS Department Project:
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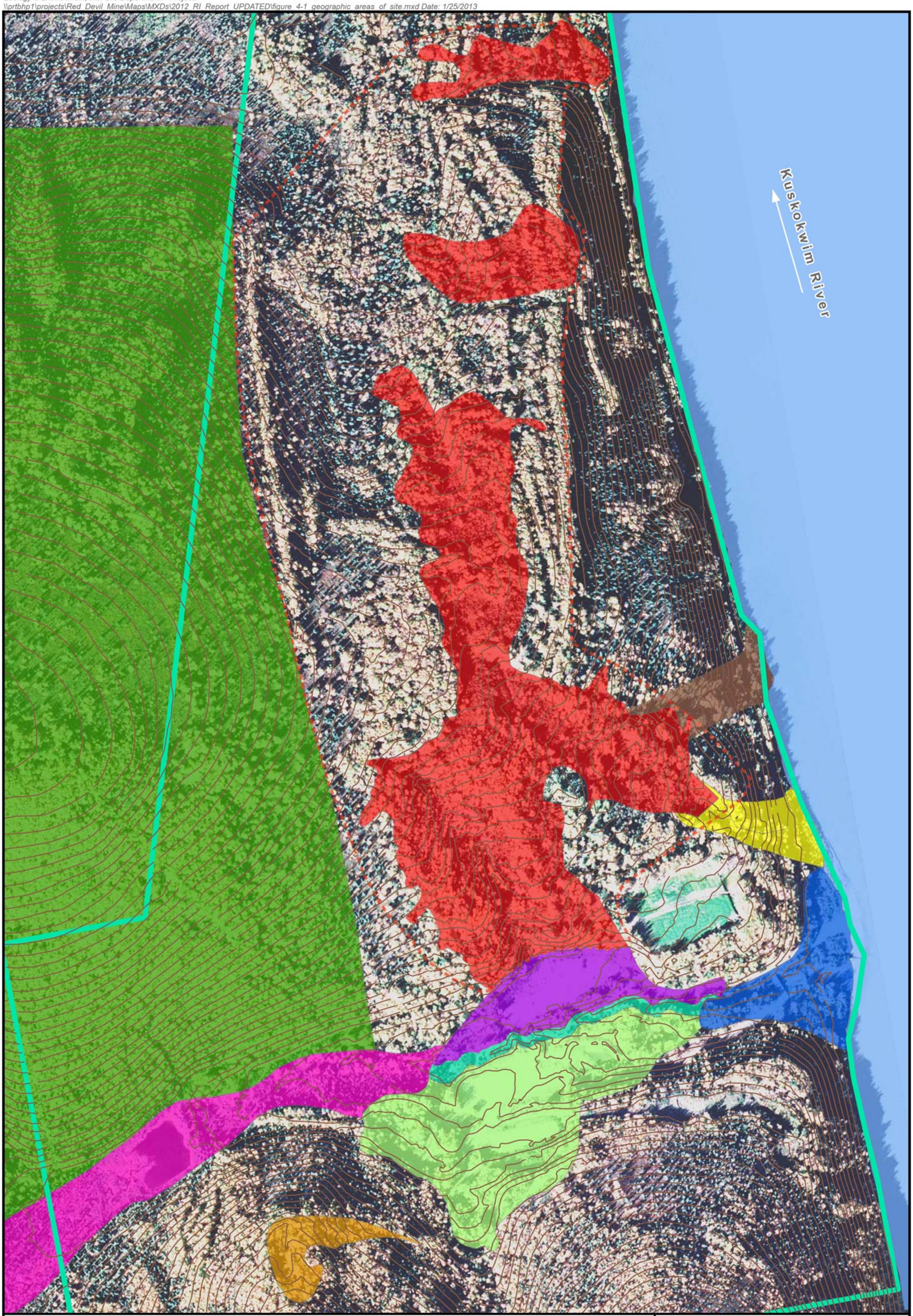

- Access Road
- Exploration Trench
- Topographic Contour (10 ft. interval)
- Site Boundary
- Dozed Area
- Area of Surface Exploration South of the Post-1955 Main Processing Area
- Red Devil Creek Downstream Alluvial Area and Delta
- Red Devil Creek Upstream Alluvial Area
- Rice Sluice and Delta
- Dolly Sluice and Delta
- Kuskokwim River
- Post-1955 Main Processing Area
- Pre-1955 Main Processing Area
- Red Devil Creek
- Surface Mined Area
- Upland Background Area

RED DEVIL MINE

Red Devil, Alaska

Figure 4-1
Geographic Areas of Site

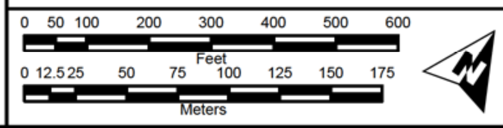

Image Source: Aero-Metric, Inc. 2010a
Topographic elevation contours source: Aero-Metric, Inc. 2010b, based on Aero-Metric, Inc. aerial photograph dated 5/29/2001

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