SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT FOR THE PROPOSED KONDIRATOR METAL SHREDDER/RECYCLER IN MINNEAPOLIS, MN

Final Report

Submitted to:
Environmental Analysis Office
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155-4194

Submitted by:
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June 30, 1995

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July 14, 1995

Mr. William Lynott
Project Manager
Environmental Analysis Office
Minnesota Pollution Control Agency
520 Lafayette Road N.
St. Paul, Minnesota 55155-4194

SUBJECT: Documentation of Uncertainty Associated With Emissions Estimates in the Kondirator HHRA and ERA

Dear Bill:

Attached you will find two tables which document the level of uncertainty and potential bias in the risks estimates in the Kondirator Screening Level Human Health Risk Assessment and Ecological Risk Assessment. Table 1 illustrates the changes in estimated health risks that would be associated with using alternative estimates of the elemental proportions of the various COCs in the feed material, compared the risks that were estimated with the Feed Material Composition from the last column of Table 3.2 of the HHRA and ERA. Table 2 illustrates the effect of using alternative elemental compositions on indices of ecological risks.

The first three numerical columns of both tables show, respectively, the weighted average composition of feed materials calculated from the MSDS data without toxicity adjustment, the toxicity-adjusted composition, and the feed material composition which was used in the HHRA and ERA to estimate exposures and risks. As you know, the elemental proportions in the third column "Feed Material Composition" is simply the higher of the weighted average or toxicity-adjusted elemental proportions. These values all come from Table 3-2 of the HHRA and ERA.

The fourth numerical column of both of the enclosed tables is the ratio of the elemental proportions of COC in the feed materials used in the HHRA and ERA to the alternative estimate which could have been used, either the weighted average or toxicity-adjusted proportions, depending on the COC. These ratios illustrate magnitude of the differences in elemental concentrations, and the magnitude of the differences in risk estimates that would have resulted if the alternative estimates of elemental proportions had been used to estimate risks.

The remaining columns of the two tables provide a summary how the cancer risk estimates (for humans, Table 1) and hazard quotients (for humans in Table 1 and for ecological receptors in Table 2) would have changed if the alternative estimates of feed materials elemental composition had been used in the HHRA and ERA instead of the "Feed Material Composition" from Table 3-2. The changes in cancer risk estimates and hazard quotients are given for each COC, for the pathway or receptor with the greatest risk or highest exposure relative to toxicity criteria. In the case of human receptors, cancer risks estimates for resident children and adults are summed, and hazard quotient values are given for child receptors, since these values are roughly an order of magnitude greater than the hazard quotients for adults.

The major findings of this analysis can be summarized as follows:

In all cases, use of the alternative estimates of exposure would have resulted in lower estimated cancer risks for humans or hazard quotients for both humans and ecological receptors. This is because the method used to derive the feed material composition in the HHRA and ERA took the higher of the weighted average or toxicity-adjusted elemental proportions, in order to provide conservative risk estimates.

Use of the alternative estimates of elemental proportions would have affected the magnitude of human cancer risk estimates only very slightly. The cancer risk for soil ingestion exposure to beryllium (the highest-risk single carcinogenic COC and pathway at 2.6×10^{-5}, accounting for about sixty percent of the total cancer risk) would not change at all, since the weighted average and toxicity- adjusted elemental proportions are the same. The cancer risk for the next highest-risk carcinogen (arsenic by soil ingestion) would change only from 1.6×10^{-5} to 1.5×10^{-5} if the toxicity-adjusted proportion had been used to estimate risks instead of the weighted average proportion. The estimated changes in cancer risk associated with use of the alternative estimates of proportions of all of the other carcinogens were minimal (six percent or less). No combination of elemental proportions would have resulted in the cancer risk estimated for any pathway or COC going from above the 10^{-5} Tolerable Risk Level to below this level.

Use of the alternative estimates of proportions of several COC could have resulted in substantial changes in the values of the hazard quotients for human exposures to these COCs. However, all of these changes would only further reduce hazard quotient estimates which are already far below the level of concern of 1.0. For instance, using the weighted average zinc proportion instead of the toxicity-adjusted value would have reduced the hazard quotient for zinc almost four-fold, but would have changed the value from of 0.002 to 0.0005. Similarly, use of the alternative elemental proportion for antimony would have reduced the hazard quotient for this element from 0.07 to 0.047.

Most of the hazard quotients for individual COC exposures changed only few percent when they were calculated with alternative elemental proportions. The hazard quotient for manganese through inhalation exposure (the highest single hazard quotient for any COC or pathway) would have changed only from 0.50 to 0.48, and the hazard quotient for arsenic (the highest for any of the ingestion pathways) would have changed only from 0.30 to 0.29. None of the potential differences in COC proportions would have resulted in the hazard quotient for any COC going from above a level of concern to below a level of concern, nor would any of the difference in proportions significantly affected the total hazard indices for any pathway.

In the case of the ecological risk assessment, most of the potential changes in elemental proportions likewise have minimal affects on the ratios of exposures to toxicity criteria. The only exception is in the case of zinc, where the four-fold reduction associated with using the toxicity-adjusted value instead of the weighted average estimate would reduce the ratio from just above the level of concern for robins (1.3) to just below the level of concern (0.33). (Note that, since the weighted average value of the proportion of zinc in feed materials is better-documented than the toxicity-adjusted value, there is a good argument to retain it in the analysis.) In all other cases where use of the alternative elemental proportion would have resulted in changes in exposure of more than a few percent, the ratios of exposure to toxicity criteria were either already below a level of concern (antimony, copper, and silver), or there is not toxicity criterion available (magnesium).

On the whole, these findings indicate that the approach taken to estimating COC elemental proportions in feed materials has had little effect on the quantitative risk results or on the basic conclusions of the HHRA or ERA regarding health or ecological risks. Please let me know if you have any questions about these results.

Sincerely,

William M. Mendez, Jr., Ph.D.
Project Manager

wmm/WMM

TABLE 1. EFFECT OF USING ALTERNATIVE FEED MATERIAL COMPOSITION ON ESTIMATED HEALTH RISKS, KONDIRATOR SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT

COC	Weighted Average Composition (a)	Toxicity Adjusted Composition (a)	Feed Material Composition (a)	Ratio of Feed Material Com-position to Alternative Value (b)	Highest Risk Pathways (c)	Highest Pathway Cancer Risk (d)	Cancer Risk Using Alternative Elemental Composition (e)	Highest Pathway Hazard Quotient (d)	Hazard Quotient Using Alternative Elemental Composition (e)
Aluminum	1.69%	1.76%	1.76%	1.040	NA	NA	NA	NA	NA
Antimony	0.03%	0.02%	0.03%	1.500	Soil	NA	NA	7.0E−02 (f)	4.7E−02 (f)
Arsenic	0.12%	0.11%	0.12%	1.045	Soil	1.6E−05 (f)	1.5E−05 (f)	3.0E−01	2.9E−01
Beryllium	0.05%	0.05%	0.05%	1.000	Soil	2.7E−05	2.7E−05	9.0E−03	9.0E−03
Boron	0.10%	0.10%	0.10%	1.000	Soil	NA	NA	9.0E−04	9.0E−04
Cadmium	0.08%	0.08%	0.08%	1.000	Inhalation, Soil	4.0E−07	4.0E−07	7.0E−02	7.0E−02
Calcium	0.10%	0.09%	0.10%	1.056	NA	NA	NA	NA	NA
Carbon	1.97%	1.84%	1.97%	1.071	NA	NA	NA	NA	NA
Chromium (VI)	0.67%	0.71%	0.71%	1.055	Inhalation, Soil	2.0E−06	1.9E−06	1.0E−02	9.5E−03
Cobalt	0.42%	0.44%	0.44%	1.040	NA	NA	NA	NA	NA
Copper	1.84%	1.42%	1.84%	1.298	Soil	NA	NA	4.0E−02	3.1E−02
Iron	90.17%	87.10%	90.17%	1.035	NA	NA	NA	NA	NA
Lead	0.38%	0.37%	0.38%	1.014	NA	NA	NA	NA	NA
Lithium	0.08%	0.08%	0.08%	1.000	NA	NA	NA	NA	NA
Magnesium	0.35%	0.22%	0.35%	1.591	NA	NA	NA	NA	NA
Manganese	1.96%	2.04%	2.04%	1.041	Inhalation	NA	NA	5.0E−01	4.8E−01
Molybdenum	0.29%	0.31%	0.31%	1.058	Soil	NA	NA	5.0E−02	4.7E−02
Nickel	0.94%	0.96%	0.96%	1.018	Inhalation, Soil	6.0E−07	5.9E−07	4.0E−02	3.9E−02
Niobium	0.10%	0.09%	0.10%	1.056	NA	NA	NA	NA	NA
Silicon	0.71%	0.60%	0.71%	1.185	NA	NA	NA	NA	NA
Silver	0.05%	0.04%	0.05%	1.250	Soil	NA	NA	9.0E−03	7.2E−03
Tin	0.59%	0.59%	0.59%	1.000	Soil	NA	NA	9.0E−04	9.0E−04
Titanium	0.10%	0.09%	0.10%	1.056	NA	NA	NA	NA	NA
Tungsten	0.40%	0.39%	0.40%	1.026	NA	NA	NA	NA	NA
Vanadium	0.21%	0.22%	0.22%	1.033	Soil	NA	NA	3.0E−02	2.9E−02
Zinc	0.74%	0.19%	0.74%	3.895	Soil	NA	NA	2.0E−03	5.1E−04
Zirconium	0.10%	0.09%	0.10%	1.056	NA	NA	NA	NA	NA
	104.22%	100.00%	104.46%						

Notes:

(a) All elemental metal compositions come from Kondirator HHRA, Table 3−2.

(b) Ratios are the feed material compostion used in the HHRA divided by either the weighted average composition or the toxicity adjusted composition.

(c) If more than one pathway is listed, the first is the pathway with the highest cancer risk, and the second is the pathway with the highest hazard quotient.

(e) Values are the highest cancer risks or hazard quotients for this COC by any pathway. Cancer risk values for the soil pathway are the sum of the children's and adult values. Hazard Index values for the soil patway are for children.

(e) Values are equal to the cancer risk or hazard quotients calculated in the HHRA divided by the ratio of the feed material composition to the alternative value.

(f) The symbol "E" refers to scientific notation. For example, 1.6E−05 is equal to a cancer risk of $1.6x10^{-5}$, etc.

TABLE 2. EFFECT OF USING ALTERNATIVE FEED MATERIAL COMPOSITION ON ESTIMATED ECOLOGICAL RISKS, KONDIRATOR SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

COC	Weighted Average Composition (a)	Toxicity Adjusted Composition (a)	Feed Material Composition (a)	Ratio of Feed Material Composition to Alternative Value (b)	Highest Risk Receptor (c)	Highest Concentration–TRV Ratio	Concentration–TRV Ratio Using Alternative Elemental Composition (d)
Aluminum	1.69%	1.76%	1.76%	1.040	Plants	3.9E-01 (e)	3.8E-01 (e)
Antimony	0.03%	0.02%	0.03%	1.500	Plants	7.0E-02	4.7E-02
Arsenic	0.12%	0.11%	0.12%	1.045	Plants	1.3E-01	1.2E-01
Beryllium	0.05%	0.05%	0.05%	1.000	Plants	6.0E-02	6.0E-02
Boron	0.10%	0.10%	0.10%	1.000	Plants	2.1E+00	2.1E+00
Cadmium	0.08%	0.08%	0.08%	1.000	Shrews	1.8E+00	1.8E+00
Calcium	0.10%	0.09%	0.10%	1.056	Worms	3.0E-05	2.8E-05
Carbon	1.97%	1.84%	1.97%	1.071	NA	NA	NA
Chromium (VI)	0.67%	0.71%	0.71%	1.055	Worms	2.0E+01	1.9E+01
Cobalt	0.42%	0.44%	0.44%	1.040	Plants	2.4E-01	2.3E-01
Copper	1.84%	1.42%	1.84%	1.298	Worms	4.1E-01	3.2E-01
Iron	90.17%	87.10%	90.17%	1.035	Acute AWQC	4.0E-03	3.9E-03
Lead	0.38%	0.37%	0.38%	1.014	Robins	1.5E-01	1.5E-01
Lithium	0.08%	0.08%	0.08%	1.000	Plants	4.4E-01	4.4E-01
Magnesium	0.35%	0.22%	0.35%	1.591	NA	NA	NA
Manganese	1.96%	2.04%	2.04%	1.041	Plants	5.0E-02	4.8E-02
Molybdenum	0.29%	0.31%	0.31%	1.058	Plants	1.7E+00	1.6E+00
Nickel	0.94%	0.96%	0.96%	1.018	Plants	3.6E-01	3.5E-01
Niobium	0.10%	0.09%	0.10%	1.056	NA	NA	NA
Silicon	0.71%	0.60%	0.71%	1.185	Plants	1.6E-01	1.4E-01
Silver	0.05%	0.04%	0.05%	1.250	Plants	2.8E-01	2.2E-01
Tin	0.59%	0.59%	0.59%	1.000	Chron. AWQC	1.1E+00	1.1E+00
Titanium	0.10%	0.09%	0.10%	1.056	Plants	2.0E-02	1.9E-02
Tungsten	0.40%	0.39%	0.40%	1.026	Plants	4.4E+00	4.3E+00
Vanadium	0.21%	0.22%	0.22%	1.033	Plants	1.2E+00	1.2E+00
Zinc	0.74%	0.19%	0.74%	3.895	Robins	1.3E+00	3.3E-01
Zirconium	0.10%	0.09%	0.10%	1.056	Plants	1.1E+00	1.0E+00
	104.22%	100.00%	104.46%				

Notes:
(a) All elemental metal compositions come from Kondirator ERA, Table 3-2.
(b) Ratios are the feed material compostion used in the ERA divided by either the weighted average composition or the toxicity adjusted composition.
(c) Values are the highest ratio of exposure concentration to any Toxicity Refeerence value for any receptor organism for this COC.
(d) Values are equal to the exposure/TRV ratios calculated in the ERA divided by the ratio of the feed material composition to the alternative value.
(e) The symbol "E" refers to scientific notation. For example, 3.9E-01 is equal to a concentration-TRV ratio of 3.9×10^{-1}, or 0.39.

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EXECUTIVE SUMMARY

ICF Kaiser Engineers, Inc. (ICF KE), was commissioned to undertake a screening level human health risk assessment (HHRA) for the proposed Kondirator metal shredding facility. The Kondirator is an advanced metal shredding device to be installed at the American Iron and Supply (AIS) Metal Recycling Facility at 2800 Pacific Street in Minneapolis, MN. A screening level ecological risk assessment (ERA) is being undertaken in a parallel effort.

The screening level assessment was a limited effort, the scope of which was severely constrained by time and resources. The objectives of the screening level assessment were—

- To identify substances emitted from the Kondirator most likely to be associated with adverse effects on human health;
- To identify human populations most likely to be exposed to the Kondirator particulate emissions;
- To rule out exposure pathways not likely to be associated with adverse effects;
- To provide quantitative estimates of potential human health risks for the potentially significant exposure pathways; and
- To provide an assessment of the level of uncertainty associated with the risk estimates.

To accomplish these goals within the allocated resources, the screening level assessment employs simplified, generic methods and assumptions developed by the U.S. Environmental Protection Agency (USEPA) and others. Only limited site-specific information was available and incorporated into the assessment. In the absence of detailed site-specific modeling, the models and assumptions that are used are generic and conservative, and the combined effect of these assumptions is to provide a high degree of assurance that Kondirator-related risks have not been underestimated.

The HHRA addressed potential risks associated with releases of metallic particulates from the Kondirator and cascade cleaning system through their associated air pollution control equipment and from the handling and conveying of materials prior to shredding. In addition, the impacts of releases from the proposed stormwater retention pond to the Mississippi River were also addressed.

All of the identified elemental constituents of the Kondirator feed stocks (metals plus arsenic) were included in the identified HHRA as chemicals of concern (COCs). Information regarding the elemental composition of feed stocks was obtained from Materials Safety Data Sheets (MSDS) for the various feed materials (Section 2.0).

Emission rates of particulates (total particulate, TSP) provided by the Applicant (AIS) were used in the risk assessment. Exposure concentrations of COCs in air and COC deposition onto soils and water were calculated by multiplying the TSP air concentrations and deposition rates by the proportions of each COC in the Kondirator feed materials. The Applicant performed the air quality impact modeling and particulate deposition modeling that served as the basis for the exposure assessment. Standard USEPA-approved methods were used (Section 3.0). A summary of the air quality modeling inputs and outputs is provided in Appendix A.

Estimates of long-term COC concentrations in air, soils, sediment, and surface water as a result of emissions from the Kondirator stacks and stormwater pond were calculated using simple mathematical models. These concentration estimates were used to evaluate potential human health risks (Sections 4.0 and 5.0 and Appendix B). Potential exposures were also estimated for COCs likely to bioaccumulate in fish in the Mississippi River (Section 6).

The receptors identified as most likely to have the highest exposures to particulate emissions from the Kondirator were hypothetical long-term residents of the neighborhood directly across the Mississippi river to the east of the facility (Section 7). Modeled air quality and particulate deposition impacts at the highest-exposure location on the east bank of the river were used to provide conservative estimates of exposures for residents in the neighborhood. Risks were calculated for both adult and child residents.

Quantitative exposure and risk estimates were developed for inhalation of airborne particulates and for the incidental ingestion of surface soils and sediments contaminated with particulate emissions from the Kondirator. Potential risks associated with the consumption of fish from the Mississippi River were also evaluated for these COCs, which have a high propensity to accumulate in aquatic organisms. Other exposure pathways relating to surface water were not included in the quantitative risk assessment because of the extremely low predicted increments in concentration of Kondirator COCs in the Mississippi River water compared with normal background levels and with water quality standards.

Potential health risks were estimated using standard models and toxicologic criteria values derived by the USEPA. The results of the risk calculations are presented in Section 9.0.

The estimated potential cancer risk associated with the ingestion of soils is 3 per 100,000 (3×10^{-5}) for hypothetical child residents and 1 per 100,000 (1×10^{-5}) for adults. The former value is above the MDH Tolerable Risk Level. The estimated potential cancer risks associated with the ingestion of contaminated sediment from the Mississippi are far below 1 in 100,000 for both adults and children.

For all of the exposure pathways and COCs with toxicologic criteria, for both adults and children, comparison of long-term exposures and dose estimates to appropriate toxicologic criteria indicate that adverse noncancer health effects are not likely to occur.

The USEPA's IEUBK Model was used to evaluate the potential effect of Kondirator emissions of lead-containing particulate on the blood lead concentrations of infants and children living near the facility (Section 9.4). The model predicts geometric mean blood lead concentrations of between 2.5 and 3.8 micrograms per deciliter (µg/dl) for 1- to 7-year-old children when both the Kondirator and estimated "background" sources of exposure are included in the calculation. These predicted value are above the MDH Safe Blood Lead Level of 1.0 µg/dl. Lead exposures associated with the Kondirator emissions result in increases in geometric mean blood lead concentrations of between 0.2 and 0.4 µg/dl, compared with "background" concentrations alone.

The level of uncertainty in the quantitative estimates of risk from the screening level assessment is very high (Section 10). This is a result of the compounded levels of uncertainty in the various steps of the analysis leading to the estimated risk levels. Major sources of uncertainty include the estimates of the proportions of COCs in the feed materials, the models used to characterize the transport and speciation of COCs in the environment, the assumed behavior of the exposed populations, the models used to estimate risks, and in the toxicological criteria values used to estimate risks. Because of the high level of uncertainty, it would not be valid to consider the risk estimates from this assessment to be any more precise than ±1 order of magnitude (a factor of 10), and the actual level of uncertainty could be much greater.

The high level of uncertainty in the risk estimates is accompanied by a high level of conservatism built into the analysis. In the absence of site-specific data, the generic models and assumptions used in the screening level assessment are intentionally conservative (tending to overestimate risks or exposures). This is a conscious strategy, intended to provide a high level of assurance that risks are not underestimated for any "real" receptor. The specific assumptions that are employed vary as to their levels of conservatism, but the combined effect is to generate risk estimates which are considerably higher than would be derived by a more detailed site-specific analysis. As in the case of the uncertainty in the assessment, the level of intentional conservatism in the risk estimates could well exceed 1 order of magnitude (a factor of 10).

1.0 INTRODUCTION AND SCOPE

Purpose——To provide basic background information on the human health risk assessment.

1.1 BACKGROUND

ICF Kaiser Engineers, Inc. (ICF KE), has been commissioned by the Minnesota Pollution Control Agency (MPCA) to perform a screening level HHRA for the Kondirator metal processing system. The Kondirator is an advanced metal shredding device to be installed at the American Iron and Supply (AIS) metal recycling facility at 2800 Pacific Street in Minneapolis. Detailed background information regarding the Kondirator and potential environmental impacts associated with its operation may be found in the completed data portion of the Draft Environmental Assessment Worksheet (Draft EAW) which has been completed by consultants to AIS. The EAW was in draft form at the time the screening level HHRA was conducted.

This HHRA is being undertaken in response to public concerns regarding potential health impacts of emissions from the Kondirator facility. A companion analysis of the potential ecological impacts of the Kondirator (ERA) is also being undertaken by ICF KE.

As will be discussed in more detail below, the MPCA staff and external reviewers representing the Minnesota Department of Health (MDH), the Applicant, and the City of Minneapolis provided comments on the assessment as it was being performed.

1.2 NATURE OF THE SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT

The limited time and resources allocated for this assessment dictated that the HHRA be limited to a screening level evaluation of the potential risks associated with the Kondirator facility. A screening level assessment is one that employs generic, conservative models and assumptions to provide approximate and conservative characterizations of potential risks. In contrast, a more detailed assessment would use more precise, site-specific information and more detailed models to develop more definitive, less conservative estimates of potential risks.

The objectives of a screening level health risk assessment are——

- To identify which chemicals emitted by the facility are most likely to be associated with adverse effects on human health and which human populations are most likely to be adversely affected;
- To rule out chemicals and exposure pathways which are not likely to be associated with adverse health effects, even under the most conservative plausible exposure and toxicity assumptions;
- To provide quantitative (numerical) estimates of potential human health risks, where such estimates can be derived, by employing conservative, simplified assumptions about exposures and toxicity; and

- To identify the exposure pathways, chemicals, and potential risks associated with the greatest uncertainty and to identify specific needs for additional data or more detailed analysis.

To the extent that quantitative risk estimates are developed in the screening level HHRA, they are likely to overestimate potential risks, compared to the risk estimates that would be developed by a more detailed analysis. This is because the screening level assessment, consistent with generally accepted practice, employs very simple and conservative assumptions to estimate potential health risks. A common misconception regarding the nature of a screening level assessment is that all methods and assumptions used to assess risks are the most conservative that can possibly be employed. If this were done, the high level of conservatism in the individual assumptions could be compounded through the assessment to the point where the resulting risk estimates would be too conservative to distinguish between those risks that were in a range of concern and those that were far below levels of concern. Thus, the point of a screening level assessment is to provide a prudent, realistic level of conservatism based on simple, generic models and reasonably conservative assumptions. For this reason, a finding of low potential risks in a screening level assessment provides a high degree of assurance that potential risks faced under actual exposure conditions are likely to be below levels of concern. This approach provides a high level of assurance that risks are not underestimated.

Because of the nature of the screening level risk assessment and generally conservative approach taken, the screening level HHRA is a limited study that should be used to determine whether a more in-depth risk assessment needs to be conducted. The limitations to the following investigation are appropriate for screening level analyses. Based on the results or limitations of the screening level analyses, risk managers can decide whether a full-scale risk assessment is needed.

The general scope and approach used in the HHRA have been developed by ICF KE in consultation with MPCA, and the final approach has been approved by MPCA. The following general approaches and assumptions have been employed in the HHRA:

- The HHRA is limited to consideration of potential risks associated with the operation of the Kondirator, and does not address potential risks associated with its construction or the combined impacts of the Kondirator emissions with "background" chemical exposures.

- The HHRA is limited to evaluating potential risks associated with particulate air releases from raw material handling and the facility stacks and deposition of particulates to soil, surface water, and sediment. Releases from the Kondirator product pile and barge loading operations could not be accommodated within the scope of the screening level assessment.

- Only a limited number of human receptors are included in the quantitative risk assessment. The primary population addressed is the residents of the neighborhood directly across the river from the facility. This population was selected because they represent the closest residential neighborhood, and will experience the greatest potential exposure from the Kondirator emissions. Individuals potentially exposed through the consumption of contaminated fish taken from the river are also included. Occupational receptors (exposed workers) are not included in the assessment.

- The primary exposure pathway considered is inhalation of airborne particulates. Also included are potential exposure to soils, sediments, and contaminated fish. One potentially significant pathway, the ingestion of home-grown vegetables, is not included because of a lack of reliable site-specific data and the extremely high level of uncertainty associated with this pathway. Potential risks from this pathway are therefore discussed qualitatively in Sections 9.0 and 10.0.

- Simple, standardized models are used to estimate potential exposure and characterize potential risks. Generally, the HHRA follows methods developed by the USEPA for similar applications.

Considerable information regarding the Kondirator feedstocks, operating practices, and air pollution control devices were developed by the Applicant, in the completed data portion of the Draft EAW. These data provide the basis for the identification of potentially toxic chemical emissions, termed constituents of concern (COCs), and for estimates of the amounts of material emitted to the air. These data were reviewed and evaluated by ICF KE in consultation with the engineering consultant for AIS. In a few instances, ICF KE has proposed alternative methods or minor adjustments in the estimates generated by the Applicant to provide what we believe to be more defensible characterization of facility emission and impacts. The data sources for all assumptions and rationale for any adjustments to the Applicant's estimates are documented. These surrogate data sets and modeled air quality impacts are used instead of monitoring data because no facility using the same process and input materials has been identified by MPCA, ICF KE, or the applicant.

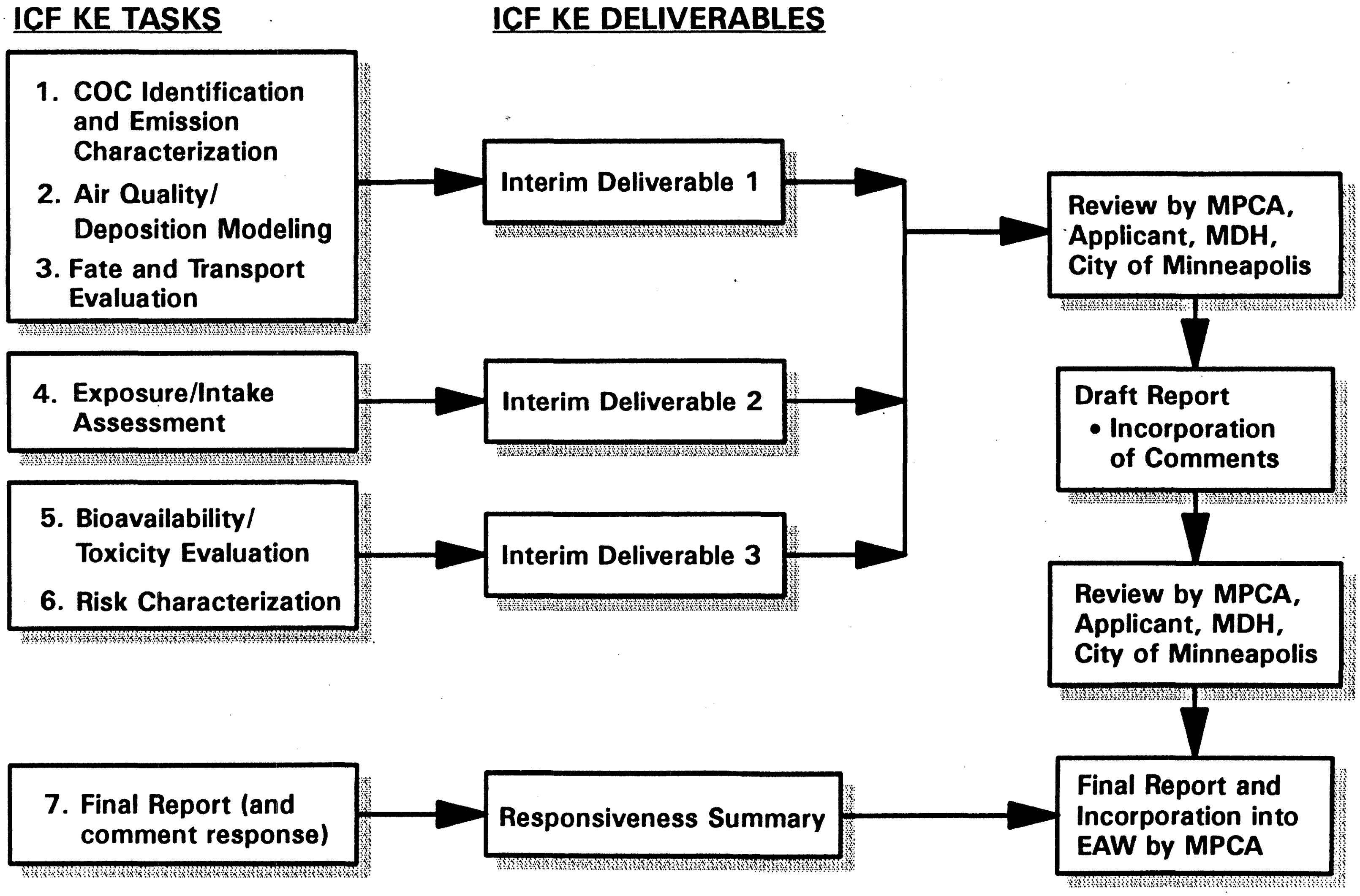
1.3 ORGANIZATION OF THE SCREENING HUMAN HEALTH RISK ASSESSMENT

The organization of the tasks in the HHRA is summarized in Figure 1-1. The screening level HHRA was broken down into six tasks. The results of the various tasks were submitted to MPCA in the form of three Interim Deliverables prior to the assembly of this Final Report. A seventh task, preparation of a Responsiveness Summary, was subsequently added by MPCA.

Each Interim Deliverable and the Draft Final Report (composed of all of the Interim Deliverables) was reviewed by MPCA, the Applicant and its consultants, representatives of the Minnesota Department of Health (MDH), and a health risk assessment expert (Dr. Robert Krieger) representing the City of Minneapolis. ICF KE, in consultation with the MPCA, has incorporated responses to the comments received during the review process into this Final Report. MPCA has final approval responsibility for all required changes/additions to the text. In addition to the Draft and Final HHRA reports, ICF Kaiser has, at the direction of the MPCA, prepared a Responsiveness Summary, which lists all of the written comments received from internal MPCA and external reviewers of the Interim Deliverables and Draft ERA, and the ICF KE/MPCA responses to these comments. Once the HHRA is completed it will be incorporated into the EAW, which will be placed on public notice for public review and comment.

FIGURE 1-1

ORGANIZATION OF SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT FOR THE KONDIRATOR FACILITY



2.0 CONSTITUENT OF CONCERN IDENTIFICATION

Purpose——To identify materials emitted by the Kondirator that are to be included in the human health risk assessment.

This section discusses the identification of specific substances that may be emitted from the proposed Kondirator which may be hazardous to human receptors. Essentially all of the information regarding the nature of the feed materials and their composition was provided by the Applicant. Only limited effort could be made under the time and resource constraints of the HHRA to confirm information provided by the Applicant. Several reviewers of the Interim Deliverables expressed concerns that not enough information was available to adequately identify potentially harmful constituents of concern (COCs). The potential uncertainties associated with this lack of data are discussed in Sections 2.2 and 10.2.

COC selection can be a two-step process. First, the identity and amount of each substance to which receptors may be exposed are estimated. Then, the comprehensive list of emitted substances is screened to eliminate those least likely to be associated with adverse effects on receptors. This allows the risk assessment to be limited only to the most toxic/highest-exposure substances. For the HHRA, the second step was eliminated from the COC selection process. *All of the chemical elements that were documented as being present in the feed materials based on the MSDS information were included in the HHRA.* The implicit assumption is that all elements present in any of the Kondirator feedstocks will also be present in emitted particulates. Adopting these assumptions allows for a suitably conservative approach to the HHRA.

2.1 IDENTIFICATION OF FEED MATERIAL COMPOSITION

According to information provided by the Applicant (Draft EAW), the proposed Kondirator will process ferrous and non-ferrous scrap metal to produce a saleable metal product. Scrap metal, including carbon steel, stainless steel, aluminum, iron and cast iron, copper, brass, and galvanized steel, will be received at the proposed Kondirator site. For economic reasons, the scrap metal will be sorted to remove the non-ferrous scrap metal and stainless steel. Generally, AIS suppliers presort the scraps before delivery to AIS to remove brass, copper, and other more valuable metals. Scrap is also sorted after it is received at AIS.

It was assumed, however, that a small proportion of the feed material could be made up of metals other than carbon steel (see Section 3.1). Thus, all of the elements identified as being present in feed materials other than carbon steel (stainless steel, aluminum, galvanized steel, cast iron, "iron," brass, and copper) were also included as COCs in the HHRA.

The elemental composition of each type of scrap metal to be processed in the proposed Kondirator was identified by the Applicant from the Material Safety Data Sheet (MSDS) for each scrap metal (Resource Consultants, 1991). The use of the MSDS data by the applicant to identify raw material constituents represents a reasonable, although not definitive, approach to determining the composition of the feed to the proposed Kondirator, as MSDS information is specifically intended for use for the purpose of identifying potentially hazardous substances. Several reviewers of the Interim Deliverables expressed concern that the MSDS information was not sufficiently reliable to identify feed material composition adequately. MPCA has requested additional information regarding feed metal composition from the Applicant. The Applicant has provided to MPCA limited additional data regarding the composition of specific scrap metals that could not be incorporated into the HHRA because of time constraints.

2.2 SELECTION OF CONSTITUENTS OF CONCERN

Table 2-1 contains a list of the COCs identified from the MSDSs for the scrap metals and selected by ICF KE for this screening level HHRA. These COCs were identified based on the assumption that the composition of the particulate emissions will be identical to the composition of the raw material feeds as indicated in the MSDSs for each scrap metal. As a simplifying assumption, all of the elements identified to be present in the Kondirator feed materials have been retained as COCs for the purposes of this HHRA.

As shown in Table 2-1, mercury (a toxic heavy metal) is not identified as a constituent in any of the raw material MSDSs. ICF KE does not expect that mercury, a volatile liquid metal, will be present in solid metal scrap. All of the raw material metals would have been produced by a smelting or electrolytic process, and any mercury that may have been present in the ores from which the metals were manufactured would have volatilized during the production process. Further, the Applicant indicated in the Draft EAW that electric switches, which may contain mercury, must be removed from scrap appliances before they are transported to the proposed Kondirator for processing. Table 2-2 summarizes the key assumptions and methods used in the COC selection.

The proposed Kondirator facility process is not a combustion process, and it is not expected that the processing of the non-metal materials associated with the raw material feed to result in the production of significant organic compound emissions. Organic compounds therefore were not identified as constituents of concern. It is possible that some of the metal processed in the proposed Kondirator will contain metal-based paints or coatings. However, based on observations made during a visit to the proposed Kondirator site and on information supplied by the Applicant, it is not expected that such paints and coatings would represent a significant amount of the total metal particulate emissions from the proposed Kondirator process. In addition, no data were available regarding the chemical composition of possible coating materials. Therefore, ingredients of paints and coatings were not explicitly considered as potential COCs.

TABLE 2-1 SELECTION OF CONSTITUENTS OF CONCERN

	PRESENT IN FEED MATERIAL? (a)								
Potential Feed Material	Carbon Steel	Stainless Steel	Aluminum	Galvanized Steel	Cast Iron	Iron	Brass	Copper	SELECTED AS COC? (b)
ALUMINUM	yes	yes	yes	yes	yes	yes	yes	yes	yes
ANTIMONY	no	no	yes	no	no	no	yes	no	yes
ARSENIC	yes	yes	no	yes	yes	yes	yes	yes	yes
BERYLLIUM	no	no	yes	no	no	no	no	yes	yes
BORON	yes	yes	no	yes	yes	yes	no	no	yes
CADMIUM	no	no	yes	no	no	no	no	yes	yes
CALCIUM	yes	yes	no	yes	yes	yes	no	no	yes
CARBON	yes	yes	no	yes	yes	yes	no	no	yes
CHROMIUM	yes	yes	yes	yes	yes	yes	no	yes	yes
COBALT	yes	yes	yes	yes	yes	yes	no	yes	yes
COPPER	yes	yes	yes	yes	yes	yes	yes	yes	yes
IRON	yes	yes	yes	yes	yes	yes	yes	yes	yes
LEAD	yes	yes	yes	yes	yes	yes	yes	yes	yes
LITHIUM	no	no	yes	no	no	no	no	no	yes
MAGNESIUM	no	no	yes	no	no	no	yes	no	yes
MANGANESE	yes	yes	yes	yes	no	no	no	no	yes
MERCURY	no	no	no	no	no	no	no	no	no
MOLYBDENUM	yes	yes	no	yes	yes	yes	no	no	yes
NICKEL	yes	yes	yes	yes	yes	yes	yes	yes	yes
NIOBIUM	yes	yes	no	yes	yes	yes	no	no	yes
SILICON	yes	yes	yes	yes	yes	yes	yes	no	yes
SILVER	no	no	yes	no	no	no	yes	yes	yes
TIN	yes	yes	yes	yes	yes	yes	yes	yes	yes
TITANIUM	yes	yes	no	yes	yes	yes	no	no	yes
TUNGSTEN	no	yes	no	no	no	no	no	no	yes
VANADIUM	yes	yes	yes	yes	yes	yes	no	no	yes
ZINC	no	no	yes	yes	no	no	yes	no	yes
ZIRCONIUM	yes	yes	no	yes	yes	yes	no	no	yes

(a) Source of elemental composition data is the MSDS data (Resource Consultants 1991). "No" indicates maximum concentration = 0.0%. "Yes" indicates maximum concentration > 0.0%.

(b) Elemental composition data for individual scrap metals is shown in Table 3-2.

Table 2-2. Key Assumptions and Methods Used in the COC Selection

Issue Addressed	Assumption/ Method Used	Reason for Approach	Data Sources
Identification of elemental metals in raw material scrap metal feeds	Elemental metal composition of each scrap metal identified in the Material Safety Data Sheet	Material Safety Data Sheets have been specifically developed for applications such as identification of constituents of concern. MPCA has requested additional information from the Applicant	Material Safety Data Sheets
Inclusion of elemental metals identified in scrap metal MSDS as constituents of concern	All elements identified in the MSDS are included as constituents of concern	Provides conservative assessment, no reason to exclude	Material Safety Data Sheets
Exclusion of non-metal (organic) compounds from constituents of concern	Organic compounds or other non-metal compounds are not included as constituents of concern	The proposed Kondirator process is not a combustion process, and is not expected to generate significant amounts of organic or other non-metal compound emissions	ICF KE professional judgment
Treatment of coatings constituents	Not included in the HHRA	Coatings are expected to comprise less than 0.1% of total feed material mass; their composition is unknown	ICF KE professional judgment, based on site visit and information provided by Applicant

3.0 EMISSIONS ESTIMATES

Purpose——To review estimates of particulate emissions developed by the Applicant, and to estimate the proportions of each COC in the total particulate emissions.

Estimates of the total amounts of particulate emitted from the Kondirator facility were developed by Applicant. Both total particulate (TSP) emissions and particle emissions of less than ten microns (PM_{10}) were estimated. Using these emission estimates, the Applicant then estimated the concentrations of TSP and PM_{10} that would occur in the air and which would be deposited on the ground and river surface in the area near the Kondirator. The first part of this section (Section 3.1) describes ICF KE's review of the TSP emission estimates developed by the Applicant, which form the basis for the air quality and deposition impacts discussed in Section 4.0.

ICF KE developed estimates of the proportions of the various COCs expected to be present in the emitted particulates, based on the proportions of the various elements in the individual feed materials and the proportions of the individual feed materials processed in the Kondirator. This analysis is discussed in Section 3.2. The results of this analysis are used to estimate the concentrations of COCs in air and other environmental media, which are presented in Sections 4.0 through 6.0. In estimating air concentrations or deposition impacts throughout the HHRA, the modeled TSP values are multiplied by the estimated proportions of the individual COCs in the feed materials.

3.1 BASIS FOR TOTAL PARTICULATE EMISSIONS ESTIMATES

A process flow diagram for the Kondirator is shown in Figure 3–1. The emissions sources at Kondirator facility are as follows:

(1) Truck traffic on site to unprocessed scrap unloading area (fugitive source)

(2) Unloading of unprocessed scrap onto raw materials storage pile (fugitive source)

(3) Unprocessed scrap storage pile (fugitive source)

(4) Loading of unprocessed scrap from storage pile to Kondirator conveyor feed (fugitive source)

(5) Kondirator hammermill shredder (point source)

(6) Conveyor transfer points in Kondirator facility (fugitive source)

(7) Cascade cleaning system (point source)

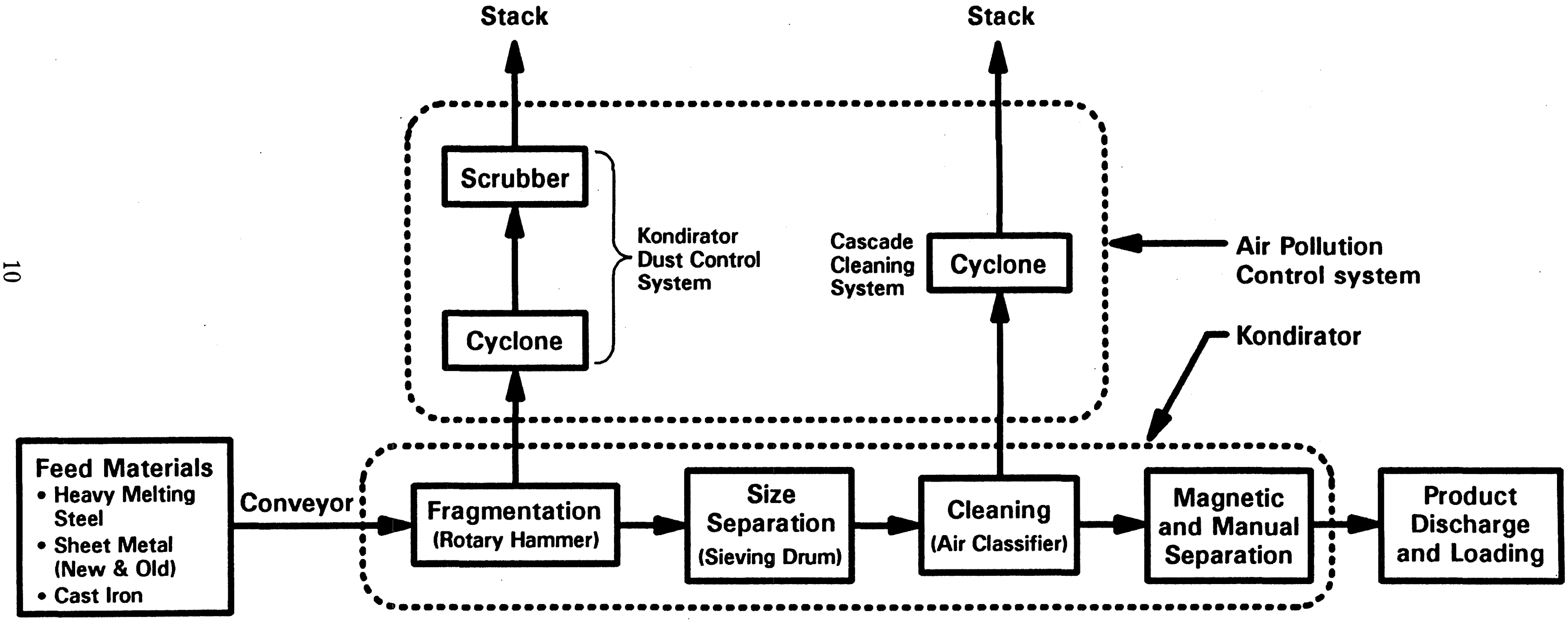
(8) Product loading to product storage pile, railcar, or barge (fugitive source)

(9) Product storage pile (fugitive source)

Emissions from truck traffic were not included in the impact analysis because the Applicant has indicated that on-site roads will be paved and that the roads will be watered, thereby reducing

FIGURE 3-1

PROCESS FLOW DIAGRAM FOR THE KONDIRATOR FACILITY



truck traffic emissions. Raw materials unloading, the raw materials storage pile, and loading to the Kondirator conveyor were included in the emissions from the Raw Material Handling Source in the air quality modeling. The conveyor transfers within the facility were not included, since all conveyors will be enclosed, not open to the atmosphere. Particulate from product loading to barges and the product storage pile were not included in the assessment, based on information from the applicant that the cascade cleaning system will effectively clean dust from the product.

The Applicant estimated TSP and PM_{10} emissions from the Kondirator dust collector at the design maximum raw material throughput of 100 tons per hour by estimating the particulate grain loading (the concentration of particulate in the exhaust gas in units of grains of particulate per cubic foot of exhaust gas) to the air emission control system, and then applying particle size distribution and air emission control system efficiency estimates provided by the air pollution control equipment vendor (Osborne Engineering, 1989; HDR Engineering, 1990). The Applicant estimated the particulate emissions from the cascade cleaning system by using material balance calculations to estimate the particulate loading to the air emission control systems and then applying particle size distribution and air emission control system efficiency estimates provided by the air emission control equipment vendor (Osborne Engineering, 1991; HDR Engineering, 1990). The vendor-supplied estimates are based on testing of equipment similar to the proposed Kondirator and its associated air emission control systems. The Applicant used USEPA emission factors published in the USEPA FIRE database (USEPA, 1994) to estimate fugitive particulate emissions from the raw material handling system, based on a design maximum raw material throughput of 100 tons per hour.

Air emission control systems such as the cyclones and venturi scrubbers proposed for the Kondirator have different particulate removal efficiencies for particles of different sizes; large particles are easier to remove than small particles. Therefore, the calculation of the overall removal efficiency of the control system depends upon the distribution of particle sizes in the inlet exhaust gas stream, and the particulate removal efficiency of air emission control systems is generally reported in terms of efficiencies for various ranges of particle sizes, as was done by the Applicant and the equipment vendor.

The emissions calculation approaches used by the Applicant to calculate stack and fugitive emissions are considered to be reasonable and well-documented, and therefore the TSP and PM_{10} emissions estimates and associated air dispersion modeling results were used in the screening level risk assessment. There are, however, some uncertainties with respect to the emissions calculations that may contribute significantly to uncertainty in the potential risk estimates, as discussed in the following paragraphs.

The Applicant estimated the uncontrolled particulate emissions from the Kondirator fragmentation exhaust based on a vendor-supplied particulate grain loading estimate of 0.2 grains per cubic foot (gr/dscf) for similar hammer mill-type shredder systems (Osborne Engineering, 1989). Additional documentation to verify this value was not available. The Applicant applied a safety factor of 25 to the vendor's estimate and used an inlet grain loading of 5 gr/dscf in the emissions calculations in the Draft EAW. This grain loading corresponds to a particulate inlet rate to the Kondirator dust control system of 1,714 lb/hr. However, emissions calculations for the proposed Kondirator included in the Draft EAW, as discussed further below, indicate that the estimated emissions, including the safety factor, would not exceed state regulatory standards for industrial process equipment. This provides some indication that the emissions estimates from the proposed Kondirator are not unrealistically conservative, even with the application of the safety factor.

The mass balance calculation results in an overall particulate loading to the cascade cleaning system of 3,896 lb/hr. The estimated particle size of the inlet loading to the cascade cleaning system and the particulate removal efficiency of the control system were provided by the vendor (Osborne Engineering, 1991).

The Kondirator dust control system is a two-stage system including a cyclone separator followed by a wet venturi scrubber. The cascade cleaning system air pollution control system is a one-stage system consisting of a cyclone separator. The particulate removal efficiencies of the two control systems are based on the particle size of the inlet particulate loading to the systems estimated by the vendor (e.g., according to the vendor reference the removal efficiency of the Kondirator dust collector for particles greater than 80 microns is 100%, while the removal efficiency for particles less than 10 microns is 53%). The inlet particle size distributions and particle size-specific control efficiencies used in preparing the emissions calculations for the two control systems appear to be reasonable, considering the types of control devices specified for the Kondirator dust collector and cascade cleaning system.

The Applicant provided references for the vendor-supplied particle size distribution and control system efficiency estimates used in preparing the emissions calculations in the Draft EAW (Osborne Engineering 1989 and 1991; HDR Engineering, 1991). The Applicant provided three stack test summaries for operational shredders (not Kondirators) in the U.S., which were used by Osborne to estimate particulate emissions from the Kondirator. Although the inlet particle size distributions and particulate control efficiency estimates in the Draft EAW appear to be reasonable, samples of actual test data for operating Kondirator systems would be useful in further establishing the appropriateness of these estimates. Table 3-1 summarizes the key assumptions and data sources for air emissions estimations. According to the Applicant, the total estimated particulate emissions from the three sources is 10.22 lb/hr. PM_{10} emissions were also estimated as a fraction of the TSP, but this value was not used in the risk assessment, as all exposure estimates were developed based on TSP values. The TSP emission estimates were used by the Applicant as input values to the air quality modeling discussed in Section 4.0, but were not used directly in the HHRA risk calculations.

3.2 EMISSIONS ESTIMATES OF INDIVIDUAL COCS

Estimates of the amount of individual COCs that would be emitted from the Kondirator have been developed based on the elemental composition of the individual feed materials, and the proportions of the various feed materials which would be processed in the facility. ICF Kaiser has reviewed these assumptions, and modified them slightly to develop estimates of individual COC emissions, which while independently calculated, still depend on data supplied by the Applicant. The results of this evaluation are summarized in Table 3-2. This does not significantly affect risk findings in Section 9.

The Applicant indicated in the Draft EAW that no more than 95% of the material input to the proposed Kondirator is expected to be metal scrap, based on worst-case operating conditions. The expected raw materials feed to the Kondirator is 90% carbon steel; 2% stainless steel; and 2% aluminum; 1% (total) iron, cast iron, copper, brass, and galvanized steel; and 5% nonmetallic scrap. These assumptions are based on the operating experience of the Applicant. The Applicant indicated that there is an economic rationale for limiting the input of non-ferrous metals to the proposed Kondirator in that non-ferrous scrap metals such as stainless steel, aluminum, brass, and copper bring a higher price on the market than carbon steel scrap. Any non-ferrous metal scrap entering the

Table 3-1. Key Assumptions and Data Sources for Emissions Estimation

Issue Addressed	Assumption/Method Used	Reason for Approach	Data Sources
Composition of raw material input vs. particulate emissions	Particulate emissions are assumed to have the same composition as the raw material scrap metal input	This assumption is reasonable considering the physical nature of the proposed Kondirator process.	ICF KE professional judgment
Partitioning of scrap metals in proposed Kondirator feed	The Applicant assumed that the worst-case raw material feed to the proposed Kondirator will be 90% carbon steel, 2% stainless steel, 2% aluminum, 1% other metals (including iron, cast iron, galvanized iron, brass, and copper), and 5% non-metal scrap. The applicant then normalized this to obtain 100%. ICF KE assumed that the worst-case raw material feed to the proposed Kondirator will be 90% carbon steel, 2% stainless steel, 2% aluminum, 1% iron, 1% cast iron, 1% brass, 1% copper, and 1% galvanized steel	The Applicant has an economic rationale for limiting the input of non-ferrous metals to the proposed Kondirator. It was determined that a better assumption would be to assume that the "other metals" category comprises 5% of the Kondirator feed material, assuming 1% *each* of iron, cast iron, galvanized iron, copper, and brass	ICF KE professional judgment
Proposed Kondirator dust collector inlet particulate loading	Inlet loading modified by safety factor from vendor's estimate based on equipment test data	The safety factor was applied by the applicant to account for differences between the proposed Kondirator and equipment tested. This safety factor is likely to be conservative.	Vendor-supplied estimate.
Cascade cleaning system inlet particulate loading	Inlet loading based on material balance calculations around cascade cleaner based on assumed quality of product material	The use of material balance calculations for cascade cleaner represents a simple approach to calculate inlet loading. The assumed "quality" of the product material is not referenced in the Draft EAW, however, and represents an uncertainty in our analysis.	Estimate of quality of product material provided by applicant.
Proposed Kondirator dust collector inlet particle size distribution	Inlet particle size distribution from vendor's estimate based on equipment test data	The use of equipment test data represents a reasonable approach to the estimation of particle size distribution provided that the equipment tested is similar to the proposed unit.	Vendor-supplied estimate.
Cascade cleaning system inlet particle size distribution	Inlet particle size distribution from vendor's estimate based on equipment test data	The use of equipment test data represents a reasonable approach to the estimation of particle size distribution provided that the equipment tested is similar to the proposed unit.	Vendor-supplied estimate.
Proposed Kondirator dust collector control system efficiency	Particle size-specific control system efficiency from vendor's estimate based on equipment test data	The use of equipment test data represents a reasonable approach to the estimation of particle size distribution provided that the equipment tested is similar to the proposed unit.	Vendor-supplied estimate.
Cascade cleaning system control system efficiency	Particle size-specific control system efficiency from vendor's estimate based on equipment test data	The use of equipment test data represents a reasonable approach to the estimation of particle size distribution provided that the equipment tested is similar to the proposed unit.	Vendor-supplied estimate.

TABLE 3-2 PROPORTIONS OF SCRAP METALS IN KONDIRATOR FEED, ELEMENTAL COMPOSTIONS OF SCRAP METALS, AND DERIVED FEED MATERIAL COMPOSITION USED IN THE RISK ASSESSMENT

	FEED MATERIAL ELEMENTAL COMPOSITION (a)										
Potential Feed Metal	Carbon Steel	Stainless Steel	Aluminum	Galvanized Steel	Cast Iron	Iron	Brass	Copper	Weighted Average Composition (b)	Toxicity Adjusted Composition (c)	Feed Material Composition (d)
Proportion Assumed by ICF KE	90% (e)	2% (e)	2% (e)	1% (f)	1% (f)	1% (f)	1% (f)	1% (f)			
Aluminum	0.1%	5.0%	70.0%	0.1%	0.1%	0.1%	8.0%	2.0%	1.69%	1.76%	1.76%
Antimony	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.03%	0.02%	0.03%
Arsenic	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	1.0%	1.0%	0.12%	0.11%	0.12%
Beryllium	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	3.0%	0.05%	0.05%	0.05%
Boron	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.10%	0.10%	0.10%
Cadmium	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.08%	0.08%	0.08%
Calcium	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.10%	0.09%	0.10%
Carbon	2.0%	3.0%	0.0%	1.0%	5.0%	5.0%	0.0%	0.0%	1.97%	1.84%	1.97%
Chromium	0.1%	27.0%	1.0%	0.1%	0.1%	0.1%	0.0%	2.0%	0.67%	0.71%	0.71%
Cobalt	0.1%	12.0%	3.0%	0.1%	0.1%	0.1%	0.0%	3.0%	0.42%	0.44%	0.44%
Copper	0.1%	5.0%	11.0%	0.1%	0.1%	0.1%	49.0%	94.0%	1.84%	1.42%	1.84%
Iron	96.0%	45.0%	2.0%	90.0%	92.0%	94.0%	4.0%	3.0%	90.17%	87.10%	90.17%
Lead	0.1%	0.1%	9.0%	0.1%	0.1%	0.1%	8.0%	2.0%	0.38%	0.37%	0.38%
Lithium	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.08%	0.08%	0.08%
Magnesium	0.0%	0.0%	11.0%	0.0%	0.0%	0.0%	13.0%	0.0%	0.35%	0.22%	0.35%
Manganese	2.0%	5.0%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	1.96%	2.04%	2.04%
Molybdenum	0.1%	10.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.29%	0.31%	0.31%
Nickel	0.1%	36.0%	3.0%	0.1%	0.1%	0.1%	4.0%	3.0%	0.94%	0.96%	0.96%
Niobium	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.10%	0.09%	0.10%
Silicon	0.1%	3.0%	23.0%	0.1%	3.0%	1.0%	6.0%	0.0%	0.71%	0.60%	0.71%
Silver	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	1.0%	2.0%	0.05%	0.04%	0.05%
Tin	0.1%	0.1%	20.0%	0.1%	0.1%	0.1%	7.0%	2.0%	0.59%	0.59%	0.59%
Titanium	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.10%	0.09%	0.10%
Tungsten	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.40%	0.39%	0.40%
Vanadium	0.1%	5.0%	1.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.21%	0.22%	0.22%
Zinc	0.0%	0.0%	9.0%	5.0%	0.0%	0.0%	51.0%	0.0%	0.74%	0.19%	0.74%
Zirconium	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.10%	0.09%	0.10%
Total Metals	101.60%	176.80%	175.00%	99.60%	101.50%	101.50%	153.00%	119.00%	104.22%	100.00%	104.46%

(a) Source is the MSDS data provided by the Applicant.

(b) Calculated by multiplying the proportion of the individual scrap metals in the feed materials by the estimated concentration of the metals in the scrap, and summing the results. The total is greater than 100% because the elemental compostions of the scrap metals are reported as ranges, and the maximum values in the ranges were used.

(c) The total metals concentrations were adjusted to 100 percent; the concentrations of the less toxic metals were reduced and the concentrations of some of the more toxic metals were increased slightly to provide a more conservative estimate of risks.

(d) The concentrations used are the larger of the values estimated in the two proceeding columns. These values were used to calculate air concentrations and deposition rates found in Tables 4–3, 4–4, 5–5, and 7–6.

(e) Same proportions of these metals were assumed as were assumed in the EAW.

(f) Proportions assumed by ICF KE to provide conservative estimate of risks. In the EAW, the total concentration of these metals combined was assumed to be one precent.

proposed Kondirator process is incorporated into the carbon steel scrap product, and thereby loses value.

ICF KE developed conservative estimates of the concentrations of individual elements in the Kondirator feed materials using slightly different methods from those employed by the Applicant. First, it was assumed that 99 percent, rather than 95 percent of the total material input to the Kondirator would be metal, thus increasing the total metal content of the feed materials. The proportions of the individual scrap metals which were assumed to be in the Kondirator feed are shown at the top of Table 3-2.

Based on this assumption, two separate estimates of the elemental concentrations were developed, using the MSDS data supplied by the Applicant. First, a simple weighted-average set of metal concentrations was calculated by multiplying the proportions of the individual scrap metals in the feed by the maximum concentrations of the individual metals in each feed metal, and totaling the results to give an estimate of the concentration of each metal weighted across all of the Kondirator feed materials. The results of this calculation are shown in Table 3-2 in the column labeled "Weighted Average Composition". The total of the estimated metals concentrations (at the bottom of this column) exceeds 100 percent because the MSDS data gives ranges of metals compostions for many of the elements, and the sums of these maximum elemental concentrations in the individual scrap metals also exceed 100 percent.

The second estimate of concentrations was derived by ICF Kaiser using professional judgement and a qualitative assessment of the toxicity of the various elements. This estimate was derived by first "normalizing" the total of the estimated metals concentrations to 99 percent (the total proportion of scrap metal in the feed materials) and then adjusting the composition of some of the more toxic metals upward slightly so that the total elemental composition was again equal to 100 percent. The upward adjustments in the concentrations of the individual metals were all less than 7 percent. The results of these calculations are referred to as "Toxicity Adjusted Composition" shown in the next-to-last column of Table 3-2. This does not significantly affect the risk findings in section 9.

Finally, the concentrations of the individual metals used in the estimation of exposures were derived by taking the greater of the Weighted Average Concentrations or the Toxicity Adjusted Concentrations. This approach provided a small additional degree of conservatism in the estimates of risk and exposure. The values are shown in the last column of Table 3-2.

The concentrations (proportions) of each of the COC elements shown in the last column of Table 3-2 were used in the exposure assessment for the HHRA. As discussed in the following sections, TSP impacts (air concentrations and deposition estimates) estimated by the Applicant were multiplied by the proportions of the individual COCs to obtain estimates of the air concentrations and deposition rates for the COCs.

4.0 AIR QUALITY AND PARTICULATE DEPOSITION MODELING

Purpose——To develop estimates of the concentrations of COCs in air and deposited on the ground and surface water due to the Kondirator operation.

The Applicant conducted the modeling studies in support of the air permit application and Draft EAW for the proposed Kondirator to estimate the ambient air concentrations and deposition of particulates from the proposed Kondirator. Data from operating Kondirator facilities were not available, so modeled values were used in the assessment. The modeled ambient air concentrations of particulates were compared to state and federal ambient air quality standards for particulate matter by the Applicant. Both the modeled ambient particulate concentrations and particle deposition rates (provided by the Applicant's consultant in computer files) serve as inputs for the screening level HHRA. This section discusses ICF KE's review of the air quality and particulate deposition modeling methodology and results prepared by the applicant.

The Applicant did not report the elemental composition of the emitted particulates, only the total PM_{10} and TSP concentration and deposition rates. ICF KE has calculated the composition of the particulates based on the composition of the raw material feeds to the proposed Kondirator, as discussed in Section 3.2. Section 4.1 discusses the methodology used by the applicant to conduct air quality concentration and deposition modeling, and Section 4.2 discusses the air quality and deposition modeling results.

4.1 REVIEW OF ENVIRONMENTAL ASSESSMENT WORKSHEET MODELING

ICF KE considers the air dispersion and deposition modeling approaches used by the applicant to estimate ambient TSP concentrations and particulate deposition to be appropriate and well-documented, and has therefore used the TSP air dispersion and deposition modeling results in the HHRA without modification. There are, however, some uncertainties with respect to the air dispersion and deposition modeling that still need to be addressed. A more detailed discussion of the basis for the air dispersion and deposition modeling and uncertainties identified in ICF KE's review of the documentation follows in this section.

4.1.1 Review of Draft EAW Air Quality Dispersion Modeling Methods

The completed data portion of the Draft EAW includes a discussion of ambient air quality modeling. According to the Applicant's modeling consultant, the modeling was revised using different assumptions after the Draft EAW was completed. The "revised" modeling results were provided in computer files to ICF KE. The assumptions that were revised included the selection of a different emission factor equation for the calculation of fugitive emissions from the raw material handling system, deletion of the modeling of fugitive emissions from product handling, and deletion of the modeling of emissions from unpaved roads on the site. The Applicant indicated that controls would be applied to these fugitive emissions sources (e.g., paving of unpaved roads) that were deleted from the modeling study, to reduce the modelled level of emissions from these sources.

Because of the changes in assumptions from those included in the Draft EAW, the results of the current modeling are somewhat different than those reported in the Draft EAW. The Applicant provided supplemental documentation to ICF KE (Barr 1994) describing the changes to the modeling assumptions and revised modeling results. The discussion in this section and Section

4.1.2 below is based on the most recent modeling methodology and results. A summary of the air quality deposition modeling input data and results provided by the Applicant's consultant is provided as Appendix A.

Ambient concentrations of particulates (TSP and PM_{10}) emitted from the proposed Kondirator stack and fugitive air emissions sources were modeled by the Applicant using the USEPA ISCST2 dispersion model. Annual and 24-hour average concentrations were estimated using meteorological data from Minneapolis. The modeling methodology and modeling results are discussed in the Draft EAW. The Applicant also provided concentration isopleth figures to ICF KE for both TSP and PM_{10} (these isopleths were not included in the Draft EAW).

The Draft EAW reported only annual average and 24-hour average concentrations. However, the evaluation of potential acute adverse effects (see Section 9.3) needs to be based on short-term (1-hour) average concentrations. ICF KE requested that the applicant perform additional modeling of 1-hour average concentrations. The Applicant agreed to perform this additional modeling, and the applicant provided ICF KE with concentration isopleths for the 1-hour average TSP and PM_{10} concentrations. The modeling results reported in this document are based on ICF KE's analysis of the isopleths provided by the applicant. ICF KE did not review background documentation for the 1-hour average modeling performed by the applicant, but assumes, based on discussions with the Applicant's modeling consultant, that the modeling was conducted using the same methodology as was used for the 24-hour and annual average modeling.

The Applicant used stack parameters taken from the April 1991 MPCA air permit application prepared by HDR Engineering and emissions information developed for the December 1990 air permit application. This information in the air permit applications has not been revised or updated since 1991. Emissions from the Kondirator dust collector system and cascade cleaning system were modeled as point sources, and the emissions from the raw material handling system were modeled as a volume source. The volume, area, and release height used in modeling emissions from the volume source were selected by the Applicant to represent a "representative" work area of the source. Both the raw material unloading pile and the noise barriers were considered as structures that could potentially induce downwash, and the Applicant considered this potential downwash in conducting the dispersion modeling.

Model receptors were located on a Cartesian coordinate system with the Kondirator dust collector system stack as the center of the receptor grid (location 0E, 0N). Model receptors were located out to a distance of 1,600 meters from the Kondirator dust collector system stack, and also located along the site boundary. The USEPA ISCST2 model was run in the "urban" land use mode, based on the characteristics of the vicinity of the facility, and the elevation of each receptor was considered in the model. Regulatory default control options were also used in the modeling. The key assumptions and methods used in the air quality modeling are shown in Table 4-1.

4.1.2 Review of Draft EAW Particulate Deposition Modeling

The Draft EAW includes a discussion of particulate deposition modeling. In the revised modeling (Barr 1994), the modeling was revisited using somewhat different assumptions (Appendix A). The assumptions that were revised included the selection of a different emission factor equation for the calculation of fugitive emissions from the raw material handling system, deletion of the modeling of fugitive emissions from product handling, and deletion of the modeling of emissions from unpaved roads on the site. The Applicant indicated that controls would be applied to the

Table 4-1. Key Assumptions and Methods Used in Air Quality Modeling

Issue Addressed	Assumption/ Method Used	Reason for Approach	Data Sources
Modeling transport of particulate emissions from stack emissions sources	Modeling was conducted by Barr Engineering using the EPA ISCST2 model	This is the most-current version of the EPA-approved model for this modeling application.	Revised air quality and deposition modeling results supplied to ICF KE by Barr Engineering
Modeling transport of particulate emissions from fugitive emissions sources	Modeling was conducted by Barr Engineering using the EPA ISCST2 model	This is the most-current version of the EPA-approved model for this modeling application.	Revised air quality and deposition modeling results supplied to ICF KE by Barr Engineering
Modeling particulate deposition from stack and fugitive sources	Modeling was conducted by Barr Engineering using the EPA ISCST2 model	ISCST2 algorithm is a simpler approach than available alternatives and therefore more appropriate for large dense particle deposition	Revised air quality and deposition modeling results supplied to ICF KE by Barr Engineering

fugitive emissions sources (e.g., paving of unpaved roads) that were deleted from the modeling study to reduce the modelled level of emissions from these sources.

Because of the changes in assumptions from those included in the Draft EAW, the results of the current modeling are somewhat different than those reported in the Draft EAW. The Applicant provided supplemental documentation to ICF KE describing the changes to the modeling assumptions and revised modeling results (Barr 1994). The discussions in this section and Section 4.1.1 above are based on the most current modeling methodology and results provided to ICF KE.

Dry deposition of particulates (TSP) emitted from the proposed Kondirator stack and fugitive air emissions sources were modeled by the applicant using the USEPA ISCST2 dispersion model. Annual average deposition was estimated using meteorological data from Minneapolis. The modeling methodology used and modeling results are discussed in the EAW (as modified by the Applicant). The Applicant also provided deposition isopleth figures to ICF KE for TSP for use in the screening level HHRA (these isopleths were not included in the Draft EAW).

The annual dry deposition (in units of grams per square meter area) of particulates (TSP) to be emitted from the three air emissions sources associated with the proposed Kondirator was estimated based on the results of the USEPA ISCST2 dispersion modeling included in the Draft EAW (as modified as discussed above) and discussed in Section 4.1.1. The USEPA ISCST2 model incorporates a deposition algorithm, and the Applicant used this algorithm to estimate deposition. The applicant reported that the USEPA ISCST2 algorithm was used instead of the Sehmel and Hodgson curves because of the relatively large size and high density of the particulate. According to the Applicant's consultant, the algorithm in the USEPA ISCST2 model is a simple algorithm based on Stoke's Law, and is more appropriate for large, dense particle deposition than the Sehmel and Hodgson curves, which contain more complex assumptions concerning secondary deposition and re-entrainment that the Applicant does not expect to be applicable to the deposition of large, dense particulate matter. The Applicant's consultants also indicated that the choice of deposition model had been discussed with the MPCA.

The Applicant estimated particulate emissions from the fugitive source in two size categories, less than 10 microns and 10 to 30 microns. According to the Applicant's consultant, this assumption was based on the USEPA emission factors for PM_{10} and TSP (the ratio of PM_{10} to non-PM_{10} emission factors is 1:1). Particle size distribution information was provided by the vendor for the particulate emissions control equipment from the two stacks (Osborne Engineering, 1989, 1991). Settling velocities of the particulate emitted were calculated by the Applicant using Stoke's Law. The key assumptions and methods used in the deposition modeling are shown in Table 4-2.

4.2 ESTIMATED AIR QUALITY IMPACTS

As will be discussed further in Section 7.0, exposures to residential receptors are estimated using a modeled receptor location almost directly across the Mississippi River to the east of the facility (see Figure 7-1). The exposure location used to model these impacts was the highest-impact location on the eastern bank of the river. Using this point to evaluate exposures represents a conservative approach to the HHRA, as it slightly overestimates exposures for the bulk of the residential area across the river from the Kondirator.

The concentration of TSP used in the assessment of chronic health risks (cancer and noncancer) was the estimated maximum annual TSP concentration at the shoreline receptor

Table 4-2. Key Assumptions and Methods Used in Deposition Modeling

Issue Addressed	Assumption/ Method Used	Reason for Approach	Data Sources
Modeling particulate deposition from stack and fugitive sources	Modeling was conducted using the EPA ISCST2 model	ISCST2 algorithm is a simpler approach than the Sehmel and Hodgson and therefore more appropriate for large dense particle deposition.	Revised deposition modeling results supplied by Barr Engineering
Proposed Kondirator dust collector outlet particle size distribution	Outlet particle size distribution from vendor's estimate based on equipment test data	The use of equipment test data represents a reasonable approach to the estimation of particle size distribution provided that the equipment tested are similar to the proposed unit. Alternative data sources could not be identified. The assumptions made regarding particle size distribution appear reasonable.	Vendor-supplied estimate.
Cascade cleaning system outlet particle size distribution	Outlet particle size distribution from vendor's estimate based on equipment test data	The use of equipment test data represents a reasonable approach to the estimation of particle size distribution provided that the equipment tested are similar to the proposed unit. Alternative data sources could not be identified. The assumptions made regarding particle size distribution appear reasonable.	Vendor-supplied estimate.

associated with Kondirator emissions (background omitted) obtained from the five-year modeling period 1987-1991. Use of this value probably provides a conservative estimate of the Kondirator air TSP impacts which would be estimated over the entire facility life. The maximum average annual air concentration at this location owing to Kondirator emissions alone was 1.3 $\mu g/m^{3.}$ For the short-term risk characterization in Section 9.3, the maximum estimated one-hour TSP concentration due to the Kondirator emissions was used. This value was 106 $\mu g/m^3$ (Barr engineering 1994).

The estimated long- and short-term concentrations of the various COCs were calculated by multiplying the long- and short-term TSP values by the proportions of the individual COCs in the feed materials (Table 3-2). The results of these calculations are shown in Table 4-3.

The spatial distribution of long term modeled TSP concentration attributable to the Kondirator plus background sources is shown in Figure 4–1. The pattern of deposition of particulates coincides with the modeled air quality impacts. As discussed above, ICF KE modified the calculation of constituent concentrations in the emissions from that prepared by the Applicant. Therefore, as shown in the table, the total concentration of all constituents at each of the receptor locations modeled from the TSP emissions sums to slightly more than the total TSP concentrations. This discrepancy does not represent a significant effect on the modeling impacts.

4.3 ESTIMATED PARTICULATE DEPOSITION

The particulate deposition rates used to model COC accumulation in soils and surface water were the maximum annual deposition rates for TSP calculated for the five-year modeling period. The soil deposition rate for the same eastern-shore receptor location that was used to estimate air quality impacts was used to calculate COC concentrations in surface soil due to Kondirator emissions. The maximum annual TSP deposition at this location calculated by the Applicant was 13.0 g/m^2-year.

Deposition rates of the individual COCs onto the Mississippi River were calculated using the maximum annual TSP deposition rate averaged over the reach of the river adjacent to the facility. The estimated deposition rate for the river was 39.75 g/m^2-year.

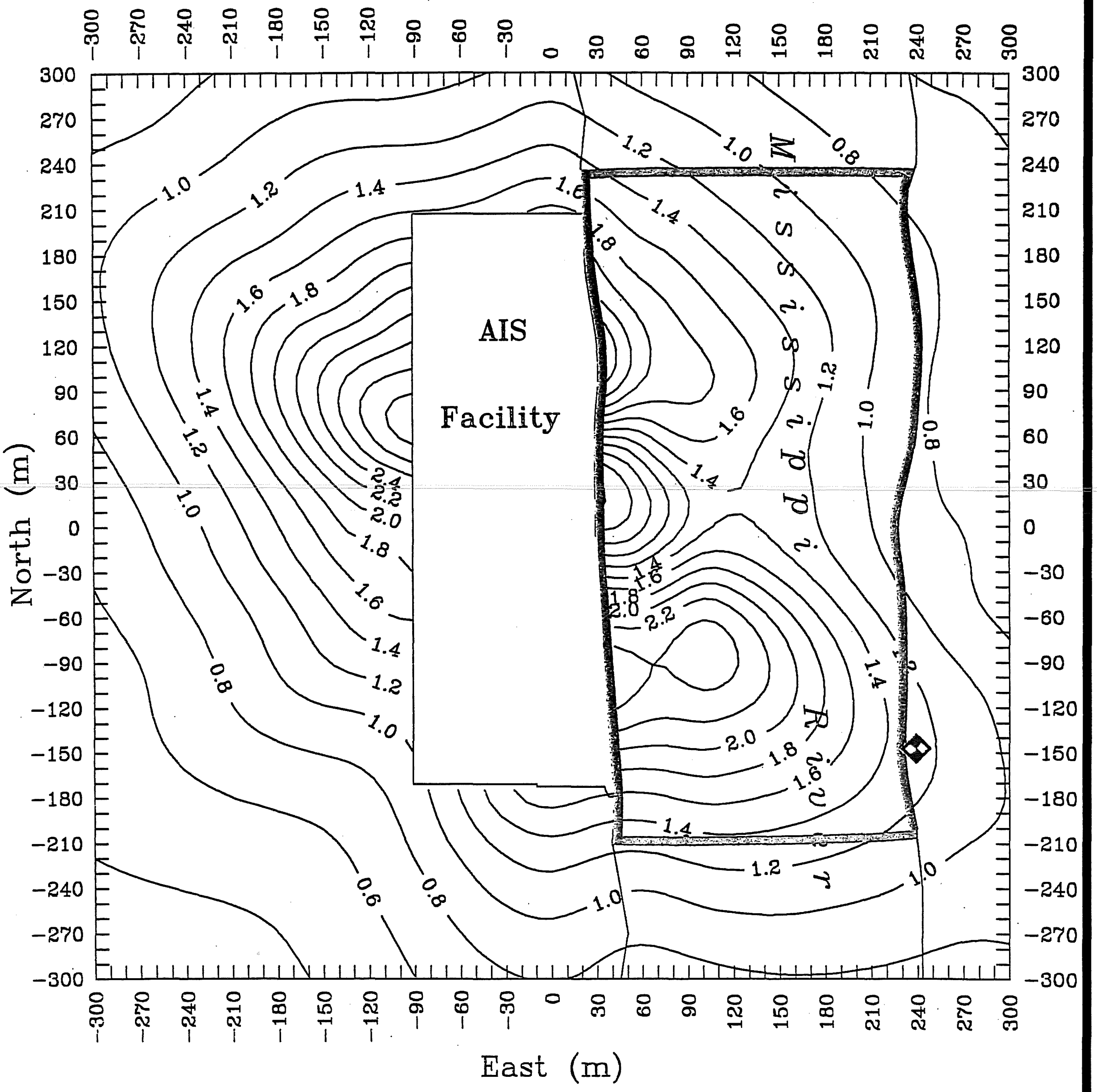
The calculated COC deposition rates for the shoreline receptor and river are summarized in Table 4-4. These values are used to estimate exposures to contaminated soils as described in Section 7.3, and to estimate concentrations of COCs in water and sediment, as described in Section 5.1.

TABLE 4–3

Summary of Estimated Short and Long–Term Air Quality Impacts From the Proposed Kondirator Facility at the Eastern Shoreline Receptor Location

Constituents of Concern	Feed Material Composition	COC Concentrations in Air (ug/m3) (a)	
		1–Hour	Annual
Aluminum	1.76%	1.87	0.023
Antimony	0.03%	0.03	0.0004
Arsenic	0.12%	0.12	0.0015
Beryllium	0.05%	0.05	0.0007
Boron	0.10%	0.10	0.0012
Cadmium	0.08%	0.08	0.0010
Calcium	0.10%	0.10	0.0012
Carbon	1.97%	2.09	0.026
Chromium	0.71%	0.75	0.009
Cobalt	0.44%	0.47	0.006
Copper	1.84%	1.95	0.024
Iron	90.17%	95.58	1.17
Lead	0.38%	0.40	0.0049
Lithium	0.08%	0.08	0.0010
Magnesium	0.35%	0.37	0.0046
Manganese	2.04%	2.16	0.027
Molybdenum	0.31%	0.33	0.0040
Nickel	0.96%	1.02	0.012
Niobium	0.10%	0.10	0.0012
Silicon	0.71%	0.75	0.009
Silver	0.05%	0.05	0.0007
Tin	0.59%	0.63	0.008
Titanium	0.10%	0.10	0.0012
Tungsten	0.40%	0.42	0.005
Vanadium	0.22%	0.23	0.003
Zinc	0.74%	0.78	0.010
Zirconium	0.10%	0.10	0.0012
TOTAL METAL	104.47%	110.74	1.36

(a) Calculated by multiplying the 1 hour or annual average TSP concentration of 106 or 1.3 ug/m3 at the shoreline receptor (located approximately 230m east and –120m north of the Kondirator facility) provided by the Applicant by the elemental metal compositions from Table 3–2. These values are used to calculate inhalation exposure concentrations (IECs) in Table 7–4, and in the short–term risk characterization in Section 9–3.



LEGEND:

▭ RIVER AREA USED FOR DEPOSITION CALCULATIONS

◈ RESIDENTIAL EXPOSURE LOCATION (LONG–TERM TSP CONCENTRATION = 1.3 $\mu g/m^3$)

—N—

ICF KAISER

9300 LEE HIGHWAY
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REVISION NO.:	DATE: 07/10/95	ACAD FILE: KONDITSP

MAXIMUM ANNUAL MODELED TSP CONCENTRATIONS ($\mu g/m^3$) FROM AMERICAN IRON AND SUPPLY SOURCES 1987 THROUGH 1991 METEOROLOGICAL DATA

DET'D:	CLIENT:	PROJECT NO.:
CST	MPCA	51429–001–00
CHK'D:	LOCATION:	FIGURE NO.:
WM	MINNEAPOLIS, MN	**4-1**

TABLE 4–4

SUMMARY OF DEPOSITION IMPACTS FROM THE PROPOSED KONDIRATOR FACILITY

Constituents of Concern	Annual Particulate Deposition to Soil at the Eastern Shoreline Receptor (g/m^2) (a)	Annual Deposition into Mississippi River (g/m^2) (b)
Aluminum	0.23	0.70
Antimony	0.004	0.012
Arsenic	0.015	0.05
Beryllium	0.007	0.02
Boron	0.012	0.04
Cadmium	0.010	0.03
Calcium	0.012	0.04
Carbon	0.26	0.78
Chromium	0.09	0.28
Cobalt	0.06	0.17
Copper	0.24	0.73
Iron	11.72	35.84
Lead	0.05	0.15
Lithium	0.01	0.03
Magnesium	0.05	0.14
Manganese	0.27	0.81
Molybdenum	0.04	0.12
Nickel	0.12	0.38
Niobium	0.01	0.04
Silicon	0.09	0.28
Silver	0.01	0.02
Tin	0.08	0.23
Titanium	0.01	0.04
Tungsten	0.05	0.16
Vanadium	0.03	0.09
Zinc	0.10	0.29
Zirconium	0.01	0.04
TOTAL METAL	13.58	41.53

(a) Calculated by multiplying the TSP deposition rate of 13.0 g/m^2 at the shoreline receptor (located approximately 230m east and –120m north of the Kondirator facility) by the feed material elemental proportions from Table 3–2. These values are used to calculate soil exposures in Tables 7–6 and 7–7.

(b) Calculated by multiplying the average TSP deposition rate of 39.75 g/m^2–year over the Mississippi River mixing zone by the elemental metal concentration from Table 3–2. These values are used to calculate water concentrations (Table 5–5) and sediment concentrations (Table 5–6).

5.0 SURFACE RUNOFF, SURFACE WATER, AND SEDIMENT TRANSPORT MODELING

Purpose—To evaluate chemical releases to water and evaluate transport in river water and sediment.

When metals are emitted into the air and subsequently deposited onto surface waters, they could affect water quality. Chemicals deposited onto soil may also run off into nearby surface water bodies. The Mississippi River lies adjacent to the Kondirator site; thus, metals directly deposited from the air, as well as metals suspended in stormwater runoff, may reach the river. Human receptors may be exposed by contact with surface water, sediment, and, possibly, contaminated biota. The following section discusses the methodology used to predict the levels of COCs in the Mississippi River as a result of emissions from the Kondirator facility.

5.1 MODELING METHODS AND ASSUMPTIONS FOR WATER QUALITY IMPACT ASSESSMENT

Screening level modeling was conducted to evaluate the potential impact on surface water quality of Kondirator operation. This screening level assessment used steady-state assumptions and conservative estimates of physical and water quality parameters. Emissions from the site may reach the Mississippi River through two separate pathways, (1) via discharge from the wet detention pond, and (2) direct deposition. Each of these transport pathways were considered in this analysis.

The following sections discuss the modeling approach for each transport pathway and the predicted concentrations in the Mississippi River. A comparison to measured background concentrations was also performed where data were available.

5.1.1 Releases from Stormwater Basin into Mississippi River

Particulate emissions from the Kondirator process will deposit on the land surface of the facility. During storm events, a portion of these particulates will be suspended in runoff and transported to the wet detention pond. Detention ponds, both wet and dry, are designed to detain stormwater and release it at a controlled rate. Additionally, wet detention ponds are designed to promote particle settling, thus reducing particulate discharge. These ponds are designed and constructed according to state specifications. In Minnesota, the design storm (the storm intensity that the pond must be able to handle) is a one-year return period storm with depth of two inches and duration of 12 hours (Draft EAW).

The amount of particulate removal depends upon many site-specific and storm-specific factors, such as antecedent soil moisture, duration of the storm, intensity of the storm, time between storm events (i.e, accumulation time), pond length-to-width ratio, and the size of the permanent pool. Each of these descriptive factors is likely to change with each storm event. A simplified scenario was used to calculate discharges from the stormwater retention pond. The major assumptions of this scenario are—

- All of the COCs deposited onto the surface of the Kondirator property are swept into the stormwater retention pond by runoff. The average annual deposition rate on the facility property was used to estimate pond COC loading.

Table 5-1. Key Assumptions and Methods Used in the Surface Water and Sediment Transport Evaluation

Issue Addressed	Assumption/ Method Used	Reason for Approach	Data Sources
Stormwater			
Intermittent flow from the wet detention pond	Wet detention pond discharges continuously	Limited time available to conduct complete hydrologic analysis. Simplifying assumption.	ICF professional judgment
Varying sizes and intensities of rainfall during a typical year	Assumed all storms are equal to the design storm (i.e., 2-inch, 12-hour)	Conservative simplifying assumption.	ICF professional judgment
Varying wet detention pond removal efficiency depending upon site conditions	Assumed all removal equal to that predicted for the 2-inch, 12-hour storm	Limited time available to conduct complete hydrologic analysis, pond routing, and prediction of pollutant concentrations	ICF professional judgment
Lateral and longitudinal variation of concentrations in the Mississippi River	Evaluated conditions at complete mixing	Highest concentrations outside of the discharge plume will occur at the point when complete mixing occurs	ICF professional judgment
Atmospheric Deposition			
Deposition rate varies along the river	Averaged deposition rates over the mixing zone	Simplifies analysis but underestimates impacts by neglecting deposition in other river reaches, runoff from soils.	ICF professional judgment
Transport of metals out of the water column area considered	All metals remain suspended in the water column	Conservative estimate of potential concentrations, simplifies analysis, some metals may deposit in sediment	ICF professional judgment
Mississippi River Flow Rate	Assumed low-flow conditions	Provide conservative estimate of concentrations, overestimates relative to average flow by less than a factor of 2	ICF professional judgment
Sediment Concentration			
Determination of annual increment in sediment concentrations due to air deposition	All particulates above critical size (approximately 85% of TSP) are assumed to be deposited in bed sediments	Provides conservative estimate of potential sediment concentrations	ICF professional judgment
Sediment Mixing Depth	Assumed 15 centimeters (cm)	Generic value corresponding to "typical" bioavailable depth; actual value may vary greatly	ICF professional judgment

- COCs accumulate on the Kondirator property for approximately 10 days, and then are washed into the stormwater pond by a 2-inch rainfall event, which is the "design storm" for the facility. Design storms are assumed to occur 35 times per year. (This is an extremely conservative assumption.) The Applicant (Draft EAW) estimates that a design storm would wash 117.4 lb (53.4 kg) of TSP into the pond.

- The discharge flow rate of the pond associated with the design storm is estimated to be 0.05 m^3/sec and to occur for 12 hours (Draft EAW). The masses of COCs which have accumulated on the property since the last storm are assumed to be discharged at uniform dilution in the volume of discharge during the 12-hour flow period, reduced by an amount equal to the retention efficiency of the pond. The masses of COCs are calculated by multiplying the TSP mass entering the pond by the proportions of each COC in the feed materials.

- The retention efficiency of the stormwater pond is assumed to be constant at 92% (as indicated by the Applicant in the Draft EAW). That is, only 8% of the deposited COCs are released from the pond into the river. The concentrations of COCs in the pond outflow are thus determined by the amount of COCs deposited on the property between storms, the flow volume and duration of the pond discharge, and the pond retention efficiency.

- To estimate concentrations of COCs in the river owing to stormwater pond discharge, the pond was assumed to discharge at a rate of 0.05 m^3/sec continuously throughout the year, and the concentration of COCs is assumed to be equal to that calculated for the 12-hour discharge. This assumption also results in a very conservative estimate of total COC releases.

- The concentration of COCs in the river from the stormwater pond discharge are calculated for a mixing zone, the size and volume of which are determined by the size and flow parameters of the river. The calculated mixing zone concentrations are equivalent to the highest concentrations that would be expected to occur in the river after mixing of the stormwater pond discharge has occurred.

All of these assumptions result in a high level of uncertainty in the estimates of stormwater pond releases. In contrast to the assumption of continuous flow, the wet detention pond will discharge only as a result of storm events and during most of the year may not discharge at all. The assumption of continuous flow may overestimate aggregate annual COC releases but does not address the issue of peak episodic releases, which could affect water quality for short periods (a few hour to a few days). During the winter, the wet detention pond will likely freeze and particulate will not be delivered to the river. In fact, during the winter in Minneapolis/St. Paul, a large proportion of precipitation will be in the form of snow. The effects of snowmelt were not considered in this screening level analysis. The effect of this assumption on the risk estimates is minimal.

The long-term average concentrations of COCs in the Mississippi River adjacent to the site were calculated as part of the surface water pathway exposure analysis for the HHRA and ERA. The equation used to estimate the concentration of COCs in the surface water from stormwater runoff is (USEPA 1991):

$$c_s = \frac{c_{so} q_s W}{q_u \left(\frac{\pi D_y L_m}{u} \right)^{0.5}} \qquad \text{Eq. (5-1)}$$

where

c_s = concentration of COC in surface water in the mixing zone (mg/l)
c_{so} = concentration in stormwater outflow (mg/l),
q_s = outflow rate from pond (0.05 m^3/sec, Draft EAW 1994),
W = width of river (213 m, Draft EAW),
q_u = flow rate in the river (91 m^3/sec, Draft EAW),
D_y = lateral dispersion coefficient (1.3 m^2/sec, see below),
L_m = mixing distance (1,707 m, see below), and
u = stream velocity (0.11 m/sec).

The estimated discharge rate from the detention pond (q_s) was provided by the Applicant. The flow rate in the river (q_u) used to estimate COC concentrations is the 7-day low-flow rate reported by the USGS monitoring station in Anoka, MN, in 1993 (USGS 1993).

The concentrations of COCs in the stormwater pond outflow (c_{so}) are calculated by:

$$c_{so} = \left(\frac{1}{\beta} \right) \frac{M_{coc} * x}{12 \text{ hours} * q_s} \qquad \text{Eq. (5-2)}$$

where

c_{so} = concentration in stormwater outflow (mg/l),
M_{coc} = mass of chemical discharged from the wet detention pond (g),
q_s = outflow rate from wet detention pond (0.05 m^3/sec),
β = constant (3600 sec/1 hour), and
x = conversion factor (1 m^3/g × 1,000 mg/l).

The mass of COCs in the stormwater outflow (M_{COC}) are calculated by multiplying the annual total mass of particulate released from the pond (8% of the total deposited mass, from Draft EAW) by the concentrations of COCs in the Kondirator feed materials (Table 3-2). The calculated annual COC emissions from the stormwater pond are shown in the first numerical column of Table 5-2. The calculated concentrations of COCs in the stormwater outflow are shown in the second numerical column of the same table.

5.1.2 Mixing Zone Analysis

The analysis of the stormwater basin discharge was confined to the mixing zone area. The mixing zone is defined as the area where an effluent discharge undergoes initial dilution (USEPA 1991). For this analysis, the longitudinal distance to complete mixing was assumed to occur when the estimated difference in concentration across the width of the river was less than 5%. The distance to complete mixing can be determined by the following equation, assuming a buoyant, point source discharge (USEPA 1991):

Table 5–2

COC Emissions from the Stormwater Pond and Predicted Surface Water Concentrations of COCs due to Stormwater Pond Discharge and Particulate Deposition

COC	Mass of COCs Emitted from Pond Per Storm Event (M_{coc}, grams) (a)	Concentrations of COCs in Stormwater Pond Discharge (c_{so}, mg/l) (b)	COC Concentration Due to Stormwater Pond Discharge (c_s, mg/l) (c)	COC Concentration Due to Particulate Deposition (c_d, mg/l) (d)	Total COC Concentration in Mississippi River Water (C_{tot}, mg/l) (e)
Aluminum	75.0	3.5E–02 (f)	1.7E–05	8.8E–05	1.1E–04
Antimony	0.9	3.9E–04	1.9E–07	1.5E–06	1.7E–06
Arsenic	4.7	2.2E–03	1.1E–06	5.8E–06	6.8E–06
Beryllium	2.1	9.9E–03	4.8E–07	2.5E–06	3.0E–06
Boron	4.3	2.0E–03	9.5E–07	5.0E–06	6.0E–06
Cadmium	3.4	1.6E–03	7.6E–07	4.0E–06	4.8E–06
Calcium	3.8	1.8E–03	8.6E–07	4.8E–06	5.6E–06
Carbon	78.0	3.6E–02	1.8E–05	9.9E–05	1.2E–04
Chromium	30.0	1.4E–02	6.8E–06	3.6E–05	4.2E–05
Cobalt	19.0	8.7E–03	4.2E–06	2.2E–05	2.6E–05
Copper	60.0	2.8E–02	1.4E–05	9.2E–05	1.1E–04
Iron	3681.0	1.7E+00	8.3E–04	4.5E–03	5.4E–03
Lead	16.0	7.3E–03	3.5E–06	1.9E–05	2.2E–05
Lithium	3.4	1.6E–03	7.6E–07	4.0E–06	4.8E–06
Magnesium	9.4	4.3E–03	2.1E–06	1.8E–05	2.0E–05
Manganese	87.0	4.0E–02	1.9E–05	1.0E–04	1.2E–04
Molybdenum	13.0	6.1E–03	3.0E–06	1.6E–05	1.9E–05
Nickel	41.0	1.9E–02	9.2E–06	4.8E–05	5.7E–05
Niobium	3.8	1.8E–03	8.6E–07	4.8E–06	5.6E–06
Silicon	26.0	1.2E–02	5.7E–06	3.6E–05	4.1E–05
Silver	1.7	7.9E–04	3.8E–07	2.5E–06	2.9E–06
Tin	25.0	1.2E–02	5.6E–06	3.0E–05	3.5E–05
Titanium	3.8	1.8E–03	8.6E–07	4.8E–06	5.6E–06
Tungsten	17.0	7.7E–03	3.7E–06	5.2E–03	5.2E–03
Vanadium	9.4	4.3E–03	2.1E–06	2.0E–05	2.2E–05
Zinc	8.1	3.7E–03	1.8E–06	1.1E–05	1.3E–05
Zirconium	3.8	1.8E–03	8.6E–07	3.7E–05	3.8E–05

(a) The mass of COCs in stormwater pond discharge are calculated as shown in Equation B–5.
(b) The concentrations of COCs in pond outflow are calculated as shown in Equation B–4.
(c) Concentrations of COCs in surface water due to stormwater discharge are calculated as shown in equation B–3.
(d) Concentrations of COCs in the mixing zone due to particulate deposition are calculated as shown in Equation B–9.
(e) The total mixing zone COC concentrations are the sum of the concentrations due to stormwater pond discharge and particulate deposition. These values are used in Equation B–13 to calculate fish tissue concentrations of COCs.
(f) The symbol "E" indicates scientific notation. For example, 3.5E–02 indicates a concentration of 0.035 (3.5×10^{-2}) mg/l.

$$L_m = \frac{mW^2u}{D_y} \qquad \text{Eq. (5-3)}$$

where

L_m = distance to complete mixing (m),
m = constant (0.4 for a side discharge with <5% concentration gradient),
W = stream width (m),
u = average stream velocity (m/sec), and
D_y = lateral dispersion coefficient (m^2/sec).

Several stream-specific parameter values are listed in Table 5-3, along with the sources for the values. The average stream velocity was calculated assuming a rectangular channel. With a rectangular channel, the flow rate (q) is equal to the product of the velocity, depth, and width. The lateral dispersion coefficient can be determined by (USEPA 1991)—

$$D_y = 0.6\,du^* \pm 50\% \qquad \text{Eq. (5-4)}$$

where

D_y = lateral dispersion coefficient (m^2/sec),
d = stream depth (m), and
u^* = shear velocity (m/sec).

A shear velocity was calculated using the following equation (USEPA 1991):

$$u^* = \sqrt{gds} \qquad \text{Eq. (5-5)}$$

where

u^* = shear velocity (m/sec)
d = stream depth (m)
g = gravitational acceleration (9.81 m/sec^2), and
s = average bed slope (m/m).

A site-specific bed slope was not available, therefore, a hypothetical bed slope of 1% was assumed. The shear velocity was assumed to be constant with flow rate and was determined using average flow conditions. Using the above equations, the values for shear velocity, lateral dispersion coefficient, and length to mixing shown in Table 5-4 were calculated.

An important consideration to the distance to complete mixing is the nature of the river. The upper Mississippi River in Minneapolis/St. Paul is relatively shallow and contains a large number of rocks (USGS 1994). Rocks in the river promote turbulent conditions, which would reduce the distance to complete mixing. Additionally, the river is regularly dredged and trafficked by barges, which may affect the lateral dispersion and mixing length.

5.1.3 Predicted Concentrations in the Mississippi River

Metal concentrations corresponding to the point when the stormwater plume is mixed across the entire width of the river were determined as described in equation 5–1.

Table 5-3. Mississippi River Physical Parameters

Parameter (Units)	Value	Source
7-Day mean flow rate (m^3/sec)	318	USGS, Anoka, MN Station, 1993
7-Day low flow rate (m^3/sec)	91	USGS, Anoka, MN Station, 1993
Average width (m)	213	Draft EAW, 1994
Average depth (m)	3.7	USGS (1994)

Table 5-4. Mixing Length Results for Low Flow Conditions

Parameter	Units	Value
Shear Velocity	m/sec	[a]0.6
Lateral Dispersion Coefficient	m^2/sec	[b]1.3
Mixing Length	m	[c]1,707

[a] Calculated as shown in equation 5–5.
[b] Calculated as shown in equation 5–4.
[c] Calculated as shown in equation 5–3.

The predicted increases in metal concentration in the Mississippi River due to the stormwater discharge are shown in Table 5-2. Note that the concentrations shown in the table neglect potential effects of particulate settling in the river, which would reduce the suspended-phase COC concentrations below these values.

5.1.4 Impacts of Particulate Deposition on the Mississippi

Another route of entry of metals from the Kondirator facility into surface water is through direct atmospheric deposition onto the surface of the Mississippi River. A screening level calculation of the potential concentrations in the mixing zone of the river was performed. A mass balance approach was used to calculate chemical concentrations as a result of deposition only. The metal-specific load to the river was calculated by

$$DL_{coc} = (DR)(COC)(A) \qquad \text{Eq. (5–6)}$$

where

DL_{coc} = COC deposition loading rate (g/yr),
DR = TSP atmospheric deposition rate (39.75 $g/m^2/yr$), and
A = surface area of interest (363,591 m^2),
COC = proportion of COC in feed.

The surface area of the mixing zone was calculated by multiplying the average stream width (213 meters) by the mixing zone length (1,707 m). This deposition calculation does not take into account particulate deposition on other less-heavily-affected reaches of the river or the contribution from materials originally deposited on the land surface near the Kondirator site and transported to the river in runoff. Thus the total particulate impact to the river from the Kondirator air emissions may be underestimated. Using a completely mixed assumption within the mixing length of the river, metal concentrations were calculated by

$$C_d = \frac{(s)(DL_{coc})}{q_u} \qquad \text{Eq. (5–7)}$$

where

C_d = COC concentration in Mississippi River water due to deposition of Kondirator particulate ($mg/m^3 = \mu g/l$),
s = conversion factor (3.2×10^{-8} years/sec),
q_u = 7-day low-flow rate (91 m^3/sec, USGS 1993).

The predicted metal concentrations in the river under low conditions are shown in the next to last column of Table 5-2. A summary of key assumptions used for water quality impact assessment are listed in Table 5-1. Note that the calculated concentration values assume total mixing and do not account for potentially significant plume depletion caused by the settling of heavy particulates into the bottom sediments of the mixing zone. Also, the calculated concentrations are suspended particulates and do not necessarily reflect the amount of material that would be bioavailable to organisms in the water column. Finally, the assumption of low-flow conditions based on the Anoka data for 1993 in the river results in an approximately threefold overestimation of the average particulate concentration over the year, compared with mean flow conditions for the year.

5.2 WATER QUALITY IMPACTS ON THE MISSISSIPPI RIVER

The overall increase of metal concentrations in the Mississippi River from Kondirator emissions was determined by adding the concentrations predicted from stormwater runoff and direct atmospheric deposition. These concentration increments are shown in Table 5-2. In all cases the predicted impact from air releases is about 5 to 6 times greater than the impact from the stormwater pond.

5.3 COMPARISON OF WATER QUALITY IMPACTS TO BACKGROUND WATER QUALITY IN THE MISSISSIPPI

Since the emissions from the proposed Kondirator facility may potentially increase concentrations of these elements already present in the Mississippi River, an analysis of the background concentrations within the river was conducted. Data from USEPA's STORET database were collected during the period from 1985 to 1991 for three nearby stations. Background data were available for 11 of the metals of concern. Summary statistics were obtained for the background data using STORET procedures[1] and are summarized in Table 5-5.

In all cases, the increases in metal concentrations predicted by the surface water modeling were two or more orders of magnitude less than either the measured average concentrations or the detection limits. Thus, emissions from the facility are not predicted to significantly or measurably increase the background concentrations of these metals.

5.4 IMPACTS ON SEDIMENT INORGANIC CONCENTRATIONS

Particulate metal that is deposited into the Mississippi River may be deposited to the bottom sediments. Atmospheric deposition was shown to be the primary source of metals to the river in the surface water analysis. Therefore, only metals deposited from the atmosphere were considered for the purposes of predicting sediment concentrations.

The following section describes the approach used to estimate increases in sediment concentrations of COCs due to the Kondirator emissions. Section 5.4.1 describes the method used to estimate the proportion of particles deposited on the river that would settle to the bottom sediment in the mixing zone. Section 5.4.2 describes the calculation of sediment concentration increments and the results of these calculations.

5.4.1 Particle Settling Analysis

A portion of Kondirator TSP deposited on the surface of the Mississippi River would be expected to settle to the bottom and contribute to COC concentrations in sediment. Another portion of the sediment (the finer, lighter fraction) would be expected to remain suspended in the water column. A simple conservation-of-energy model was used to estimate the minimum size particle which would be expected to settle to the bottom of the river and to estimate the fraction of Kondirator TSP which would end up in the sediment in the mixing zone. This model is described in detail in Appendix B.6.

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[1] STORET includes detection limits in the average.

Table 5-5. Comparison of Predicted Water Column Chemical Concentrations to Background Chemical Concentrations in the Upper Mississippi River

Constituent	Frequency of Detection[a]	Average Measured Concentration (μg/l)	Predicted Surface Water Concentration Due to Facility Emissions[b] (μg/l)
Aluminum	4/4	350	1.1×10^{-1}
Arsenic	4/5	1.54	6.8×10^{-3}
Cadmium	6/6	[d]2.05	4.8×10^{-3}
Calcium	3/3	120	5.6×10^{-3}
Chromium	2/4	0.975	4.2×10^{-2}
Copper	5/7	1.7	1.1×10^{-1}
Iron	1/1	650	5.4
Lead	6/7	2.33	2.2×10^{-2}
Manganese	1/1	110	1.2×10^{-1}
Nickel	0/2	[c]ND (1)	5.7×10^{-2}
Zinc	4/5	19.5	1.3×10^{-2}

[a] The number of samples in which the metal was detected divided by the total number of samples analyzed.

[b] From Table 5-2; values have been converted to μg/l to facilitate comparison with STORET data.

[c] USEPA STORET data for nearby stations, 1985–1991, nickel was not detected with a detection limit of 1 μg/l.

[d] This value may be misleadingly high, due to the presence of one data point that was significantly higher than the others.

The results of this modeling indicate a threshold particle size for deposition of approximately 0.2 mm; particles substantially above this diameter will sink quickly through the water column and be deposited into the sediment, while particles smaller than this will remain suspended in the water column for extended periods of time and will not reach the sediment in the mixing zone.

The majority of the particulate emitted from the Kondirator is much smaller than 0.2 mm. Based on an evaluation of the particle size distribution provided by the Applicant (see Appendix B.6), ICF KE estimated that approximately 15 percent of the TSP deposited on the river would contribute to sediment COC concentrations in the mixing zone. This value is used to calculate sediment COC concentrations in the following section.

5.4.2 Calculation of COC Concentrations in Sediment

The following equation was used to calculate constituent concentrations in river sediment after the 15-year facility life:

$$C_s = \frac{(\mathrm{TSP})(\mathrm{COC})(\mathrm{FL})(\mathrm{F})(x)}{(\mathrm{SD})(\mathrm{BD})} \qquad \text{Eq. (5-8)}$$

where

C_s = concentration of constituent in sediment (mg/kg),
TSP = TSP deposition rate over the river (39.75 g/m^2-yr),
COC = COC proportion of total particulate (unitless)
FL = facility life (15 years),
F = proportion of particulate settling onto bottom sediment (0.1478, unitless)
x = conversion factor (1,000 mg/g),
SD = sediment mixing depth (0.15 m), and
BD = sediment bulk density (1.17×10^3 kg/m^3).

As in estimating soil COC concentrations, the emitted constituents were assumed to accumulate over the 15-year facility life, assuming no loss. The depth of mixing used to estimate sediment concentrations was assumed to be 15 cm (ICF KE professional judgement). The bulk density of 1.17×10^3 kg/m^3 which was used for soil calculations was also assumed for sediment. Both of these values are quite uncertain, and could vary widely over the study areas as a result of natural processes (sediment deposition and resuspension, bioturbation and mixing) and human activities (barge traffic, dredging).

The results of the sediment COC concentration calculations are shown in Table 5-6. These values are used as inputs to the HHRA sediment exposure calculations.

TABLE 5-6

Estimated Sediment Concentrations Resulting from Emissions from the Proposed Kondirator Facility

Constituents of Concern	Feed Material Composition (a)	Maximum Estimated Sediment Concentration (mg/kg) (b)
Aluminum	1.76%	8.87
Antimony	0.03%	0.15
Arsenic	0.12%	0.58
Beryllium	0.05%	0.25
Boron	0.10%	0.48
Cadmium	0.08%	0.40
Calcium	0.10%	0.48
Carbon	1.97%	9.93
Chromium	0.71%	3.58
Cobalt	0.44%	2.22
Copper	1.84%	9.29
Iron	90.17%	454.31
Lead	0.38%	1.89
Lithium	0.08%	0.40
Magnesium	0.35%	1.76
Manganese	2.04%	10.28
Molybdenum	0.31%	1.56
Nickel	0.96%	4.84
Niobium	0.10%	0.48
Silicon	0.71%	3.58
Silver	0.05%	0.25
Tin	0.59%	2.97
Titanium	0.10%	0.48
Tungsten	0.40%	2.02
Vanadium	0.22%	1.11
Zinc	0.74%	3.73
Zirconium	0.10%	0.48

(a) From Table 3-2

(b) Calculated as shown in equation 5-8. The TSP deposition rate (39.75 g/m^2-year) is from deposition modeling conducted by Barr Engineering (Appendix A). The sediment concentrations are used to calculated sediment ingestion doses shown in Tables 7-8 and 7-9.

6.0 TRANSPORT IN AQUATIC FOOD WEBS

Purpose——To identify COCs that might accumulate in the aquatic environments and to estimate fish tissue concentrations of COCs.

In this section, COCs having the potential to bioaccumulate in aquatic and/or terrestrial food webs are identified for evaluation in the HHRA. As will be discussed in Section 7.1, human exposures to COCs from Kondirator emissions could occur through the ingestion of fish taken from the Mississippi River. Bioaccumulation is the accumulation of chemicals by organisms to levels that are above those in the surrounding environment. Bioaccumulation accounts for the accumulation of chemicals by all possible potential exposure pathways, including direct uptake from water and uptake via all other potential exposure pathways (e.g., the ingestion of food and sediment). Elevated concentrations of chemicals in organisms have the potential to adversely affect humans consuming these organisms.

6.1 POTENTIAL FOR ACCUMULATION OF COCs IN THE AQUATIC ENVIRONMENT

Bioconcentration factors (BCFs) for fish were used to identify chemicals having the potential to accumulate in the aquatic food web. BCFs represent the ratio of the concentration of chemicals occurring in aquatic life (e.g., fish) to those occurring in water. Bioconcentration only quantifies the accumulation of chemicals directly from water and does not consider contributions via other potential pathways of exposure (e.g., the ingestion of contaminated food and sediment). Although bioaccumulation may occur through pathways not accounted for by BCFs, BCFs were selected for this initial evaluation because they are readily available in the scientific literature and are generally reliable indicators of the propensity for chemicals to accumulate in the aquatic food web.

BCFs available for the Kondirator facility COCs are summarized in Table 6-1, along with hypothetical fish tissue concentrations, which were calculated from the modeled surface water concentrations using equation 6–1.

$$C_f = (C_{tot})(BCF_{f:w}) \qquad \text{Eq. (6–1)}$$

where

C_f = estimated COC concentration in fish tissue (mg/kg),
C_{tot} = estimated COC concentration in the water due to Kondirator emissions(mg/l)
$BCF_{f:w}$ = fish:water BCF (unitless) for COC

BCFs based on measurements of whole-body concentrations were used when available because they most accurately represent potential exposure concentrations to potential predator species (because most predators consume the whole prey). Use of these values may over- or under-estimate concentrations of COCs to which fish consumers are exposed, depending on which tissues are consumed and how COCs are distributed among the various tissues. The calculated values are rough estimates of chemical concentrations. Actual concentrations near the proposed facility are likely to vary from these estimates. For example, the fish tissue concentrations were calculated using the assumption that all of the metals emitted from the facility are in a form that is soluble and available for uptake by fish. This assumption is likely to substantially overestimate chemical concentrations in

Table 6-1. Bioconcentration Factors Reported for Fish and Estimated Fish Tissue Concentrations Based on Predicted Surface Water Concentrations

Chemical	Bioconcentration Factor (BCF) for Fish	Species/Exposure Conditions[a]	Reference	Fish Tissue Concentration[b] (mg/kg)
Aluminum	147–231	brook trout; whole body, 15-day exposure	Cleveland et. al (1986 in EPA 1988a)	2×10^{-2}–2.5×10^{-2}
Antimony	not significant	bluegill; whole body, 28-day exposure	Barrows et.al (1980 in EPA 1988b)	—
Arsenic	4	bluegill; whole body	EPA (1978)	3×10^{-5}
Beryllium	19	bluegill; whole body, 28-day exposure	EPA (1980)	6×10^{-5}
Cadmium	3–7,440	brook trout; muscle tissue, 490-day exposure to mosquito fish; whole body, 26-week exposure	Benoit et al. (1976 in EPA 1985a) Giesy et al. (1977 in Eisler 1985)	1.4×10^{-5}–3.6×10^{-2}
Chromium	3	rainbow trout; whole body and muscle tissue	EPA (1985b)	1.3×10^{-4}
Lead	1–726	plaice; whole body, 96-hour exposure to rainbow trout; whole body, 7-day exposure	Maddock and Taylor (1980 in Eisler 1988) Wong et al. (1981 in Eisler 1988)	2.2×10^{-5}–1.6×10^{-2}
Manganese	84	unidentified freshwater fish from an African lake	Greichas et al. 1978 in AQUIRE 1990	1×10^{-2}
Nickel	47–106	fathead minnow; whole body, 30-day exposure	Calamari et al. (1982 in EPA 1986a)	2.7×10^{-3}–5×10^{-3}
Silver	11–150	largemouth bass; muscle tissue, 120-day exposure to bluegill; whole body, 180-day exposure	EPA (1987a) Cearly (1971 in EPA 1987b)	3.2×10^{-5}–4.4×10^{-4}
Zinc	51–1,000	freshwater fish	EPA (1986b) and EPA (1987b)	6.6×10^{-4}–1.3×10^{-2}

[a] Whole body concentrations were used whenever available.
[b] Calculated as shown in equation 6–1, water concentrations from Table 5–1.

fish tissue if particulate is of limited solubility. In addition, as already indicated, BCFs only account for chemical uptake directly from water and do not account for the potential uptake of chemicals through other potential exposure pathways (e.g., the ingestion of contaminated food and sediment). In most cases, this assumption underestimates the chemical concentration in fish tissue. At a screening level, the estimated fish tissue concentrations provide approximations that can be used in conjunction with the BCFs to select COCs for evaluation in the HHRA.

As shown in Table 6-1, the BCFs and fish tissue concentration estimates indicate that cadmium, lead, and zinc have the greatest potential to accumulate in the aquatic food web. Accordingly, fish consumption exposure for these three chemicals are considered in detail in the HHRA. However, it is unlikely that these chemicals would accumulate to a significant extent in the aquatic environment as a result of emissions from the Kondirator alone. Modeled concentrations of cadmium, lead, and zinc in surface water (see Table 5-2) are approximately 2 to 4 orders of magnitude below Minnesota State Water Quality Standards for chronic exposure (1.72 μg/l, 6.3 μg/l, and 166 μg/l, respectively[1]) (MPCA 1994). Federal Ambient Water Quality Criteria (AWQC) chronic concentrations are the same as the Minnesota Water Quality Standards for these chemicals. These predicted incremental concentrations of the COCs in water resulting from the Kondirator emissions are also far below measured background concentrations, as discussed in Section 5.1. Key assumptions for evaluation of bioaccumulation are shown in Table 6-1.

BCFs were not found for boron, calcium, carbon, cobalt, copper, iron, lithium, magnesium, molybdenum, niobium, silicon, tin, titanium, tungsten, vanadium, and zirconium; however, Eisler (1985 and 1988) suggests these chemicals do not accumulate significantly in the aquatic environment.

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[1] Based on a hardness of 170 mg/l as calcium carbonate, as reported by MPCA (1994).

Table 6-2. Key Assumptions and Methods Used in the Selection of Chemicals of Concern for the Evaluation of Bioaccumulation

Issue Addressed	Assumption/ Method Used	Reason for Approach	Data Sources
Identification of metals having the potential to bioaccumulate in the aquatic food webs.	Fish Bioconcentration Factors (BCFs) used to screen the potential for chemicals to bioaccumulate in the aquatic environment. Assumed method represents overall potential for chemicals to accumulate in the aquatic food web. The highest BCF value from the literature was used.	Rapid and cost-effective methods for identifying chemicals having the potential to bioaccumulate in the aquatic food webs.	Scientific literature (see Table 6-1).

7.0 HUMAN HEALTH EXPOSURE ASSESSMENT

Purpose——To identify exposed populations and potential exposure pathways.

This screening level exposure assessment considers the potential for human receptor populations to be exposed to the constituents of concern (COCs) at or originating from the proposed Kondirator facility. As discussed in previous sections of this HHRA, constituents associated with Kondirator operation may move off-site through dispersion of airborne particulates and then may be deposited on the land or in water. After deposition onto land or water bodies, the COCs may run off into surface water and sediment or bioaccumulate in the food web. The course a constituent takes from a source to an exposed individual is called an exposure pathway. An exposure pathway consists of a source of release of constituents to the environment; an environmental transport medium (e.g., air, surface water); a point of potential contact for humans with the contaminated medium; and an exposure route (e.g., inhalation, ingestion) at the exposure point. All of these elements must be present for a pathway to be considered "complete" (USEPA 1989a).

In this section, the human receptor populations with the potential for exposure to the constituents from the proposed Kondirator site are identified. In addition, potentially complete exposure pathways are identified, and incomplete exposure pathways are screened from further evaluation. Finally, a methodology is described to determine the magnitude of these potential exposures and the intakes of COCs resulting from the exposures.

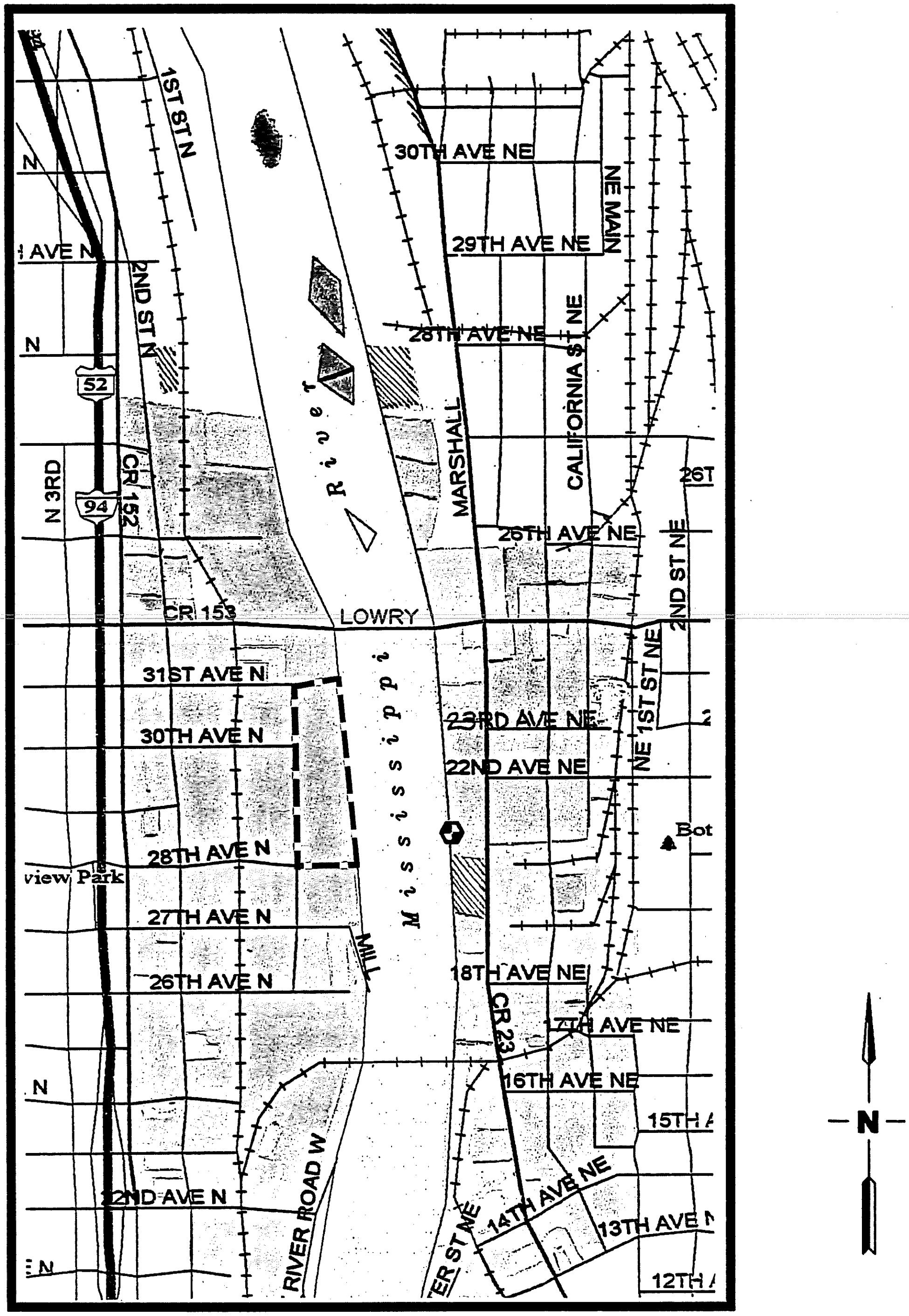
7.1 IDENTIFICATION OF POTENTIALLY EXPOSED POPULATIONS

This section discusses the identification of the populations with the highest potential exposure to emissions from the proposed Kondirator site. The most exposed populations are determined by considering several important issues: the proximity of the receptor to the site, the types of activities (e.g., residential, recreational) prevalent in the area, and the pattern of transport of contaminants in the environment. The populations that are determined to be the most potentially exposed are further evaluated in the next section to determine if the exposure pathways are complete.

7.1.1 Residential Exposure

As stated in the completed data portion of the Draft EAW, the location of the proposed Kondirator is in "an area generally known as the North Washington Avenue Industrial Park. Surrounding land uses are of a heavy industrial nature with open storage, noise, and heavy truck traffic prevalent throughout the district" (Draft EAW 1994). There are no residences directly adjacent to the site. The residential scenario considered in this screening level evaluation is a conservative, hypothetical scenario, which is intended to describe a population with the highest potential exposure in the vicinity of the site.

Three nearby residential areas were considered for evaluation in the report. A map of the site is shown in Figure 7–1 and may be used to identify potentially the location of these areas. Considerations used to identify potentially exposed populations are summarized in Table 7-1. The first and largest residential area includes the neighborhoods west of the site across Interstate Highway 94. The second residential area is the small group of houses approximately 300 meters northwest of the AIS property boundary near the intersection of Lowry Avenue North (CR 153) and 2nd Street North. The third residential area is east of the site across the Mississippi River, on Marshall Street



APPROXIMATE SCALE 1:15,625

LEGEND:

▨	PARK
☐	UNDEVELOPED/UNUSED LAND (HABITATS IN THESE AREAS COULD NOT BE DETERMINED FROM AVAILABLE INFORMATION)
☐	INDUSTRIAL/COMMERCIAL
☐	RESIDENTIAL
▒	WETLANDS
☐	LAND USE COULD NOT BE DETERMINED FROM AVAILABLE INFORMATION
▨	WOODED AREA
⊕	LOCATION OF SHORELINE RECEPTOR
— — —	KONDIRATOR FACILITY BOUNDARY

ICF KAISER
9300 LEE HIGHWAY
FAIRFAX, VIRGINIA
22031-1207

REVISION NO.:	DATE: 01/30/95	ACAD FILE: KONDIHA2

RESIDENTIAL LOCATION AND LAND USE MAP

DET'D: CST	CLIENT: MPCA	PROJECT NO.: 51429-002-00
CHK'D: ME	LOCATION: MINNEAPOLIS, MN	FIGURE NO.: 7-1

Table 7-1. Rationale for Identification of Potentially Exposed Populations

Population Type	Populations/Location Selected	Rationale/Comments
Residential	Adults and children residing in the neighborhood along Grand Avenue across the Mississippi River to the east of the facility	Residents have the largest, most frequent exposures to Kondirator emissions. Other nearby residential locations (west of I-94, north of 30th Avenue) had lower exposures
Recreational	Waders, recreational boaters, fishers in area of river near the facility	River access from shore or by boat is possible (there is a dock across the river from the facility), and anecdotal evidence suggests fishing occurs in this area
Subsistence Fishers	Subsistence fishers on river near the facility	Anecdotal evidence suggest subsistence fishing populations are present in the area
Occupational	Not included	Occupational exposures are governed by OSHA standards, and are not within the scope of the assessment

Northeast (CR23) near 23rd Avenue Northeast. The nearest residences are about 240 meters from the proposed Kondirator location. Two other lots to the west of the facility, but to the east of I-94, are identified in the land use map (Figure 7-1) as being "residential." Currently, however, neither of these locations is used as a residence. The maximum air concentrations from the proposed Kondirator facility are predicted to occur within the site boundary. The air concentrations become diluted as the airborne particulates are dispersed in the vicinity of the site. There is a general, long-term trend for slightly higher off-site air concentrations across the river from the site in the predominant wind direction. Exposure concentrations at the other potential residential locations are lower. Therefore, the residential area located across the river is evaluated in this exposure assessment.

7.1.2 Recreational Exposure on the Mississippi River

Constituents emitted from the proposed Kondirator facility may reach the Mississippi River as a result of direct deposition onto the river or surface runoff into the river. Recreational use of the river by local populations may result in potential exposure to these constituents. The generally industrial nature of this portion of the Mississippi River precludes extensive recreational use of the river, but use of the river for recreational purposes is not prohibited. Use of the river may include boating or fishing; there is a small dock directly across the river from the facility. This portion of the river has no public beach areas or designated swimming areas, but sediment along the shore line is accessible from private property and from park land. Fishing, boating, wading, or playing may result in potential exposure to constituents in the river water, sediment, or fish. Therefore, a hypothetical recreational receptor population exposed to surface water and sediment is considered in this assessment, as well as a hypothetical population consuming fish caught in the reach of the river near the Kondirator.

7.1.3 Occupational Exposure

Worker exposures to emissions from the proposed Kondirator facility would be controlled by OSHA regulations. Potential exposures to workers are not addressed in this report.

7.2 IDENTIFICATION OF POTENTIAL EXPOSURE PATHWAYS

In this section, the potential pathways through which human populations may be exposed to COCs are discussed, and exposure pathways are selected for further review based on a screening evaluation. The considerations used to select exposure pathways for inclusion in the assessment are summarized in Table 7-2.

7.2.1 Inhalation Pathways

The principal release and transport mechanism of constituents from the Kondirator is the generation of airborne particulates from the stack and materials handling operations. Therefore, inhalation of airborne particulates is likely to be a major exposure pathway for Kondirator emissions. Potential risks associated with this pathway are evaluated quantitatively using the methodologies discussed in the next section of the HHRA. The most heavily exposed population via this pathway is the residential population located across the river from the site.

Table 7-2. Rationale for Selection of Exposure Pathways

Potential Exposure Pathway	Likely to be Complete?	Rationale for Inclusion/Exclusion
Inhalation of particulates	Yes	Included, based on air modeling results
Ingestion of contaminated soils	Yes	Included, particulates deposited on soils may result in human exposures through incidental ingestion
Ingestion of home-grown vegetables	Yes	Not included; exposures by this pathway may occur, but insufficient site-specific data are available to support the development of defensible risk estimates within the scope of the screening assessment
Dermal contact with contaminated soils	No	Not included; strong evidence indicates that absorption of inorganic elements through intact skin is not normally significant compared with soil ingestion
Dermal contact/ingestion of surface water	Yes	Not included; although dermal contact and incidental ingestion of river water may occur during recreation, calculated water concentrations of COCs resulting from Kondirator emissions are so low that this pathway was judged to be insignificant
Ingestion of contaminated fish	Yes	Included; river access and fishing are possible near the facility
Ingestion of sediment	Yes	Included; recreational populations may incidentally ingest contaminated river sediment
Dermal contact with sediment	No	Not included; dermal uptake of inorganic COCs from sediment would be insignificant compared with uptake from ingestion

7.2.2 Indirect Pathways

Particulate emissions from the proposed Kondirator facility may be deposited onto other environmental media including surface soil and surface water. In addition, surface runoff may cause constituents to migrate from the site into surface water. These "indirect" pathways are evaluated in this section to ascertain whether they may be associated with significant human health risks. The selection of indirect exposure pathways for inclusion in the quantitative HHRA is based on the amounts of contaminants emitted, their toxicity and environmental fate characteristics, and the availability of sufficient data to support meaningful screening level risk estimates.

Surface Soil. Deposited particulates may become mixed into soil, and receptor populations may come into contact with contaminated soil through gardening or other outdoor activities. Children in particular are likely to ingest soils incidentally while playing outdoors. Thus potential exposures due to the incidental ingestion of soil by hypothetical residents, both children and adults, were evaluated.

Constituents in soils that contact the exposed skin of residents may be absorbed dermally. Scientific studies of dermal absorption of metals, particularly from soil, show that a negligible amount of absorption of inorganic compounds, if any, actually occurs from short-term exposures. Therefore dermal exposures to COCs in soil are not included in the risk assessment.

Homegrown Vegetable Pathways. Residents in the vicinity of the facility may grow vegetables for consumption. Homegrown produce may be exposed to emitted constituents by direct deposition onto plant surfaces and indirectly by root uptake from soils. Residents may then be exposed to emitted chemicals through ingestion of this produce. The highest exposures are likely to occur among residents who regularly grow and rely on homegrown produce as a major food source. While it is likely that some residents do grow vegetables for consumption, there are no good site-specific data that would allow a reliable estimate of the potential risks associated with this pathway to be evaluated within the scope of this screening level assessment. The principal reason for not including this pathway in the assessment was that the lack of site-specific data, and uncertainties about metals speciation, plant uptake, and toxicity would have produced unreliable indicators of actual site risks. The potential risks associated with this pathway are therefore discussed qualitatively in Section 10.5.

Surface Water Pathways. Constituents emitted from the proposed facility and deposited onto the Mississippi River will become suspended in the water. Additionally, some of the constituents deposited onto the surface of the site may run off into the river, as described in Section 5.4. Recreational populations that use the river may come into contact with dissolved constituents in the water. Potential exposure to surface water may occur through incidental ingestion or dermal contact with the skin. However, exposure by this pathway is unlikely to be significant given the very low concentrations of constituents in surface water resulting from Kondirator emissions. Surface water concentrations resulting from facility emissions were compared to background levels (shown previously in Table 5-7) and to federal drinking water quality standards (shown in Table 7-3). Although the comparison of surface water concentrations to these Federal MCLs is very conservative, this comparison was performed for the screening level assessment in order to screen the pathway from further evaluation. The result of these comparisons show that the surface water concentration increments of COCs due to Kondirator emissions are much less than background levels and much less than the health-based water quality standards. Therefore, the surface water exposure pathways are not evaluated further in the HHRA.

TABLE 7–3

Predicted Incremental Mississippi River COC Concentrations due to the Kondirator Facility, Compared to Federal Drinking Water Standards

Constituents of Concern	Total Concentrations Modeled in the Mississippi River (μg/l) (a)	Federal Maximum Contaminant Levels (MCLs) (μg/l) (b)
Aluminum	0.11	50 (c)
Antimony	0.0017	6
Arsenic	0.0068	50
Beryllium	0.003	4
Boron	0.006	600 (d)
Cadmium	0.0048	5
Chromium	0.042	100
Copper	0.11	1000 (c)
Iron	5.4	300 (c)
Lead	0.022	15
Manganese	0.12	50 (c)
Molybdenum	0.019	40 (d)
Nickel	0.057	100
Silver	0.0029	100 (c)
Vanadium	0.013	20 (d)
Zinc	0.038	5000 (c)

(a) From Table 5–2, includes concentration increments due to both stormwater pond release and particulate deposition.

(b) National Primary Drinking Water Regulations are listed unless noted. COCs for which standards have not been promulgated are not included in this table.

(c) Secondary MCLs from USEPA National Secondary Drinking Water Regulations.

(d) USEPA Drinking Water Health Advisory for lifetime exposure.

Sediment Pathways. Constituents that are transported into the river through deposition or surface runoff may subsequently be deposited onto the river sediment. Recreational users of the Mississippi River may come into contact with these constituents in the sediment. For example, a recreational user may wade in the river while wading, playing, docking a boat, or fishing. Small amounts of the sediment may be incidentally ingested during this activity. Potential exposure resulting from incidental ingestion of COCs in sediment by recreational users of the river is included in the quantitative HHRA.

In addition, COCs in the sediment that come into contact with the exposed skin of residents may be absorbed dermally. As with soil, a negligible amount of dermal absorption of metals is expected to occur from sediment. Therefore, this pathway is not quantitatively evaluated in this assessment.

Fish Consumption Pathway. Chemicals in the surface water or sediment of the Mississippi River may accumulate in fish that inhabit the river. Recreational or subsistence fishers may be exposed to COCs through the ingestion of fish tissues. In this assessment, potential COC intakes are estimated for populations assumed to regularly fish from the river and consume their catch. As described in Section 6.1, only three of the constituents of concern are likely to bioaccumulate in fish. Therefore, these metals (i.e., cadmium, lead, and zinc) are the only constituents that are evaluated through this exposure pathway.

7.3 EXPOSURE AND INTAKE ASSESSMENT MODELS

This section presents an overview of the methodologies used to calculate potential COC exposures and intakes for each of the exposure pathways selected for detailed evaluation. These simplified, generic approaches are generally consistent with risk assessment guidance developed by USEPA (1989a, 1989b, 1991, 1992, 1994).

In order to estimate potential exposures, the concentrations of each COC at the points of exposure were quantified. This concentration is referred to as the exposure point concentration (EPC). All EPCs used to estimate potential human health risks are based on the air dispersion and particulate deposition modeling conducted by Barr Engineering for the Kondirator facility. Appendix B describes in more detail how predicted EPCs are calculated for the other environmental media from the results of the air dispersion modeling. All EPCs are modeled concentrations and are not based on actual measured values because data from operating Kondirator facilities were not available. Predicted EPCs are combined with information describing the extent, frequency, and duration of potential exposure for each receptor of concern, and each exposure pathway, to calculate intakes of contaminants. The equations used to calculate intake (i.e., daily doses and exposure concentrations) are presented in Appendix B. The exposure parameter values used in the equations are described below.

To calculate potential risks, exposure and dose estimates are combined with toxicity criteria for individual COCs. The conventional units for USEPA-approved inhalation toxicity criteria and ingestion toxicity criteria are different; therefore, different methodologies are used to assess risks for each type of potential exposure. For the inhalation pathway, potential exposures for the selected COCs are estimated as air concentrations in units of milligram per cubic meter (mg/m^3). For the pathways that involve ingestion, potential exposure is converted to estimates of average daily dose, expressed in units of milligram COC per kilogram body weight per day (mg/kg-day). Average daily doses are estimated differently when assessing noncarcinogenic toxicological effects and carcinogenic toxicological effects. Average daily doses for noncarcinogens are averaged over the duration of potential exposure, and following USEPA (1992) guidance, are given the acronym ADDs (for Average Daily Doses). For carcinogens, average daily doses are averaged over a lifetime, and are given the acronym LADDs (for Lifetime Average Daily Doses). Some chemicals exhibit both carcinogenic and noncarcinogenic effects and therefore have both ADDs and LADDs calculated (e.g., arsenic and beryllium). Further discussion on the toxicity of the COCs is presented in Section 8.0.

7.3.1 Inhalation of Particulates

Potential exposures to COCs resulting from inhalation of airborne particulates are calculated for a hypothetical resident living across the river from the Kondirator facility. The exposure point location used to evaluate potential exposures for the residential area is shown on Figure 7–1. The long-term average air concentrations at this point are likely to be somewhat greater than the concentrations over most of the nearby residential area, as the residences are all somewhat farther from the proposed Kondirator location. Thus, the air exposure concentrations over the entire residential area are likely to be somewhat overestimated.

To evaluate potential cancer risks and the potential for noncancer adverse health effects, it is necessary to develop estimates of the long-term (chronic) exposure concentrations for residents in the area. The first input to this calculation is the estimated long-term average TSP concentration from the ISCST2 model. Using the total particulate (TSP) value rather than the estimated concentration of fine particulates (PM_{10}) provides a conservative estimate of exposure concentrations because some of the coarse particulates are above the "respirable" size range; that is, when inhaled they are too coarse to reach the lung and are instead deposited in the nasopharynx. The TSP value was used in the analysis to provide an added level of conservatism to the inhalation risk estimates in light of the uncertainty about the actual size distribution of particulates emitted from the Kondirator. In addition, a substantial portion of the inhaled coarse particulates may also be absorbed into the body after deposition into the nasopharynx or bronchi.

To develop a realistic estimate of time-averaged exposure concentration, it is necessary to adjust the long-term average concentration from the ISCST2 model to take into account the less-than-continuous, less-than-lifetime exposures of the residents. This adjusted concentration is called the inhalation exposure concentration (IEC) and serves as the input to the risk characterization models discussed in Section 9.1. IECs are calculated as follows:

$$\mathrm{IEC} = \mathrm{Ca} * \frac{\mathrm{EF}}{365} * \frac{\mathrm{ED}}{\mathrm{AT}} \qquad \text{Eq. (7–1)}$$

where

IEC = inhalation exposure concentration ($\mu g/m^3$),
Ca = long-term average air concentration of COC ($\mu g/m^3$) (Table 4–3),
EF = exposure frequency (350 days/year),
ED = exposure duration (15 years),
AT = exposure averaging time (15 years for noncarcinogenic COCs, 70 years for carcinogenic COCs).

In calculating IECs, it is necessary to make a number of assumptions about the releases from the Kondirator and the behavior of the exposed populations. A number of the key assumptions used in calculating IECs are summarized in Table 7-4. In calculating long-term air concentrations, it was

Table 7-4. Rationale for Selection of Exposure Parameter Values

Parameter	Value Used in the Assessment	Comment/Alternatives Value
Body weight (adult, all pathways)	70 kg	Standard Default Value recommended by USEPA (1989), value of 60 kg representing female receptors is sometimes used.
Body weight (child 1-6 years old, all pathways)	15 kg	Standard USEPA Default Value, near the national mean body weight for this age group (both sexes)
Exposure duration (inhalation)	15 yr (adult); 6 yr (child)	Value for adults corresponds to facility lifetime provided by Applicant; value for children corresponds to duration of age group
Exposure frequency (inhalation)	350 days/yr	USEPA (1989) Default value, generally considered to be conservative
Exposure time (inhalation)	24 hr/day	Default value, may greatly overstate duration of outdoor particulate inhalation exposure
Exposure duration (soil ingestion, fish ingestion)	24 yr (adult); 6 yr (child)	USEPA (1989) default value; Combined adult and child exposure durations correspond to approximately 95th percentile national housing tenure; probably a conservative estimate of local average residential tenure
Exposure frequency (soil and sediment ingestion)	285 days/yr (adult and child)	Corresponds to approximate annual average number of days with maximum temperature greater than 32 F in Minneapolis (see text); it is assumed that on colder days, soil/sediment contact would not occur. This is a very conservative estimate of exposure frequency
Soil/sediment ingestion rate	200 mg/day (child); 100 mg/day (adult)	USEPA (1989) Default Value; generally considered to be conservative estimates of average soil ingestion by these age groups; sediment ingestion might be expected to be even lower. This is a very conservative estimate of exposure frequency
Relative bioavailability (all ingestion pathways)	1.0 (100%, all COCs)	It is assumed that all of the COCs in the Kondirator particulate would become available for uptake by humans or biota during the exposure period; see Section 8.4
Exposure frequency (fish ingestion)	365 days/yr	Corresponds to subsistence fisher; probably a very conservative estimate for recreational fish consumers
Fish ingestion rate	30 g/day (adult); 10 g/day (child)	Values typical of daily fish ingestion in Great Lakes Region (Ruffle et al. 1994), these values are somewhat greater than recommended USEPA default values.
Exposure averaging time (all pathways)	Exposure period 15 yr (non-carcinogens) 70 yr (carcinogens)	USEPA (1989) default values; toxicity parameters are defined to be consistent with these exposure averaging periods

assumed that the Kondirator would operate 3,378 hr/yr. This assumption was based on information submitted by the Applicant as representing the maximum annual duration of operations. In calculating lifetime average air concentrations for the purpose of estimating cancer risks, a Kondirator facility life of 15 years was also assumed, again based on information supplied by the Applicant. As these assumptions have a direct effect on the estimated long-term emissions and exposures to residents, the MPCA is considering the possibility of including these assumptions as permit conditions for the Kondirator facility. The affects of alternative assumptions regarding facility lifetime is discussed in Section 9.2.

Residents are assumed to be exposed to the Kondirator emissions for the entire 15-year duration of its operation. Potential exposures before and after that period are not considered, and exposures to "background" concentrations of naturally occurring COCs and COCs emitted from other sources also could not be addressed within the limited scope of the screening level analysis. Residents are assumed to be exposed for 24 hr/day for 350 days/yr to COCs in ambient air. These assumptions are standard conservative "default" assumptions defined by the USEPA for use in screening level analysis (Table 7-4). They most likely overestimate actual exposure durations, as most actual residents would most likely spend a substantial proportion of their time at work or in school or other activities away from home.

Table 7-5 summarizes the results of the IEC calculations for each of the COCs.

7.3.2 Incidental Ingestion of Soil

Potential COC doses to residents from incidental ingestion of soil are also quantified in the assessment. The approach used involves the calculation of a soil intake per day of exposure, per unit body weight, followed by adjustment for the concentration of the COC in the soil, and for the frequency and duration of exposure, to generate an estimate of the intake (dose) of the COC per unit body weight per day, averaged over the period of exposure. The major assumptions used to estimate COC doses to residents are listed in Table 7-5, and are briefly described below. The equation used to estimate the concentration of COCs in soils is—

$$C_{soil}=\frac{(DEP)(COC)(FL)(x)}{(SD)(BD)} \qquad \text{Eq. (7-2)}$$

where

C_{soil} = concentration of chemical in soil after 15 years (mg/kg),
DEP = estimated TSP deposition rate (13.0 g/m^2-yr),
COC = estimated proportion of COC in particulate (unitless, Table B-3),
FL = facility life (15 years),
x = conversion factor (1,000 mg/g),
SD = soil depth of mixing (0.02 m for HHRA, 0.15 m for ERA), and
BD = soil bulk density (1.17x10^3 kg/m^3).

For this pathway, a hypothetical 30-year residential receptor is evaluated, considering a young child for 6 years and an adult for 24 years. This cumulative 30-year residential exposure duration is consistent with the standard exposure default for duration in the same house by a residential receptor, as defined by USEPA. A longer exposure period (30 yr compared with 15) is used to evaluate soil exposures than is used to evaluate inhalation exposures because, while the Kondirator air emissions are assumed to cease after the 15-year facility life, the emitted COCs are expected to persist

TABLE 7–5

Annual Average Air Concentrations and Inhalation Exposure Concentrations for Residents Living Across the River from the Kondirator Facility Assuming 15–Year Facility Life

Constituents Exhibiting Potential Carcinogenic Effects	Annual Average Air Concentrations (µg/m³) (a)	Inhalation Exposure Concentrations (µg/m³) (b)
ARSENIC	0.0015	0.0003
BERYLLIUM	0.0007	0.0001
CADMIUM	0.0010	0.0002
CHROMIUM (TOTAL)	0.0092	0.0019
NICKEL	0.012	0.0026

Constituents Exhibiting Potential Noncarcinogenic Effects	Annual Average Air Concentrations (µg/m³) (a)	Residential Exposure Concentrations (µg/m³) (b)
BORON	0.0012	0.0012
MANGANESE	0.027	0.025

Constituents without Toxicity Criteria	Annual Average Air Concentrations (µg/m³) (a)	Residential Exposure Concentrations (µg/m3) (b)
ALUMINUM	0.023	0.022
ANTIMONY	0.0004	0.0004
CALCIUM	0.0012	0.0012
CARBON	0.026	0.025
COBALT	0.0057	0.0055
COPPER	0.024	0.023
IRON	1.17	1.12
LEAD	0.0049	0.0047
LITHIUM	0.0010	0.0010
MAGNESIUM	0.0046	0.0044
MOLYBDENUM	0.0040	0.0039
NIOBIUM	0.0012	0.0012
SILICON	0.0092	0.0089
SILVER	0.0007	0.0006
TIN	0.0077	0.0074
TITANIUM	0.0012	0.0012
TUNGSTEN	0.0052	0.0050
VANADIUM	0.0029	0.0027
ZINC	0.0096	0.0092
ZIRCONIUM	0.0012	0.0012

(a) From Table 4–3.
(b) Inhalation Exposure Concentrations (IECs) are calculated as shown in equation 7–1. These values are used to calculate inhalation pathway risks, as shown in appendix Table C–2, summarized in Table 9–1.

indefinitely in soils after air emissions stop. The predicted exposure point concentrations and calculated daily doses of potential COCs for this pathway are shown in Table 7-6 for the child and Table 7-7 for the adult.

Like the inhalation scenario, the estimated soil concentrations were based on a facility operating life of 15 years. The maximum estimated soil concentration after 15 years of facility operation, neglecting all mechanisms of loss such as runoff, were used to estimate doses to the hypothetical resident. The resident is assumed to live in the residential area across the river from the proposed Kondirator facility during the entire exposure period. For noncarcinogenic constituents, the residential exposure is averaged over a 30-year exposure period, while for carcinogenic constituents, the residential exposure is averaged over a 70-year lifetime exposure period.

For the soil pathway, the child receptor is considered along with adults because soil ingestion rates are thought to be higher for younger children than for adults. Standard USEPA default soil ingestion rates of 200 mg/day for the child and 100 mg/day for the adult were used in this assessment. The body weights are the commonly used default values of 15 kg for the 1-6 year-old child and 70 kg for the adult which have been found to be near the mean of the body weight distributions for these age groups (USEPA 1989b). To provide a conservative estimate of soil exposures, children and adults are assumed to be exposed to soil every day that the temperature was above freezing; on colder days, it was assumed that soil contact would be precluded by heavy clothing, snow cover, or failure to go outdoors. Measurements collected in Minneapolis-St. Paul, Minnesota (NOAA 1990) indicate that the maximum daily temperature is less than or equal to 0°C (32°F) on approximately 80 days per year. The exposure frequency for both the child and adult was thus assumed to be 285 days per year (i.e., a person could contact and incidentally ingest soil on all days with a temperature above freezing: 365−80 = 285). For the purposes of the exposure assessment, it was assumed that all of the particulate deposited in the soil over the operating life of the facility would remain in the top 2 centimeters of soil, and that none of the COCs would be removed by leaching or runoff. This is a very conservative assumption.

7.3.3 Incidental Ingestion of Sediment

Residents who use the Mississippi River for recreational purposes could come into contact with sediment in the river. For this pathway, a hypothetical 30-year resident is again evaluated, considered to be a young child for 6 years and an adult for 24 years. This cumulative 30-year residential exposure duration is consistent with the standard USEPA exposure default for residence in the same house. The estimated sediment predicted EPCs and daily doses are shown in Table 7-8 for the child and Table 7-9 for the adult. The equations used to estimate children's and adults' intake of COCs from sediment are described in detail in Appendix C (Section C.3).

Like the soil scenario, the sediment concentrations were estimated based on a facility operating life of 15 years. The maximum estimated sediment concentrations after 15 years of facility operation, neglecting all mechanisms of loss, were used to estimate doses to the hypothetical resident. Sediment COC concentrations were estimated using equation 5-8 and are summarized in Table 5-6. For noncarcinogenic constituents, the residential exposure is averaged over a 30-year exposure period, while for carcinogenic constituents, the residential exposure is averaged over a 70-year lifetime exposure period. A sediment mixing depth of 15 centimeters was used to calculate COC concentrations in sediment. This value is larger than that used for soils because it is expected that deposition and resuspension by the river currents will periodically mix sediments to at least this depth. The actual mixing depth of sediments in the river depends greatly on site-specific characteristics such as river flow conditions, dredging, and barge traffic, and the mixing depth may vary greatly at different

TABLE 7-6

Maximum Estimated Soil Concentrations and Calculated Daily Doses for Incidental Ingestion of Soil by a Child Resident Across the River from the Kondirator Facility Assuming 15-Year Facility Life

COCs Exhibiting Potential Carcinogenic Effects	Maximum Estimated Soil Concentration (mg/kg) (a)	Potential Lifetime Average Daily Dose (mg/kg-day) (b)
ARSENIC	9.58	9x10^{-6}
BERYLLIUM	4.17	4x10^{-6}

COCs Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Soil Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ANTIMONY	2.50	3x10^{-5}
ARSENIC	9.58	1x10^{-4}
BERYLLIUM	4.17	4x10^{-5}
BORON	7.92	8x10^{-5}
CADMIUM	6.67	7x10^{-5}
CHROMIUM (TOTAL)	59.17	6x10^{-4}
COPPER	153.58	2x10^{-3}
MANGANESE	170.00	2x10^{-3}
MOLYBDENUM	25.83	3x10^{-4}
NICKEL	80.00	8x10^{-4}
SILVER	4.17	4x10^{-5}
TIN	49.17	5x10^{-4}
VANADIUM	18.33	2x10^{-4}
ZINC	61.67	6x10^{-4}

COCs Without Toxicity Criteria	Maximum Estimated Soil Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ALUMINUM	146.67	2x10^{-3}
CALCIUM	7.92	8x10^{-5}
CARBON	164.17	2x10^{-3}
COBALT	36.67	4x10^{-4}
IRON	7,514	8x10^{-2}
LEAD	31.25	3x10^{-4}
LITHIUM	6.67	7x10^{-5}
MAGNESIUM	29.17	3x10^{-4}
NIOBIUM	7.92	8x10^{-5}
SILICON	59.25	6x10^{-4}
TITANIUM	7.92	8x10^{-5}
TUNGSTEN	33.33	3x10^{-4}
ZIRCONIUM	7.92	8x10^{-5}

(a) Calculated as described in Equation 7-2.

(b) Calculated as shown in Table C-3. These values are used to calculate soil ingestion risks as shown in Table C-3, which are summarized in Table 9-1.

TABLE 7-7

Maximum Estimated Soil Concentrations and Calculated Daily Doses for Incidental Ingestion of Soil by an Adult Resident Across the River from the Kondirator Facility Assuming 15-Year Facility Life

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Soil Concentration (mg/kg) (a)	Potential Lifetime Average Daily Dose (mg/kg-day) (b)
ARSENIC	9.58	4x10^{-6}
BERYLLIUM	4.17	2x10^{-6}

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Soil Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ANTIMONY	2.50	3x10^{-6}
ARSENIC	9.58	1x10^{-5}
BERYLLIUM	4.17	5x10^{-6}
BORON	7.92	9x10^{-6}
CADMIUM	6.67	7x10^{-6}
CHROMIUM (TOTAL)	59.17	7x10^{-5}
COPPER	153.58	2x10^{-4}
MANGANESE	170.00	2x10^{-4}
MOLYBDENUM	25.83	3x10^{-5}
NICKEL	80.00	9x10^{-5}
SILVER	4.17	5x10^{-6}
TIN	49.17	5x10^{-5}
VANADIUM	18.33	2x10^{-5}
ZINC	61.67	7x10^{-5}

Constituents Without Toxicity Criteria	Maximum Estimated Soil Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ALUMINUM	146.67	2x10^{-4}
CALCIUM	7.92	9x10^{-6}
CARBON	164.17	2x10^{-4}
COBALT	36.67	4x10^{-5}
IRON	7,514	8x10^{-3}
LEAD	31.25	3x10^{-5}
LITHIUM	6.67	7x10^{-6}
MAGNESIUM	29.17	3x10^{-5}
NIOBIUM	7.92	9x10^{-6}
SILICON	59.25	7x10^{-5}
TITANIUM	7.92	9x10^{-6}
TUNGSTEN	33.33	4x10^{-5}
ZIRCONIUM	7.92	9x10^{-6}

(a) Calculated as shown in Equation 7-2.

(b) Calculated as shown in Table C-4. These values are used to calculate soil ingestion risks as shown in Table C-4, which are summarized in Table 9-1.

TABLE 7-8

Maximum Estimated Sediment Concentrations and Calculated Daily Doses for Incidental Ingestion of Mississippi River Sediment by a Child Resident Using the River for Recreation Assuming 15-Year Facility Life

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Sediment Concentration (mg/kg) (a)	Potential Lifetime Average Daily Dose (mg/kg-day) (b)
ARSENIC	0.58	$5x10^{-7}$
BERYLLIUM	0.25	$2x10^{-7}$

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Sediment Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ANTIMONY	0.15	$2x10^{-6}$
ARSENIC	0.58	$6x10^{-6}$
BERYLLIUM	0.25	$3x10^{-6}$
BORON	0.48	$5x10^{-6}$
CADMIUM	0.40	$4x10^{-6}$
CHROMIUM (TOTAL)	3.58	$4x10^{-5}$
COPPER	9.29	$1x10^{-4}$
MANGANESE	10.28	$1x10^{-4}$
MOLYBDENUM	1.56	$2x10^{-5}$
NICKEL	4.84	$5x10^{-5}$
SILVER	0.25	$3x10^{-6}$
TIN	2.97	$3x10^{-5}$
VANADIUM	1.11	$1x10^{-5}$
ZINC	3.73	$4x10^{-5}$

Constituents without Toxicity Criteria	Maximum Estimated Sediment Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ALUMINUM	8.87	$9x10^{-5}$
CALCIUM	0.48	$5x10^{-6}$
CARBON	9.93	$1x10^{-4}$
COBALT	2.22	$2x10^{-5}$
IRON	454.31	$5x10^{-3}$
LEAD	1.89	$2x10^{-5}$
LITHIUM	0.40	$4x10^{-6}$
MAGNESIUM	1.76	$2x10^{-5}$
NIOBIUM	0.48	$5x10^{-6}$
SILICON	3.58	$4x10^{-5}$
TITANIUM	0.48	$5x10^{-6}$
TUNGSTEN	2.02	$2x10^{-5}$
ZIRCONIUM	0.48	$5x10^{-6}$

(a) Calculated as discussed in Appendix B.6, shown in Table B-8.
(b) Calculated as shown in appendix Table C-5. These values are used to calculate sediment pathway risks, which are also shown in Table C-5 and summarized in Table 9-1.

TABLE 7-9

Modeled Sediment Concentrations and Calculated Daily Doses for Incidental Ingestion of Mississippi River Sediment by an Adult Resident Using the River for Recreation Assuming 15-Year Facility Life

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Sediment Concentration (mg/kg) (a)	Potential Lifetime Average Daily Dose (mg/kg-day) (b)
ARSENIC	0.58	$2x10^{-7}$
BERYLLIUM	0.25	$1x10^{-7}$

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Sediment Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ANTIMONY	0.15	$2x10^{-7}$
ARSENIC	0.58	$6x10^{-7}$
BERYLLIUM	0.25	$3x10^{-7}$
BORON	0.48	$5x10^{-7}$
CADMIUM	0.40	$4x10^{-7}$
CHROMIUM (TOTAL)	3.58	$4x10^{-6}$
COPPER	9.29	$1x10^{-5}$
MANGANESE	10.28	$1x10^{-5}$
MOLYBDENUM	1.56	$2x10^{-6}$
NICKEL	4.84	$5x10^{-6}$
SILVER	0.25	$3x10^{-7}$
TIN	2.97	$3x10^{-6}$
VANADIUM	1.11	$1x10^{-6}$
ZINC	3.73	$4x10^{-6}$

Constituents without Toxicity Criteria	Maximum Estimated Sediment Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg-day) (b)
ALUMINUM	8.87	$1x10^{-5}$
CALCIUM	0.48	$5x10^{-7}$
CARBON	9.93	$1x10^{-5}$
COBALT	2.22	$2x10^{-6}$
IRON	454.31	$5x10^{-4}$
LEAD	1.89	$2x10^{-6}$
LITHIUM	0.40	$4x10^{-7}$
MAGNESIUM	1.76	$2x10^{-6}$
NIOBIUM	0.48	$5x10^{-7}$
SILICON	3.58	$4x10^{-6}$
TITANIUM	0.48	$5x10^{-7}$
TUNGSTEN	2.02	$2x10^{-6}$
ZIRCONIUM	0.48	$5x10^{-7}$

(a) Sediment concentrations are estimated as described in Appendix B.6, shown in Table B-8.

(b) Calculated as shown in appendix Table C-6. These values are used to calculate sediment pathway risks, which are also shown in Table C-6, and summarized in Table 9-1.

locations throughout the area. The use of the 15-centimeter mixing depth introduces a substantial degree of uncertainty into the sediment exposure assessment.

The soil ingestion rates discussed above were also used for sediment ingestion. The standard default body weights of 15 kg and 70 kg were also used in the dose calculations for child and adult receptors, respectively. Similar to the soil pathway, the receptors were not assumed to come in contact with sediment on days in which the maximum daily temperature is less than or equal to 0°C (32°F) (approximately 80 days/yr). Therefore, the exposure frequency for both the child and adult was conservatively assumed to be 285 days/yr.

7.3.4 Ingestion of Fish

As discussed in Section 7.2, it is possible that some individuals could consume fish caught in the reach of the river near the Kondirator. Average daily doses of COCs associated with the consumption of fish by hypothetical fish consumers are evaluated. For this pathway, a hypothetical 30-year subsistence fisher is evaluated, modeled as a young child for 6 years and an adult for 24 years. The assumptions used to calculate the doses are shown in Table 7-5, and the predicted EPCs and daily doses are summarized in Table 7-10 for the child and Table 7-11 for the adult. The equations used to evaluate children's and adults' COC doses through fish ingestion are described in detail in Appendix C (Section C.4). As described in Section 6.1, only three of the constituents of concern are likely to bioaccumulate in fish. Therefore, these metals (i.e., cadmium, lead, and zinc) are the only constituents that are included in this exposure pathway.

For the fishing scenario, a subsistence fisher of the Mississippi River is assumed to consume fish caught in the river 365 days per year. For noncarcinogenic constituents, the residential exposure is averaged over a 30-year exposure period. Fish consumption rates of 10 grams per day for children and 30 grams per day for adults are used, based on a study by Ruffle et al. (1994). Once again, the standard default body weights of 15 kg and 70 kg were also used in the dose calculations.

TABLE 7–10

Fish Tissue Concentrations and Calculated Daily Doses for Ingestion of Fish from the Mississippi River by a Child

Constituents Exhibiting Potential Noncarcinogenic Effects	Fish Tissue Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg–day) (b)
CADMIUM	0.036	$2x10^{-5}$
ZINC	0.013	$9x10^{-6}$

Constituents without Toxicity Criteria	Fish Tissue Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg–day) (b)
LEAD	0.016	$1x10^{-5}$

(a) Calculated as described in equation 6–1 and Appendix B–7, shown in Table B–9.
(b) Calculated as shown in appendix Table C–7. The values are used to calculated fish ingestion pathway hazard quotients, also shown in Table C–7, and summarized in Table 9–1.

TABLE 7–11

Fish Tissue Concentrations and Calculated Daily Doses for Ingestion of Fish from the Mississippi River by an Adult

Constituents Exhibiting Potential Noncarcinogenic Effects	Fish Tissue Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg–day) (b)
CADMIUM	0.036	$2x10^{-5}$
ZINC	0.013	$6x10^{-6}$

Constituents without Toxicity Criteria	Fish Tissue Concentration (mg/kg) (a)	Potential Average Daily Dose (mg/kg–day) (b)
LEAD	0.016	$7x10^{-6}$

(a) Calculated in equation 6–1 and Appendix B–7, shown in appendix Table B–9.
(b) Calculated as shown in appendix Table C–8. The values are used to calculate fish ingestion pathway hazard quotients, also shown in Table C–8, and summarized in Table 9–1.

8.0 TOXICOLOGIC EVALUATION OF COCS

Purpose——To describe how the toxicologic criteria values for the various COCs have been selected, and to discuss some of the limitations of the criteria.

In this section, the toxicological criteria values for the COCs are identified. The general approach taken in this HHRA (1) to identify toxicologic criteria for the COCs, and (2) to use these criteria, along with the potential exposure and dose estimates developed in previous sections, to develop numerical estimates or indicators of the potential health risks associated with exposures to emissions from the Kondirator. Toxicologic criteria are sometimes described as dose-response values, which describe the toxic properties of the COCs at various dose levels. For cancer risks, Cancer Slope Factors and Unit Risk values describe the increase in cancer risks that could be expected to occur as a result of an additional unit of exposure. In the case of noncancer risks, Reference Doses (RfDs) and Reference Concentrations (RfCs), which include "safety factors" to protect sensitive populations, represent estimates of the highest doses or exposure levels at which adverse effects are unlikely to occur. Both cancer and noncancer criteria are used in the following sections to develop estimates of potential risks associated with "chronic" (long-term) exposures to COCs.

In this screening level assessment, all of the toxicity criteria used to derive quantitative risk estimates have been derived by the USEPA. These values have been used to provide a convenient and consistent basis for the evaluation of health effects. The derivation and meaning of the toxicologic criteria are described in detail in Section 8.1. It should be noted that annual average air concentration limits (ACLs) received from MPCA (1994) have the same toxicologic basis as the USEPA criteria. Therefore, only USEPA criteria are used in this assessment.

Toxicity criteria are derived using standardized methods, which are discussed in more detail below. The toxicity criteria are intended to serve as general indicators of risk, which can be used, along with standardized methods of exposure and dose assessment, to provide approximate, but not definitive, characterizations of potential risk. The data bases supporting the development of the criteria are of varying quality and completeness, and extensive use of professional judgment is needed to derive the criteria for each COC. Each COC has a complex set of toxicologic properties, and the procedures prescribed to derive toxicologic criteria may fit some COCs better than others. Because of the potential lack of fit of data to models, the approach taken to defining toxicity criteria is designed to err on the side of conservatism (health-protectiveness).

In a detailed assessment, the use of the predefined toxicity criteria would represent only the first step in a quantitative evaluation of potential risk; the specific toxicologic properties of each COC would be reviewed in detail, and risk estimates would be derived using a variety of plausible assumptions about toxicity and potential risk. In this HHRA, this detailed approach was not possible. Instead, the existing toxicity criteria are used to derive all of the risk estimates. Only in the cases of the few COCs that seem to account for the greatest potential risk is any discussion presented of the uncertainties surrounding the risk estimates and possible alternative approaches to estimating potential risks. More detailed discussions of the toxicity of the other COCs is beyond the scope of this screening level assessment. The implications of the use of these toxicity criteria for specific potential risk results is discussed in detail in Section 10.6.

The general approach for the classification of health effects and the methods used in the derivation of health effects criteria are described in Section 8.1. Specific criteria values used to develop estimates of potential risk associated with chronic exposures to the COCs are presented in

Section 8.2. Some special issues arising from the specific chemical and physical properties of the Kondirator particulates are discussed in Section 8.3. The issue of chromium speciation is addressed in Section 8.4.

8.1 HEALTH EFFECTS CLASSIFICATION AND CRITERIA DEVELOPMENT

For risk assessment purposes, individual chemicals are typically separated into categories of toxicity depending on whether exposure to them may be associated with carcinogenic (cancer-causing) or noncarcinogenic effects, or both. (Potential exposures to several of the COCs emitted from the Kondirator are known to be associated with both carcinogenic and noncarcinogenic adverse effects, and both types of effect are evaluated for these COCs.) The distinction between carcinogenic and noncarcinogenic effects relates to the currently held regulatory consensus (which parallels a broad toxicologic consensus) that the general mechanisms of action resulting in each category of toxic effect are different. For the purpose of assessing potential risks associated with potential carcinogens, USEPA and numerous other Federal and State agencies have adopted the position that a small number of molecular events can evoke changes in a single cell, or a small number of cells, that can lead to tumor formation. This is described as a non-threshold mechanism, because it is assumed that any non-zero exposure to a carcinogen poses some finite probability of causing cancer.[2]

In the case of chemicals exhibiting noncarcinogenic effects, the prevailing toxicologic model takes into account the fact that organisms have repair and detoxification capabilities that must be exceeded by some critical (threshold) level of exposure or dose before an adverse effect is manifested. For example, an organ can have a large number of cells performing the same or similar functions that must be significantly depleted before the effects on the organ are measurable. This threshold view holds that a range of potential exposures from just above zero to some finite value can be tolerated by the organism without appreciable potential risk of causing the disease.

These two models of toxic effect lead to two different general types of toxicologic or health effects criteria, as noted above. For carcinogenic effects, Cancer Slope Factors and Unit Risks define the incremental risk of cancer associated with an incremental dose of an agent; for noncarcinogenic adverse effects, RfDs and RfCs describe "safe" dose and exposure levels that should not be associated with adverse effect. The derivation of these two types of toxicity criteria are discussed below.

8.1.1 Health Effects Criteria for Potential Carcinogens

For chemicals exhibiting carcinogenic effects, USEPA's Carcinogen Risk Assessment Verification Endeavor (CRAVE) evaluates data concerning the carcinogenic activity of chemicals in humans and animals to derive Cancer Slope Factors and Unit Risk values. These toxicity criteria are listed in USEPA's Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST) and Supplements. In keeping with the changing state of knowledge, the criteria values may change as new evidence regarding particular chemicals becomes available. Cancer Slope Factors (CSFs) are expressed in terms of reciprocal lifetime daily dose, in units of (mg chemical/kg body weight-day)$^{-1}$. They describe the upper-bound estimate of the increase in an individual's potential risk of developing cancer over a 70-year lifetime per unit of daily dose. Unit Risks are expressed as a reciprocal air concentration in units of (μg/m^3)$^{-1}$, and again represent the incremental risk of cancer associated with each unit of air exposure. The derivation of CSFs and

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[2] This nonthreshold hypothesis is currently undergoing internal USEPA review.

Unit Risks does not take into account the possible varying potency of chemicals to cause cancer when exposures occur over different life stages, or possible differences in potency resulting from intermittent versus continuous exposures. Because regulatory efforts are generally focused toward protecting public health, including even the most sensitive members of the population, the cancer slope factors and unit risks are derived using conservative assumptions.

CSFs and Unit Risks are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies usually are conducted using a small number of animals and relatively high doses in order to detect possible elevated cancer incidence. Because humans are expected to be exposed to doses lower than those used in the animal studies, mathematical models must be employed to estimate human risk at the much lower doses. The data from animal studies are typically analyzed using a procedure called the "linearized multistage model" to obtain a dose-response curve in the low-dose region that is of interest in the evaluation of environmental risks. In general, after the data are fit to the dose-response model, the 95% upper confidence limit of the slope of the resulting dose-response curve is calculated. This upper-bound estimate is subjected to various adjustments, and an interspecies scaling factor is applied (which takes into account differences between animal and human body weight, surface area, and physiology) to derive the slope factor or unit risk for humans. Thus, the actual human risks associated with exposure to a potential carcinogen quantitatively evaluated based on animal data are very uncertain and imprecise. USEPA guidance indicates that cancer risks estimated using slope factors or unit risks derived from animal studies should be interpreted as upper-bound estimates, and that the great uncertainty surrounding such criteria implies that true incremental risk may be as low as zero (USEPA 1986).

Where they are available, dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an *ad hoc* basis. CSFs and Unit Risks based on human epidemiological data are also derived using very conservative assumptions and, as such, they too are unlikely to underestimate potential risks for a given level of exposure.

In addition to the numerical description of potential risk, USEPA also assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. The weight-of-evidence classification characterizes the nature and strength of the available information as to whether an agent is a human carcinogen. The classification thus affects the interpretation of potential health risks, although it is not directly related to carcinogenic potency or to the magnitude of risk estimates. Definitions for the five categories of USEPA's final classification of the overall evidence are as follows:

> Group A chemicals (human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and cancer.
>
> Groups B1 and B2 chemicals (probable human carcinogens) are agents for which there is limited (B1) or inadequate (B2) evidence of carcinogenicity from human studies. Group B2 agents also have sufficient evidence of carcinogenicity from animal studies.
>
> Group C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals.

Group D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available.

Group E chemicals (evidence of non-carcinogenicity in humans) are agents for which there is no evidence of carcinogenicity in adequate human or animal studies.

The toxicity criteria for carcinogens presented in this report are all accompanied by this weight-of-evidence classification. The reader should keep in mind that regardless of the magnitude of the potency estimate, there are important differences in the certainty of the relationship between exposure and carcinogenicity between chemicals that have been demonstrated to be human carcinogens and those chemicals for which the evidence is limited.

8.1.2 Health Effects Criteria for Noncarcinogens

Health criteria for chemicals exhibiting noncarcinogenic effects take the form of RfDs and/or RfCs. These are developed by USEPA's RfD/RfC Work Group and are listed in IRIS or HEAST. The RfD is expressed in units of dose (mg chemical/kg body weight-day), while the RfC is expressed in concentration units (mg chemical/m^3 air). RfDs and RfCs are most often derived from human studies involving workplace exposures or from animal studies. The RfD or RfC is defined by USEPA as "an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable potential risk of deleterious effects during a lifetime" (IRIS 1994). The RfD/RfC is used as a reference point for gauging the potential for noncarcinogenic effects of exposures.

The RfDs/RfCs are derived using uncertainty factors that reflect scientific judgment regarding the adequacy of the data used to estimate the RfD/RfC. In simple terms, the fewer data available, and the lower the data quality, the higher a "margin of safety" is required to estimate a dose that is unlikely to cause adverse effects. RfDs/RfCs are estimated from lowest-observed-adverse-effect levels (LOAELs) or no-observed-adverse-effect levels (NOAELs) in human or animal studies. Uncertainty factors, which can take values as high as 10, are employed to adjust the observed dose. Uncertainty factors are intended to account for—

(1) The variation in sensitivity among members of the human population;

(2) The uncertainty in extrapolating animal data to humans;

(3) The uncertainty in extrapolating data obtained in a study that is less-than-lifetime exposure to lifetime exposure;

(4) The uncertainty in using LOAEL data rather than NOAEL data; and

(5) The inability of any single study to adequately address all possible adverse outcomes in humans.

To derive RfDs/RfCs, NOAELs or LOAELS are divided by one or more uncertainty factors, as appropriate. When taken together, these uncertainty factors may apply a total margin of safety of up to 10,000 to the experimentally obtained toxicity endpoint. In some cases, modifying factors are also applied to RfDs/RfCs to cover other uncertainties in the toxicity database and reflect the professional judgment of those reviewing the database. The net result is that RfDs/RfCs tend to result in risk characterizations that err in the direction of overestimation of the potential for adverse noncarcinogenic effects.

All of the RFDs and RFCs used in this HHRA are chronic values; that is they are derived for use in evaluating the impact of exposures of duration 7 years or longer. Subchronic RfDs/RfCs are available from USEPA's Environmental Criteria and Assessment Office (ECAO) and may be used to characterize the potential for the occurrence of noncarcinogenic effects associated with subchronic exposures [2 weeks to 7 years as defined by USEPA (1989)]. The child resident exposure scenarios evaluated in this assessment would be classified as subchronic exposures according to this USEPA definition. Subchronic RfDs/RfCs are developed similarly to chronic RfDs/RfCs, and are typically equal to chronic RfDs/RfCs or are one order of magnitude greater (less stringent). Therefore, the subchronic RfDs/RfCs that were available for the COCs in this HHRA (i.e., chromium RfD and manganese RfC) were not used, and the more conservative chronic RfDs/RfCs were used instead.

8.2 CHRONIC HEALTH EFFECTS CRITERIA FOR THE CHEMICALS OF CONCERN

Tables 8-1 and 8-2 present the health effects criteria used to quantitatively evaluate potential health effects of chronic human exposures to the COCs emitted from the proposed Kondirator facility. Health effects criteria for chronic exposures via the oral route (slope factors and chronic RfDs) are presented in Table 8-1, and health effects criteria for chronic inhalation exposures (unit risks and chronic RfCs) are presented in Table 8-2. The toxicity criteria were obtained from USEPA's Integrated Risk Information System (IRIS 1994) and Health Effects Assessment Summary Tables (HEAST 1994) and Supplements.

No chronic health effects criteria (i.e., neither oral nor inhalation pathways) were available from USEPA for the following metals emitted from the Kondirator: aluminum, calcium, carbon, cobalt, iron, lead, lithium, magnesium, niobium, silicon, titanium, tungsten, and zirconium. In addition to the metals listed above, no chronic inhalation health effects criteria were available for antimony, copper, molybdenum, silver, tin, vanadium, and zinc. Potential risks associated with exposures to chemicals lacking criteria were not quantitatively evaluated. Exclusion of the chemicals listed above from quantitative evaluation is not anticipated to result in significant underestimates of overall potential risk, because these elements are present in very low concentrations in the emissions, or because they are of known low toxicity.

In addition, USEPA has not developed an RfD or RfC for lead. In this assessment, potential adverse effects of lead exposure are evaluated using USEPA's Integrated Exposure/Uptake Biokinetic (IEUBK) model, as described in detail in Section 9.2.5

8.3 BIOAVAILABILITY AND TOXICITY OF METAL PARTICULATES

An unusual feature of this risk assessment is that the chemical and physical properties of the particulates emitted by the proposed Kondirator are different from those of the particulates commonly emitted by combustion sources (waste incinerators or fossil fuel boilers). They are also different from the types of metallic particulates for which fate and transport properties are generally derived, and from which toxicity criteria are estimated. These differences affect both the fate and transport of the particles in air and water (as discussed previously) and the availability of these particles to be absorbed by humans or ecological receptors. This latter property is called

TABLE 8-1

ORAL TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN

	Noncarcinogenic Effects				Carcinogenic Effects		
Chemical	Chronic RfD (mg/kg-day) [Uncertainty Factor] (a)		Target Organ/ Critical Effect/ Disease (b)	Source	Cancer Slope Factor (CSF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification (c)	
Inorganic Chemicals:							
Aluminum	---		---	---	---	---	---
Antimony	0.0004	[1000]	Blood chemistry	IRIS	---	---	---
Arsenic	0.0003	[3]	Skin	IRIS	1.75	A	IRIS
Beryllium	0.005	[100]	None Observed	IRIS	4.3	B2	IRIS
Boron	0.09	[100]	Testicular	HEAST	---	---	---
Cadmium	0.001	[10]	Kidney	IRIS	---	---	---
Calcium	---		---	---	---	---	---
Carbon	---		---	---	---	---	---
Chromium III	1.0	[1000]	Liver	IRIS	---	---	---
Chromium VI	0.005	[500]	CNS	IRIS	---	---	---
Cobalt	---		---	---	---	---	---
Copper	0.37	[1]	GI irritation	HEAST	---	---	---
Iron	---		---	---	---	---	---
Lead	---		CNS	IRIS	---	B2	IRIS
Lithium	---		---	---	---	---	---
Magnesium	---		---	---	---	---	---
Manganese	0.14	[1]	CNS	IRIS			
Molybdenum	0.005	[30]	Blood Chemistry	IRIS	---	---	---
Nickel	0.02	[300]	Decreased Body Weight	IRIS	---	---	---
Niobium	---		---	---	---	---	---
Silicon	---		---	---	---	---	---
Silver	0.005	[3]	Argyria	IRIS	---	---	---
Tin	0.6	[3000]	Liver/Kidney	IRIS	---	---	---
Titanium	---		---	---	---	---	---
Tungsten	---		---	---	---	---	---
Vanadium	0.007	[100]	None Observed	IRIS	---	---	---
Zinc	0.3	[3]	Blood Chemistry	IRIS	---	D	IRIS
Zirconium	---		---	---	---	---	---

IRIS = Integrated Risk Information System, 1994
HEAST = Health Effects Assessment Summary Tables, Annual 1994
--- = No information available.

(a) Factors used to reflect scientific judgement regarding the various types of data used to estimate the RfD. The factors (which are each generally 10-fold) are intended to account for uncertainty in: the variation in sensitivity among members of the human population, extrapolating animal data to humans, extrapolating from data obtained in a study that is less than lifetime exposure, using lowest-observable-adverse-effect level (LOAEL) data rather than no-observable-adverse-effect level (NOAEL) data; and the inability of any single study to adequately address all possible adverse outcomes in humans (USEPA 1991b). The magnitude of the uncertainty factors used to derive an RfD do not necessarily reflect the overall level of uncertainty associated with the RfD value.

(b) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ.

(c) EPA Weight of Evidence Classification for Carcinogenic Effects: [A] = human carcinogen based on adequate evidence from human studies; [B1] = probable human carcinogen based on limited human data; [B2] = probable human carcinogen based on inadequate evidence from human human studies and adequate evidence from animal studies; [D] = not classified as to human carcinogenicity.

TABLE 8–2

INHALATION TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN

	Noncarcinogenic Effects			Carcinogenic Effects		
Chemical	Chronic RfC (mg/m^3) [Uncertainty Factor] (a)	Target Organ/ Critical Effect/ Disease (b)	Source	Unit Risk (UR) $(ug/m^3)^{-1}$	Weight–of–Evidence Classification (c)	Source
Inorganic Chemicals:						
Aluminum	---	---	---	---	---	---
Antimony	---	---	---	---	---	---
Arsenic	---	---	---	0.0043	A	IRIS
Beryllium	---	---	---	0.0024	B2	IRIS
Boron	0.02 [100]	Respiratory Tract	IRIS	---	---	---
Cadmium	---	---	---	0.0018	B1	IRIS
Calcium	---	---	---	---	---	---
Carbon	---	---	---	---	---	---
Chromium III	---	---	---	---	---	---
Chromium VI	---	---	---	0.012	A	IRIS
Cobalt	---	---	---	---	---	---
Copper	---	---	---	---	---	---
Iron	---	---	---	---	---	---
Lead	---	CNS	IRIS	---	B2	IRIS
Lithium	---	---	---	---	---	---
Magnesium	---	---	---	---	---	---
Manganese	0.00005 [1000]	CNS	IRIS	---	D	IRIS
Molybdenum	---	---	---	---	---	---
Nickel	---	---	---	0.00024 (d)	A	IRIS
Niobium	---	---	---	---	---	---
Silicon	---	---	---	---	---	---
Silver	---	---	---	---	---	---
Tin	---	---	---	---	---	---
Titanium	---	---	---	---	---	---
Tungsten	---	---	---	---	---	---
Vanadium	---	---	---	---	---	---
Zinc	---	---	---	---	D	IRIS
Zirconium	---	---	---	---	---	---

(a) Factors used to reflect scientific judgement regarding the various types of data used to estimate the RfD. The factors (which are each generally 10–fold) are intended to account for uncertainty in: the variation in sensitivity among members of the human population, extrapolating animal data to humans, extrapolating from data obtained in a study that is less than lifetime exposure, using lowest–observable–adverse–effect level (LOAEL) data rather than no–observable–adverse–effect level (NOAEL) data; and the inability of any single study to adequately address all possible adverse outcomes in humans (USEPA 1991b). The magnitude of the uncertainy factors used to derive an RfC do not necessarily reflect the overall level of uncertainty in the RfC value.

(b) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfCs are based on toxic effects in the target organ.

(c) EPA Weight of Evidence Classification for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B1] = Probable human carcinogen based on limited human data;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies;
[D] = Not classified as to human carcinogenicity;
[E] = Evidence of noncarcinogenicity for humans.

(d) Value from IRIS for nickel refinery dust.

IRIS = Integrated Risk Information System, 1994
HEAST = Health Effects Assessment Summary Tables, Annual 1994
--- = No information available.

bioavailability, and differences in bioavailability can have major consequences for estimates of the potential risk associated with exposures to the metallic elements present in the particles.

In addition to the bioavailability of COCs, the metallic form of the particulates expected from the Kondirator may also affect the toxicity of the particulate in other ways. That is, the chemical form of the particulate (metal dust) may affect how toxic the various metal constituents are, in addition to simple differences in bioavailability. It is possible that even the simple physical form of the particles may result in toxic properties unlike the properties of the compounds for which toxicity criteria are derived. Both of these issues are discussed below.

The key difference between the Kondirator particulates and the particulates commonly encountered in risk assessment is that the Kondirator particulates are essentially finely ground and shredded metal. Particulates from combustion sources and soils are generally made up of either silicious (sand-like), carbonaceous (sooty), or organic particles, and they are generally much less dense than pure metallic particulates. More important, the metallic elements in particles from these sources tend to be, at least to some extent, immediately soluble in water (and body fluids). In contrast, the metallic particulates emitted by the Kondirator would not be expected to be immediately soluble, as they are essentially pure bulk metal. Thus exposure to the freshly emitted metallic particulate from the Kondirator might be expected to result in less actual absorption of metal by a receptor than exposure to the more soluble soil or combustion source particulates. In addition, toxicity information for metals is usually derived from studies of metallic compounds, which are quite soluble. For this reason, it was necessary to evaluate the relative bioavailability of the Kondirator particulate compared to other particulates for which toxicity parameters have been derived.

After reviewing the literature on metal particulates, the approach taken in this assessment has been to assume that the Kondirator particulates are as bioavailable, in the long term, as metals from other sources. The rationale for this decision is the consideration that the predominantly fine carbon steel particulate, while not soluble immediately, may become bioavailable after emission rather quickly as a result of corrosion (rusting) of the particles as they come in contact with atmospheric moisture, with moisture in soil, or with the water in the Mississippi River. Most common grades of carbon steel (the predominant feed material for the Kondirator) are characterized as having "somewhat limited corrosion resistance," and in general use tend to exhibit corrosion rates on the order of 0.1 to 0.5 millimeters/year (0.004 to 0.02 inches/year, Krisher and Siebert 1984). Since the great majority of the particulates emitted by the Kondirator are much smaller than this, (76% are less than 30 microns, about 0.001 inches) it is clear that, within a relatively short time (a few months), they will be completely oxidized, and all of the trace elements may become bioavailable and may be absorbed by receptors. The corrosion of the predominantly iron particles can be expected to release all of the trace elements in the carbon steel. While it is possible that some coarse particles that are deposited in sediment may corrode more slowly due to the relatively low oxygen content in this environment, it is clear that the bulk of the particulate will rather rapidly be converted to soluble or colloidal metal oxides/hydroxides.

Detailed analyses of the corrosion properties of the other scrap metal inputs to the Kondirator have not been undertaken, but the assumption of 100% bioavailability has been applied to the elemental constituents of these metals as well. This assumption may significantly affect the results of the HHRA for some COCs whose overall concentration in the scrap metal feed is strongly related to their presence at high concentrations in scrap metals other than carbon steel. This is the case for chromium (whose major source in Kondirator feed materials is stainless steel), for lead (whose major sources are aluminum and brass), and for copper.

In any event, the relative bioavailability factor for the metals in the particulates emitted by the Kondirator is assumed to be 1.0, which means that metals are completely bioavailable immediately following release into the environment. This assumption may slightly overestimate metal doses and potential risks (if some of the particulates do not corrode during the exposure period) or underestimate doses (if in fact corrosion of metal particulates makes them more bioavailable than the metals used to estimate toxicity). The uncertainty in the dose and risk estimates introduced by the uncertainty in the bioavailability of metals from the Kondirator particulates is most likely small compared with some other sources of uncertainty in the assessment, for example the uncertainty in toxicity estimates.

In addressing the toxicity of the metallic forms, the decision has been made to use the existing toxicity criteria to develop risk estimates, as few alternatives are available within the scope of the screening assessment. Almost all of the chronic toxicity criteria values for the COCs are derived based on elemental forms other than metallic dusts. This introduces a substantial amount of uncertainty into the risk characterization for the inhalation pathway, since inhalation exposures will be to "fresh," uncorroded particles, and the effect of differences in physical and chemical forms on toxicity will be more pronounced than for the other pathways. It is very difficult to evaluate the effect of this assumption on the level of uncertainty in the risk estimates. It is unlikely that the chemical forms of the metallic elements released by particle corrosion are very toxicologically dissimilar to the compounds for which toxicity criteria have been derived. In Section 10.6, the potential uncertainty associated with bioavailability and chemical speciation issues are discussed for specific COCs which appear to be associated with the highest potential risks.

8.4 CHROMIUM SPECIATION

An additional issue that needs to be addressed in assessing the potential risks associated with COC exposures is the ionic speciation of the metals emitted from the Kondirator. This issue is particularly important in the case of chromium because the two most prevalent ionic species, the trivalent and hexavalent forms, differ widely in toxicity. The trivalent form is of relatively low toxicity to humans and is not known to be carcinogenic, while the hexavalent form is considerably more toxic, and some hexavalent chromium compounds are known human carcinogens. For purposes of this assessment, it has been assumed that 10% of the chromium emitted from the Kondirator would be in the more toxic hexavalent form when human exposure occurs. This assumption is likely to be conservative for a number of reasons. First, while the valence state of metals in alloy form are not well defined, elemental metals generally occur in a low valence state or in the form of the pure metal (i.e., a zero valence state). In the case of chromium emitted from the Kondirator, quite vigorous oxidizing conditions would be required to increase the valence state of any of the pure metal to the hexavalent state of the metal. These conditions are not expected to occur at the Kondirator facility. Even in fine particulate emissions from combustion sources, most chromium is generally trivalent. For example, Siebert and Austin-Guiden (1991) found that an average of only 3.4% of the chromium in particulates emitted from hazardous and medical waste incinerators was hexavalent. Similar results have been reported for particulates emissions from coal-fired combustors.

Strong oxidizing conditions do not normally prevail in the environment, and it is generally agreed that under normal geochemical conditions the predominant form of chromium is trivalent (Cotton and Wilkinson 1962). In the soil-water environment, chromium generally cycles slowly between the trivalent and hexavalent state, with the equilibrium greatly favoring the more stable, less soluble trivalent compounds. The oxidation of chromium to higher valence states is favored by the presence of specific oxidizing ions, the concentrations of which may be quite low in soil and water.

In the presence of sunlight and organic particulates or other reducing agents, hexavalent chromium is rapidly reduced to the trivalent form (Cantor and Gloyna 1968).

For these reasons, it is quite likely that the great preponderance of the chromium emitted from the Kondirator will ultimately end up in the trivalent state, and the assumption that 10% hexavalent chromium is present will substantially overestimate the overall chromium toxicity. The uncertainty associated with this assumption will be discussed in more detail in Section 10.6.

9.0 RISK CHARACTERIZATION

Purpose——To estimate potential risks using exposure/dose information and toxicity criteria.

In this section, the potential human health risks associated with emissions from the Kondirator facility are evaluated. Potential risks are characterized separately for chronic (long-term) and acute (short-term) exposures to contaminants having toxicity criteria, and separately for exposures to lead, where a special risk model developed by USEPA is used to estimate the potential facility impact on children's blood lead concentrations.

In Section 9.1, the methods used to characterize chronic carcinogenic and noncarcinogenic health risks are described. Exposure and dose estimates derived in Section 7.2 are combined with USEPA chronic toxicity criteria to develop quantitative estimates of potential chronic health risks. The results of the risk evaluation for each of the exposure pathways are summarized in Section 9.2. In Section 9.3, the estimated short-term maximum (1-hour) air concentrations of COCs emitted from the proposed Kondirator are compared to acute toxicity standards to evaluate the potential for acute adverse effects. Finally, Section 9.4 describes the results of the application of USEPA's IEUBK model to lead emissions from the facility.

9.1 RISK CHARACTERIZATION METHODS

USEPA (1986a,b, 1989, 1992) has developed methods for assessing the potential risks to individuals from potential exposure to carcinogenic (cancer-causing) and noncarcinogenic (effects other than cancer) constituents, which are generally followed in this HHRA. For potential exposures to constituents exhibiting carcinogenic effects, the estimated incremental lifetime cancer risks were calculated by multiplying the inhalation pathway inhalation exposure concentrations or the ingestion pathway lifetime average daily dose (LADD) by the appropriate toxicity criteria (cancer slope factors for the ingestion pathways and unit risk values for the inhalation pathway). For the ingestion pathway,

$$\text{Risk} = \text{LADD} * \text{CSF} \qquad \text{Eq. (9–1)}$$

where

Risk = the estimated increase in lifetime cancer risk,
LADD = the Lifetime Average Daily Dose of the carcinogen (mg/kg-day),
CSF = the ingestion pathway Cancer Slope Factor for the carcinogen $(\text{mg/kg-day})^{-1}$.

For the inhalation pathway,

$$\text{Risk} = \text{IEC} * \text{UR} \qquad \text{Eq. (9–2)}$$

where

IEC = the Inhalation Exposure Concentration ($\mu g/m^3$),
UR = inhalation pathway Unit Risk Value $(\mu g/m^3)^{-1}$.

In developing cancer risk estimates, the exposure concentrations or doses of constituents with potential carcinogenic effects are estimated over a lifetime. This approach is used because all of the cancer slope factors and unit risk values have been derived based on the same lifetime dose averaging method. The result of the calculation is an estimated cancer risk, which should be interpreted as an upper-bound estimate of the increase in probability of contracting cancer as a result of exposure to the potential carcinogen over a 70-year lifetime under the specified exposure conditions. Because of the nature of the dose-response model that is used, every increment of exposure to a carcinogen, no matter how small, results in an increase in the calculated cancer risk. There are, however, other dose-response models for carcinogenic risk that do not make this assumption, and it is generally believed that the linear non-threshold model used in this assessment is conservative. Thus, the potential risk is unlikely to be underestimated but it may very well be overestimated owing to the inherent conservatism in the cancer toxicity criteria, the exposure assumptions used, and the conservatism of the risk model itself.

Estimated potential cancer risks are expressed in terms of probabilities. For example, a risk of one in one million represents an upper-bound probability that one individual per one million hypothetically exposed people could contract cancer as a result of exposure to the potential carcinogen over a 70-year lifetime under the specified exposure conditions. In order to assess the estimated incremental lifetime cancer risks associated with simultaneous exposure to multiple COCs, the potential risks associated with exposures to the individual constituents were summed within each exposure pathway. This approach is consistent with USEPA's guidelines for evaluating the toxic effects of chemical mixtures (USEPA 1986b).

The cancer risk estimation method itself does not provide an indication of which risks should be considered "significant" for policy-making purposes. Guidance under the USEPA Superfund program generally considers calculated cancer risks of 1 in 1,000,000 (10^{-6}) to be below levels requiring remediation, and allows discretion in decisions as to whether risks in the range between 1 in 1,000,000 and 1 in 10,000 (10^{-6} to 10^{-4}) need to be remediated. Under the Federal Clean Air Act, emission standards for Hazardous Air Pollutants are set based on estimated cancer risks to the general population of 1 in 1,000,000 and risks to the most exposed individual of 1 in 10,000. In defining annual average Air Concentration Limits (ACLs), the MPCA (1994a) bases their calculations on the "tolerable risk level" of 1 in 100,000 (10^{-5}) set by the Minnesota Department of Health (MDH), and this value is used as the benchmark for comparing cancer risk estimate in the HHRA. To place the risk estimates in perspective, it should be noted that the American Cancer Society has estimated the background lifetime risk of cancer in the United States to be roughly 3 in 10, or 30% (ACS 1992). Thus, the MDH tolerable risk level is more than 1,000 times smaller than the background cancer risk.

The potential for chronic adverse noncarcinogenic effects associated with potential exposures to COCs emitted from the proposed Kondirator was evaluated using a technique recommended by USEPA (1989). The ratio of the chronic average exposure concentration (for the inhalation pathway) or chronic doses (for the ingestion pathway) to the appropriate toxicity criteria (RfDs for ingestion pathways, RfCs for inhalation) were calculated for each constituent. For the ingestion pathway—

$$HQ = ADD/RfD \qquad \text{Eq. (9-3)}$$

where

HQ = Hazard Quotient (unitless),
ADD = the Average Daily Dose, averaged over the exposure period (mg/kg-day),
RfD = the ingestion pathway Reference Dose (mg/kg-day).

For the inhalation pathway—

$$HQ = IEC/RfC \qquad \text{Eq. (9–4)}$$

where

IEC = inhalation exposure concentration, averaged over the exposure period (mg/m^3),
RfC = inhalation pathway reference concentration (mg/m^3).

In calculating these Hazard Quotients, exposures and doses are averaged over the duration of potential exposure, rather than over a lifetime, because it is assumed that chronic noncancer effects may develop over less than lifetime exposures. Unlike the cancer risk calculations, hazard quotients do not represent the probability of an adverse effect. Rather, a hazard quotient less than 1 indicates that the associated exposure is not likely to result in any adverse health effects, while ratios greater than 1 indicate that adverse health effects may occur. For each COC, RfC and RfD values are derived for the adverse effect that occurs at the lowest exposures. The hazard quotient value does not indicate the nature or severity of adverse effects that might occur. The nature and severity of the critical toxic effects vary widely among chemicals.

Hazard quotient values far below 1.0 convey a high degree of assurance that adverse effects will not occur, while values far above 1.0 indicate a high degree of concern that adverse effects may actually occur. Values near 1.0 may indicate the need for more detailed analysis to evaluate whether adverse effects are likely to occur. Both USEPA in the Superfund program and the MPCA identify a hazard quotient threshold value of 1 as being indicative of concern over the occurrence of adverse health effects. The hazard quotient value of 1.0 is used as the benchmark in the evaluation of various adverse effects in the HHRA. It is important, however, to remember the existence of numerous uncertainties inherent in the estimation of hazard quotients. Those uncertainties could potentially affect the estimates of hazard quotients by an order of magnitude or greater and are discussed in detail in Section 10.6.

The potential for the occurrence of adverse noncancer effects from simultaneous exposures to the multiple COCs is evaluated by summing the individual hazard quotients within each exposure pathway. This sum, commonly known as the Hazard Index, serves the same function for the mixture as the individual ratios do for each COC. In general, hazard index values are interpreted in the same way as hazard quotients; values greater than 1 are indicative of concerns for the occurrence of health effects, and values less than 1 indicate a low level of concern. If a hazard index for a given pathway is calculated that was greater than 1, the COCs would be subdivided into categories based on the target organ/critical effect associated with exposure (e.g., liver, central nervous system) in accordance with USEPA (1989). Hazard indices would then be recalculated for these categories to better identify the potential for noncarcinogenic effects. However, none of the hazard indices calculated in this assessment were equal to or greater than 1. Therefore, the hazard indices are not broken down with regard to target organ. Addition of individual hazard quotients across exposure pathways is generally not appropriate (USEPA 1994). This is because RfDs and RfCs are often derived for different toxic effects, and because the nature and severity of effect may depend strongly on the route of exposure. High exposures by more than one pathway may be a source of concern, but the potential for adverse effects across pathways cannot be adequately characterized by summing hazard quotients.

9.2 RISKS ASSOCIATED WITH CHRONIC EXPOSURES TO COCs WITH TOXICITY CRITERIA

This section presents the risk estimates associated with each potentially complete exposure pathway evaluated. Quantitative risk estimates associated with COC exposures are presented and discussed in the text. Where estimated incremental lifetime cancer risks exceeds 1 in 1,000,000 or the hazard index approaches 1 for a specific exposure pathway, the constituents associated with the greatest individual risks are identified. For simplicity, only a summary of the risk assessment results is given in Table 9-1. The detailed calculations of cancer risks and hazard quotients, derived for each exposure pathway and COC, using equations 9-1 through 9-4, are presented in Appendix C.

9.2.1 Risks Associated with Inhalation of Particulate

The potential cancer risks associated with inhalation exposures to particulate COCs emitted from the Kondirator are presented in Table C-2 and summarized in Table 9-1. The total excess lifetime cancer risk associated with this pathway was estimated to be 5 in 1 million (5×10^{-6}). This risk is primarily associated with potential exposures to chromium and arsenic. This value is approximately one-half the tolerable risk level defined by MDH. Key uncertainties associated with this calculation are the assumption that 10% of the chromium emitted would be hexavalent, and uncertainties in the toxicity criterion for arsenic. These issues are discussed in more detail in Section 10.6.

The total hazard ratio associated with inhalation of air emissions by residents was less than 1. The hazard quotient for manganese alone (0.5) accounted for essentially all (greater than 99.9%) of this value. The uncertainty associated with the toxicologic criteria for manganese is discussed in more detail in Section 10.6. This hazard quotient is close to, but less than the MPCA and EPA threshold of concern of 1.0.

9.2.2 Potential Risks Associated with Incidental Ingestion of Soil by Residents Living Across the River from the Kondirator Facility

Potential health risks to nearby residents exposed to constituents in surface soil were estimated for long-term child and adult residents. Table C-3 in Appendix C provides detailed calculations of the potential risks to child residents associated with incidental ingestion of soil. As shown in Table 9-1, the total estimated incremental lifetime cancer risk associated with this pathway for child residents was estimated to be 3 in 100,000 (3×10^{-5}). This potential risk, which is greater than the MDH tolerable risk level, is associated with potential exposures to beryllium and arsenic. The uncertainties associated with the risk estimates for these two chemicals are discussed in more detail in Section 10.6.

The hazard index associated with ingestion of soil by children was just less than 1 (0.7). The largest individual contribution to the hazard index was from arsenic exposures (hazard quotient = 0.3)

Table C-4 summarizes the risk calculations associated with incidental ingestion of soil by adult residents. The total estimated incremental lifetime cancer risk associated with this pathway for adults was estimated to be 1 in 100,000 (1×10^{-5}), equal to the MDH tolerable risk level. As is the case for children, these potential risks were associated with potential exposures to beryllium and arsenic. If it were assumed that a single individual received exposures both as a child and as an adult residing in the same neighborhood, the combined estimated lifetime incremental cancer risk would be equal to the sum of the childhood and lifetime cancer risks, or 4 in 100,000 (4×10^{-5}).

The hazard index associated with ingestion of soil by adults was much less than 1 (0.07), indicating that noncarcinogenic effects in adults are unlikely to be associated with this pathway. As noted in Section 8.1, it is not correct to add hazard indices for childhood and adult exposures because they reflect the potential for adverse effects at two life stages, not additive risks over a lifetime.

If it is assumed that a resident were exposed to carcinogenic COCs in soil as both a child and an adult, then the estimated cancer risk for that individual would be the sum of cancer risks due to childhood and adult exposures. In the case of the soil pathway, the combined full-lifetime cancer risk from this pathway would be 4 per 100,000 (4×10^{-5}). Since the potential for adverse noncancer effects to occur is not a function of lifetime dose, the hazard quotients for adults and children cannot be added.

9.2.3 Potential Risks Associated with Incidental Ingestion of Mississippi River Sediment

Potential health risks to both child and adult residents who use the Mississippi River for recreation were calculated for potential exposures to COCs in sediment. The potential risks associated with this pathway are summarized in Table 9-1. Table C-5 presents the detailed calculations of potential risks to children associated with ingestion of sediment. The total estimated incremental lifetime cancer risk associated with this pathway for children was estimated to be 2 in 1 million (2×10^{-6}), which is below the MDH tolerable risk level. Again, these potential risks are associated with ingestion of arsenic and beryllium. The hazard index associated with ingestion of sediment by children was less than 1 (0.04), indicating that adverse noncarcinogenic effects in children are unlikely to be associated with this pathway.

Table C-6 presents the potential risks calculations associated with ingestion of sediment by adults, which are also summarized in Table 9-1. The total estimated incremental excess lifetime cancer risk associated with this pathway for adults was 8 in 10 million (8×10^{-7}), which was also associated with potential exposures to arsenic and beryllium. The hazard index associated with ingestion of sediment by adults was less than 1 (0.005), indicating that noncarcinogenic effects in adults are unlikely to be associated with this pathway.

For both children and adults, the estimated cancer risks and hazard quotients associated with sediment ingestion are more than 10 times lower than those associated with soil ingestion. The combined lifetime cancer risk for childhood plus adult exposure due to sediment ingestion is 3 per million, or 3×10^{-6}.

9.2.4 Potential Risks Associated with Ingestion of Fish from the Mississippi River by Subsistence Fishers

Potential health risks to consumers of fish from the Mississippi River were also evaluated for both children and adults. Table C-7 presents the detailed risk calculations associated with fish consumption by children, and Table C-8 presents the risk calculations for fish consumption by adults. These potential risks are summarized in Table 9-1. The constituents associated with fish consumption are not considered to be carcinogenic by ingestion according to the USEPA toxicity sources

Table 9-1. Summary of Chronic Health Risks for the Proposed Kondirator Facility Assuming 15 Year Facility Life

Pathway	Total Cancer Risk[a]	Primary COCs	Total Hazard Index[b]	Primary COCs (with target organ)	Appendix Table
		AIR			
Inhalation of air emissions by resident adults	5 per 1,000,000 (5×10^{-6})	Chromium (as Cr(VI)), arsenic	<1 (0.5)	Manganese (CNS)	C-2
		SOIL			
Incidental ingestion of soil by a child resident	3 per 100,000 (3×10^{-5})	Arsenic, beryllium	<1 (0.7)	Arsenic (skin)	C-3
Incidental ingestion of soil by an adult resident	1 per 100,000 (1×10^{-5})	Arsenic, beryllium	<1 (0.07)	NA	C-4
Total soil ingestion risk (child plus adult)	4 per 100,000 (4×10^{-5})	Arsenic, beryllium	NA	NA	NA
		SEDIMENT			
Incidental ingestion of sediment in the Mississippi River by a child resident	2 per 1,000,000 (2×10^{-6})	Arsenic, beryllium	<1 (0.04)	NA	C-5
Incidental ingestion of sediment in the Mississippi River by an adult resident	8 per 10,000,000 (8×10^{-7})	Arsenic, beryllium	<1 (0.004)	NA	C-6
Total sediment ingestion risk (child plus adult)	3 per 1,000,000 (3×10^{-6})	Arsenic, beryllium	NA	NA	NA
		FISH			
Ingestion of fish from the Mississippi River by a child	NE	NA	<1 (0.02)	NA	C-7
Ingestion of fish from the Mississippi River by an adult	NE	NA	<1 (0.02)	NA	C-8
		REGULATORY RISK BENCHMARKS			
	MDH Tolerable Cancer Risk: 1 per 100,000 (1×10^{-5})		MPCA Noncancer Level of Concern Hazard Index = 1.0		NA

[a] Calculated as shown in equations 9-1 and 9-2.
[b] Calculated as shown in equations 9-3 and 9-4.

Abbreviations: NA = not applicable; NE = not evaluated.

referenced. Therefore, only the potential risks of adverse noncarcinogenic effects were evaluated for this pathway. The hazard indices associated with fish consumption by children (0.02) and adults (0.01) were both much less than 1, indicating that noncarcinogenic effects are unlikely to be associated with this pathway.

9.2.5 Effect of Longer Facility Life on Risk Estimates

A number of reviewers of the Interim Deliverables and Draft HHRA expressed concern that the potential risks associated with Kondirator emissions would be greater if the facility lifetime were longer than 15 years. Many of the calculated risks would, in fact, change, increasing in direct proportion to change in facility lifetime.

If, for example, it were assumed that the Kondirator facility lifetime were 70 years (equal to the EPA "default" human lifespan), rather than 15 years, the estimated inhalation pathway cancer risk would increase to 2 per 100,000 (2×10^{-5}). Similarly, the estimated combined childhood plus adult cancer risk associated with soil exposures would increase to 2 per 10,000 (2×10^{-4}), and the combined child and adult cancer risk associated with sediment exposure would be 1 per 100,000 (1×10^{-5}).

The hazard quotients and hazard indices for the indirect pathways would also change, since the assumption of a longer facility life would allow for a greater buildup of COCs in soil and sediment. The child's hazard index would increase to 3 (greater than the MPCA level of concern). All of the other hazard indices would still be far below 1.0, even if a facility lifetime of 70 years were assumed. Hazard indices for the inhalation pathway would not change if a longer facility life were assumed, since these values are not a function of the duration of exposure, and the actual exposure concentration in air would not change.

9.3 RISKS ASSOCIATED WITH ACUTE INHALATION EXPOSURES

Federally approved acute (short-term) toxicity values for the general population are not available for the potential COCs. Therefore, for this screening level assessment, occupational threshold limit values (TLVs) from the National Institute for Occupational Safety and Health (NIOSH 1990) and the American Conference of Governmental Industrial Hygienists (ACGIH 1994) were referenced for a screening level assessment of short-term effects. The estimated maximum 1-hour air concentrations at the residential receptors from the proposed Kondirator facility (as shown previously in Table 4-3) are all far below these acute occupational standards. This comparison does not entirely rule out the potential for adverse effects of acute exposures. The occupational standards are designed to be protective of healthy adult workers and may not be protective of children, the elderly, or individuals with respiratory disease.

9.4 POTENTIAL RISKS ASSOCIATED WITH EXPOSURES TO LEAD

As noted in Section 8, there are currently no conventional toxicologic criteria (RfD or RfC) values that can be used to characterize the potential risks associated with potential exposures to lead compounds. USEPA has determined that the standard RfD/RfC approach is not appropriate for evaluating health impacts associated with lead exposures, both because it does not address the cumulative impacts of lead exposures from multiple pathways and because it does not address the potential for adverse effects of lead exposures in young children, who represent the group most sensitive to lead exposures. To evaluate the health impacts of lead exposures, USEPA advocates the use of the IEUBK model (USEPA 1994). This PC-based computer model integrates contributions from multiple exposure pathways (air, soil/dust, diet, drinking water, and maternal blood lead) to evaluate changes in blood lead concentrations in infants and children associated with specified lead exposures.

The IEUBK model was used in this assessment to estimate changes in children's blood lead concentrations that would be expected to occur as a result of potential exposures arising from the Kondirator air emissions. The results of the modeling were then compared with the "Safe Blood Lead Level" defined by the Minnesota Department of Health (MDH 1992). The approach taken was to run the model twice, once using a set of input values for lead concentrations in soil, water, air, etc., representing background conditions and then to run the model again with the concentrations of lead arising from Kondirator emissions added to the default environmental concentrations. This approach and the results of the analysis are summarized in Table 9-2.

In this evaluation, it was assumed that only the concentrations of lead in soil and air would change as a result of Kondirator emissions, and that potential exposures from dietary sources and drinking water would not increase. The default air concentration of lead specified in the model (0.10 $\mu g/m^3$) was increased to 0.1049 $\mu g/m^3$ owing to Kondirator emissions. The background soil concentration estimate used in this analysis was 140 mg/kg. This value is the arithmetic average surface soil concentration found by the MPCA (1994b) in a recent sampling effort at an industrial facility adjacent to the Kondirator. This concentration is not unusual for industrialized urban areas, but is probably somewhat higher than typical urban soil concentrations. The contribution from the Kondirator (31 mg/kg) increased this value to 171 mg/kg. The incremental exposure due to the increased concentration of lead in sediment (1.89 mg/kg) was not included in this analysis, but this source would not be expected to contribute significantly to potential exposures when compared to the much greater increment in soil concentration.

The center panel of Table 9-2 shows the geometric mean blood lead concentrations for children of various ages predicted by the IEUBK model using the background environmental concentrations and using the background concentrations plus the contributions from the Kondirator. Under default conditions, the estimated geometric mean blood lead concentrations range from 2.3 $\mu g/dl$ to 3.7 $\mu g/dl$, depending upon the age of the children being evaluated. With the added contribution from the Kondirator (mainly through the soil pathway), the predicted blood lead concentrations range from 2.5 to 4.1 $\mu g/dl$. In both cases (with and without the contribution from Kondirator emissions), the predicted geometric mean blood lead concentration was greater than the MDH Safe Blood Lead Level. It should be noted, however, that the majority of all children in the United States have blood lead concentrations in excess of this value. In each of the age groups studied, the increment in blood lead concentration associated with the Kondirator emissions ranges from 0.2 to 0.4 $\mu g/dl$.

The bottom panel of the table shows the predicted increments in the proportions of infants and children whose blood lead concentrations would be expected to be greater than 10 $\mu g/dl$, under the default exposure conditions, and default conditions plus the contribution from the Kondirator. The USEPA identifies the prediction of 5% of children's blood concentrations exceeding 10 $\mu g/dl$ as cause for concern. For infants 0–12 months old the proportion of individuals with blood lead concentrations greater than 10 $\mu g/dl$ increases from 0.97% to 1.50% of the exposed population, and the proportion of children 1–7 years old with blood lead concentrations above this level increases from 0.49% to 0.92%.

TABLE 9–2.

CHANGES IN CHILDREN'S BLOOD LEAD CONCENTRATIONS ASSOCIATED WITH KONDIRATOR EMISSIONS PREDICTED BY USEPA IEUBK MODEL

SOURCE	**LEAD CONCENTRATIONS AND INTAKE FROM VARIOUS SOURCES** Background Conditions	Background Conditions Plus Kondirator
Air Lead Concentration (ug/m^3)	0.1000 μg/m^3	0.10485 μg/m^3
Soil Concentration (mg/kg)	140 mg/kg	171.1 mg/kg
Dietary Lead Intake (μg/day)	5.5–7.0 μg/day	Unchanged
Drinking Water Lead Concentration (μg/l)	4.0 μg/l	Unchanged
Maternal Blood Lead Concentration (μg/dl)	2.5 μg/dl	Unchanged

AGE RANGE	**GEOMETRIC MEAN BLOOD LEAD CONCENTRATIONS (ug/dl)** Background Conditions	Background Conditions Plus Kondirator
0.5 to 1 years	3.4 μg/dl	3.8 μg/dl
1 to 2 years	3.7 μg/dl	4.1 μg/dl
2 to 3 years	3.5 μg/dl	3.9 μg/dl
3 to 4 years	3.3 μg/dl	3.7 μg/dl
4 to 5 years	2.8 μg/dl	3.1 μg/dl
5 to 6 years	2.5 μg/dl	2.7 μg/dl
6 to 7 years	2.3 μg/dl	2.5 μg/dl

MDH (1992) "Safe Blood Lead Level" = 1.0 μg/dl

AGE RANGE	**PROPORTION OF CHILDREN BLOOD LEAD CONCENTRATIONS GREATER THAN 10 μg/dl (Percent)** Background Conditions	Background Conditions Plus Kondirator
0 to 12 months	0.97 %	1.56 %
12 to 84 months	0.49 %	0.92 %

USEPA level of concern = 5% of children with blood lead >10 μg/dL

10.0 UNCERTAINTIES AND BIAS IN RISK ESTIMATION

Purpose——To provide a review of the major sources of uncertainty and deliberate conservative biases in the HHRA.

10.1 SOURCES OF UNCERTAINTY AND BIAS IN THE HUMAN HEALTH RISK ASSESSMENT

All health risk assessments involve the use of assumptions, judgment, and incomplete data to varying degrees. This results in uncertainty in the final estimates of potential risk. Consideration of the uncertainty associated with various aspects of the risk assessment process permits a better evaluation of the health risk assessment results and understanding of the potential impacts associated with emissions of metals selected for screening level evaluation for the Kondirator facility.

Uncertainty in a screening level health risk assessment may arise from many sources including:

- Selection of chemicals for evaluation;
- Choice of models and input parameters in exposure assessment and fate and transport modeling;
- Choice of models for exposure assessment; and
- Assumptions concerning toxicologic evaluation and risk characterization.

The general level of uncertainty may be magnified in the assessment through the interaction of these various sources.

There are a number of quantitative techniques available for evaluating the degree of uncertainty in the health risk assessment. These include sensitivity analysis, importance analysis, and explicit probabilistic methods such as Monte Carlo simulation. Because of the screening nature of this analysis, only a qualitative evaluation of uncertainty is possible. Similarly, the scope of the uncertainty discussions in a screening level assessment must be limited to the most important sources of uncertainty in the risk estimates. The discussion that follows is thus limited to those COCs, pathways, and models that are associated with the highest and most uncertain risks. For example, a potential twofold uncertainty in the amount of copper emitted would not warrant extensive discussion if the highest estimated potential risk associated with copper exposure is several orders of magnitude below levels of concern.

Another factor that needs to be kept in mind when evaluating the uncertainty in the HHRA is that screening level assessments are conservative by design. As discussed in Section 1.2, this is because they employ generic, conservative assumptions and parameter values in a conscious strategy to provide useful results at low cost and to provide risk estimates that are most unlikely to underestimate the "true" potential risk. The less knowledge there is about a model or parameter value, the greater the need to substitute conservatism for precise knowledge. The distinction is always maintained, however, between conservatism and bias. It is well-known that the net effect of combining numerous conservative assumptions is to produce estimates of potential risk that are likely to be greatly overestimated. In the discussions that follow, major potential sources of conservative bias and major potential sources of uncertainty in the risk estimates are discussed together, primarily because they are often the same. The primary aim of the screening level assessment is to provide a conservative, cost-effective analysis that is, however, not so conservative that it obscures the difference between risks and incorrectly identifies all risks as "significant."

The major sources of uncertainty in the HHRA are summarized in Table 10-1. The table identifies the most important sources of uncertainty in each aspect of the HHRA, provides a judgmental estimate of the nature of the potential bias and uncertainty which the assumptions introduce into the HHRA, and includes clarifying comments on each assumption. Assumptions that intentionally introduce conservative bias into the risk estimates are noted. Other factors contribute to the uncertainty in the potential risk estimates, but those in the table appear to be those which have the most impact on the potential risk estimates for the most important pathways and COCs.

In compiling the table, the magnitude of the effect of each source of uncertainty on the uncertainty of the potential risk estimates was placed into one of the following three groups based on best professional judgment:

- Low: The uncertainty's effect on potential risk is less than or equal to 1 order of magnitude (i.e., a factor of 1 to 10);
- Moderate: The uncertainty's effect on potential risk is greater than 1 order of magnitude, but less than or equal to two orders of magnitude (i.e., a factor of 10 to 100); and
- High: The uncertainty's effect on potential risk is greater than 2 orders of magnitude (i.e., a factor of greater than 100).

This categorization reflected a judgment, based on experience with other risk assessments, that finer distributions with regard to the level of uncertainty in most assumptions are difficult to make. In addition, a column is provided in Table 10-1 to characterize the potential bias ("Direction of Effect") for each source of uncertainty. Each group of assumptions, dealing with the major aspects of the health risk assessment, are briefly discussed below.

10.2 SELECTION OF COCS FOR EVALUATION

COCs were selected for evaluation in the HHRA based on the estimated product composition and elemental concentration of the scrap metal feed to the proposed Kondirator. Various types of scrap metal are expected to be received at the Kondirator facility, including carbon steel, stainless steel, galvanized steel, iron and cast iron, aluminum, copper, and brass. Elemental composition data for each metal type was obtained from the Material Safety Data Sheets. The identification of COCs was very simple: Any element that showed up as being present in any concentration in any potential feed material was included as a COC.

This method of selecting waste constituents for evaluation, while likely to be quite conservative, introduces some uncertainty into the HHRA. There are three major sources of uncertainty in the COC selection process: uncertainty in the MSDS information regarding the elemental composition of the feed wastes, uncertainty in the specification of feed materials, and uncertainties regarding potential nonmetallic emissions (organic compounds and coating constituents). Although MSDS data are based on the composition of each metal type, and consider the hazards

Table 10-1. Uncertainties in the Human Health Risk Assessment for the Proposed Kondirator Facility

Assumption	Magnitude of Effect on Risk[a]	Direction of Effect on Risk	Comments
SELECTION OF CHEMICALS FOR EVALUATION			
Identities of COC metals included in the risk assessment were based on scrap metal compositions taken from the Material Safety Data Sheets (MSDS) for the various types of scrap metal expected to be fed to the proposed Kondirator	Low to moderate	May under- or over-estimate risk	MSDS data is not complete, but identifies most major trace elements; the likelihood of missing an element that contributes in a major way to toxicity is judged to be small; risks could be overestimated if some elements are not actually present.
Type of waste feed to the proposed Kondirator identified by Applicant	Low	May over- or under-estimate risk	Compositional variability of feed stocks appears to be small relative to level of uncertainty associated with other aspects of the assessment.
Stack and fugitive organic compound emission rates from coatings and other sources, both expected to be very low, were not considered in the risk assessment.	Low	May underestimate risk	As the organic content of the feed stock is low, and the Kondirator process does not involve high temperatures, the assumption of no significant organic releases appears to be reasonable.
EMISSIONS ESTIMATES			
Chemical composition of feed waste derived from MSDS data	Low	May over- or under-estimate risks[b]	MSDS composition data not definitive. Worst-case assumptions were used to derive overall COC emissions from defined waste input, most likely provide slight overestimations of emissions of the most toxic metals.
Emissions based on toxicity——adjusted elemental composition	Low	May overestimate risk	Adjustment to elemental proportions is extremely small compared to other sources of uncertainty (<10%).
Emission rates for particulate metals used in the risk assessment were based on emission factors and air emission control system efficiency data from similar, but not identical, scrap metal processing facilities	Low to moderate	May over- or under-estimate risk	Database supporting emission estimates is quite limited, source characteristics, amounts emitted, and particle size distribution assumptions may affect risk results strongly. No data from operating Kondirator were available.
Stack emissions parameters were based on expected allowable operating conditions. Emission rate calculations at expected allowable operating conditions assumed waste feed rates of 100 tons/hr for 3,778 hr/yr	Low	May overestimate risk	Magnitude of uncertainty in these parameters is low relative to uncertainty in other aspects of the assessment. Applicant indicates feed rate and operating hours estimate are overestimated.
Assumed 15-year facility life	Low	May underestimate risks	If actual facility lifetime exceeds 15 years, inhalation cancer risks and indirect exposure pathway hazard quotients are correspondingly increased.
Paints and coatings not included in emissions estimates	Low	May underestimate risk	Paints and coatings expected to comprise at most 0.1% of feed waste mass. Site visit and data supplied by Applicant suggest little, if any, coated materials will be shredded. Composition of coatings not known.

Table 10-1. Uncertainties in the Human Health Risk Assessment for the Proposed Kondirator Facility (Continued)

Assumption	Magnitude of Effect on Risk[a]	Direction of Effect on Risk	Comments
Fugitive particulate metal emission rates from materials handling and product piles were not considered in the risk assessment.	Low to moderate	May underestimate risk	Data regarding possible fugitive emissions from these operations is very limited.
Propagation of rounding error in stormwater pond emission estimates	Low	May over- or under-estimate risk	Effect on risk estimates for water pathway is very low.
AIR DISPERSION AND DEPOSITION MODELING			
Use of ISCST2, deposition methodology	Low to moderate	Air quality impacts may be over- or under-estimated; particle deposition probably overestimated	Models are appropriate for screening level analysis.
Particle size distribution for metals used in the risk assessment were based on emission factors and air emission control system efficiency data from similar scrap metal processing facilities.	Low to moderate	May over- or under-estimate risk	Particle size distribution affects deposition velocity assumptions, limited effects on exposure estimates for soil, sediment and surface water.
The air quality impact and deposition rates used in the risk assessment was based on the highest modeled long-term air concentration at the eastern Mississippi River bank.	Low	May overestimate risk[b]	Average air impacts in residential areas near to the maximum impact point would be slightly lower (factor of 2 or less).
EXPOSURE AND INTAKE ASSESSMENT			
Inhalation, soil, sediment, and fish ingestion included as exposure pathways	Low to moderate	May overestimate risk[b]	Risks are overestimated for receptors who are not actually exposed by these pathways
Vegetable ingestion, dermal contact and surface water ingestion excluded	Low to moderate	May underestimate risk	Exclusion of home-grown vegetable ingestion is most likely to result in significant under-estimation of risks. Risks through this pathway could be on the same general magnitude as those for soil ingestion. Exclusion of dermal contact and surface water pathways are not likely to have resulted in appreciable underestimation of total risks
Exposure scenarios are based on long-term nearby residents with behavioral characteristics which are associated with high exposures.	Moderate	May overestimate risk[b]	Assumptions which contribute most to conservatism are length of residence, frequency and duration of inhalation exposures, and the amounts of soil and sediment ingested
Particulates from Kondirator are assumed to be deposited in top two centimeters of soil, and assumed not removed by leaching or runoff.	Low to moderate	May overestimate risk[b]	Deposited particulates would be naturally removed from shallow surface soil by leaching and runoff over the time scale used in this assessment. Tilling or mixing of soil would also increase the mixing depth and lower surface soil concentrations

Table 10-1. Uncertainties in the Human Health Risk Assessment for the Proposed Kondirator Facility (Continued)

Assumption	Magnitude of Effect on Risk[a]	Direction of Effect on Risk	Comments
Assumed sediment mixing depth, sediment density	Low	May under- or over-estimate risks	Both assumptions are approximate and generic; actual sediment depth, density could vary significantly across exposure areas as a function of flow conditions and human activities
Relative bioavailability of COCs from Kondirator particulate assumed to be 100%	Low to moderate	Probably over- but may under-estimate risks	Over the course of the multiyear exposure period, the bulk of the COCs are likely to be released from the Kondirator particulate owing to oxidation and corrosion. Assumption made in the absence of definitive data.
Toxicologic Evaluation and Risk Estimation			
Nonthreshold model for estimating cancer risks assumes any increment in exposure results in increased cancer risks.	Low to high	Probably overestimates risk[b]	Other available dose-response models predict less than linear response at low doses. Risks could be greatly overestimated. Slight chance that risks could be underestimated
Noncancer risk characterization model employs comparisons to conservatively defined dose-response criteria (RfCs and RfDs)	Low to moderate	May overestimate potential for adverse noncancer effects[b]	Little effect on risk results because no adverse health effects are predicted, despite the conservatism of the RfCs and RfDs.
Additivity of multiple COC risks	Probably low	Under- or over-estimate risks	Effect of multiple exposures on cancer risks are hard to estimate. Effects on noncancer risk estimates are likely to be low.
No dose-response criteria available for some COCs for inhalation and/or ingestion exposures	Low	May underestimate risk	Toxicity criteria are available for all of the known high-toxicity COCs, all of the known carcinogenic COCs. It is unlikely that COCs having no dose-response criteria account for appreciable additional risks.
Standard EPA inhalation toxicity values are used in the long-term quantitative risk assessment	Moderate to high	May over- or under-estimate risks	The toxicologic properties and bioavailability of the metal particulates from the Kondirator may be different from the types of metal compounds for which the toxicity criteria have been derived
Level of uncertainty in EPA inhalation RfC for manganese is high	Moderate	May overestimate potential for adverse effect[b]	Literature evidence suggests that the RfC for manganese is extremely conservative, compared to other RfCs, and may be too low by a factor of 10 or more
Level of uncertainty in EPA oral cancer slope factor for beryllium is high	Moderate to high	May overestimate risk[b]	The toxicologic study from which the oral slope factor was derived does not show a statistically significant relationship between beryllium intake and risk; risk could be much lower

Table 10-1. Uncertainties in the Human Health Risk Assessment for the Proposed Kondirator Facility (Continued)

Assumption	Magnitude of Effect on Risk[a]	Direction of Effect on Risk	Comments
It has been assumed that 10% of the total chromium exposure is to hexavalent form, and that the remainder is trivalent	Moderate	May over- or underestimate risk	It is likely that less than 10% of the total chromium is hexavalent. Inhalation pathway cancer risk conceivably could be underestimated by a factor of 10 if all of the chromium is hexavalent; if none of the chromium is hexavalent, there would be no inhalation cancer risk associated with chromium exposure.
Doses and risks are characterized only for incremental contributions of Kondirator to background concentrations of metals in air water and soil	Low to moderate	Underestimates total exposures and risks	Doses/risks associated with Kondirator are generally comparable to or lower than doses/risks associated with exposures to naturally occurring concentrations of elements in soil, air, and water

[a] Low = <1 order of magnitude effect. Moderate = >1 to ≤2 orders of magnitude effect. High = >2 orders of magnitude effect.
[b] Identifies generic assumptions that intentionally introduce conservatism into screening level risk estimates.

associated with each elemental metal, the data are intended to be generic, and are not intended to be specific to a particular type of carbon steel or stainless steel, for example. The inherent variability in the composition of scrap metals is not well-reflected in the MSDS data. The use of the MSDS data to identify COCs may over- or under-predict the potential risk. If an element has been identified to be present which is not actually present in any of the feed materials, then risks may be overestimated. If, on the other hand a COC has been missed, then risks may be underestimated. Compared to other sources of uncertainty, this is probably not a major source of uncertainty in the health risk assessment. The majority of the most toxic metals that are likely, on metallurgic grounds, to be present in the scrap were selected as COCs. It would be quite unexpected if a major toxic metal had not been identified.

The sole source of information regarding the selection of feed materials for the Kondirator was the Applicant. The rationale for the identification of feed waste was based on past experience, established commercial relationships, and considerations of the economic value of the various types of waste metals. While the rationale given for identifying the most likely input wastes is economic, it is important to keep in mind that, if feed material selection changes, additional elements could be emitted, and risk estimates would change accordingly.

Emissions of coatings and organic chemicals from scrap metal processing are expected to be low, and such emissions were therefore not considered in HHRA. The reason for this omission was that the amount of coating and organic material present in the feed stocks of the Kondirator is expected to be quite low, and that the shredding process does not involve temperatures high enough to result in the generation of highly toxic organic compounds from what little organic material is present. Emissions of organic compounds from the proposed Kondirator may be low, but are not expected to be zero. Therefore, potential risk may be slightly underestimated by lack of consideration of organic compound emissions.

10.3 UNCERTAINTIES IN EMISSION ESTIMATES

There are several major sources of uncertainty associated with emissions estimates for the Kondirator. The emission rates are critical inputs into the dispersion models and subsequent potential risk calculations.

The elemental composition of the various feed wastes, and consequently the composition of the emitted particulates, has been characterized entirely based on elemental composition data from the MSDS for the identified feed materials. On the whole, ICF KE expects that these data are generally accurate and representative of the composition of the feed materials. MSDS are expressly designed to provide information regarding toxic constituents of materials and appropriate precautions in their handling. In addition, the amounts of the toxic elements present in the Kondirator particulate were estimated using credible worst-case assumptions about feed waste composition and elemental compositions. Thus ICF KE believes that emission rates of the most toxic elements are more likely to have been overestimated than underestimated and that the MSDS data represent a relatively minor source of uncertainty in the risk assessment compared with other assumptions regarding exposure and toxicity, to be discussed below.

On the other hand, the MSDS data are not definitive and represent data summarized from other sources in a manner that has not been documented by the Applicant. ICF KE did not independently confirm these data from primary sources, and the Applicant has not yet provided definitive data to support the elemental composition of the feed wastes. Thus the use of these data represent a potential source of uncertainty in the assessment, which has been identified by several reviewers as a major source of concern.

The emissions of particulates were estimated assuming maximum expected operating conditions of 100 tons per hour for 3,778 hours per year. The Applicant reports that these conditions are unlikely to be exceeded, or even approached, over the life of the facility. MPCA is also considering imposing these operating specifications as permit conditions. It is thus likely that use of these assumptions resulted in an overestimate of actual emissions, although the extent of the overestimation is likely to be small.

Several reviewers indicated that the facility lifetime of 15 years reported by the Applicant and used in the HHRA was likely to underestimate actual facility life. If the Kondirator were to operate for more than 15 years, the magnitude of the cancer risks associated with inhalation of particulates, and the magnitude of both cancer risks and noncancer hazard indices associated with all of the indirect exposure pathways, would increase accordingly. As discussed in Section 9.2.5, the magnitude of the risks and hazard indices for these pathways would be increased by approximately five-fold if the facility operated for seventy years rather than 15 years.

Another potentially important source of uncertainty in the risk estimates is the potential for fugitive emissions from the Kondirator itself, or from storage piles and barge loading. The scope of the screening level assessment did not address releases from the Kondirator product pile and barge loading. These potentially significant sources of particulate emissions were identified by several commenters on the Interim Deliverables as a major concern. Fugitive emissions are judged to be a source of "low to moderate" uncertainty in the risk estimates, however, because it is unlikely that they would be any greater than the stack emissions that were included in the assessment. Omitting these emissions may have resulted, of course, in underestimates of risks.

The combined impact of these factors was judged to be a low to moderate source of uncertainty in the risk assessment (emission rates could vary by between a factor of 10 and a factor of 100). Emissions could either be over- or under-estimated.

10.4 UNCERTAINTIES IN AIR DISPERSION AND DEPOSITION MODELING

The Industrial Source Complex Short-Term (ISCST2) model was used by the applicant in modeling the deposition of particulate metals, and the applicant's modeling results were used in conducting this health risk assessment. The ISCST2 model is an appropriate air dispersion model for calculating deposition rates of particulate metals emitted from the facility at receptors up to stack height. The ISCST2 model is included in EPA modeling guidelines for such applications, and the model generally yields conservative results (USEPA 1990). Deposition fluxes and the associated deposition rates are a function of the emitted particle diameters, size distributions, and particle densities, as well as surface characteristics and meteorological conditions. The methods used are generally appropriate for a screening level risk assessment, and may either slightly over- or under-estimate exposures and risks.

All potential exposures for the receptors were estimated using the calculated deposition rates for the point of highest long-term impact on the eastern shoreline residential area of the river. Thus, the actual exposure concentrations for the majority of receptors across the river from the proposed Kondirator facility would be somewhat lower than those used in the assessment. The maximum impact point across the river is, however, located at the edge of the shoreline, and the extent of overestimation of exposure for the maximum impact point compared to exposures across the river from the facility might be only a factor of two or less.

The final source of uncertainty that has been identified in the deposition estimates is the potential overestimates of particulate deposition rates associated with the assumption of no depletion of the particulate plume over time as it moves away from the facility. This assumption, which is justified in a screening level assessment, could substantially overestimate particulate deposition at locations distant from the facility, particularly deposition of the coarse high-density particulate fraction. It was not possible to quantitatively estimate the extent of this overestimation, but based on the relative fraction of coarse and fine particulate in the Kondirator emissions, this was judged to be the source of a "low" level of uncertainty in overall risk estimates.

10.5 UNCERTAINTIES ASSOCIATED WITH EXPOSURE AND INTAKE ASSESSMENT

As discussed in Section 7, there are numerous sources of uncertainty associated with the methods used to estimate human exposures to COCs emitted from the Kondirator, and with the parameter values used in the exposure and dose assessment models. One of the major factors affecting the level of uncertainty in the risk estimates is identification of exposure pathways for inclusion in the quantitative assessment. The pathways included were particulate inhalation and soil, sediment, and fish ingestion. These pathways were selected because they are most likely to be "complete" for some residents near the Kondirator. In actuality, not all residents would be exposed through all of these pathways. Thus, inclusion of all of the pathways may result in an overestimate of risks.

Another key assumption that may have significantly affected the overall risk estimates is the decision not to quantitatively evaluate potential exposures associated with the ingestion of home-grown vegetables. This pathway is often included in risk assessments for combustion sources and for other sources of particulate air emissions. This pathway was omitted because of a professional judgment that usefully reliable risk estimates could not be developed based solely on the generic data available. The development of risk estimates based on the available data would have involved several additional levels of exposure and dose modeling (leaf deposition and/or root uptake, dietary intake estimation), each of which would have introduced a large but unquantifiable additional level of uncertainty into the assessment. For this reason, this pathway was not included.

Omission of this pathway has resulted in an underestimation of the potential risk associated with the Kondirator emissions. It is not possible to estimate accurately the extent of this underestimation, but approximate judgments can be made about the relative magnitude of potential risks through this pathway compared to the soil pathway, based on experience in other assessments. It is likely the potential risks would be most seriously underestimated for metals that are highly toxic and that are efficiently taken up by edible plants. In this assessment, the only COC that might fall into this category is cadmium, and it is possible that the hazard quotient (i.e., noncancer risk) for cadmium in home-grown vegetables might be comparable to or greater than the hazard quotient associated with the soil pathway. Potential risks associated with vegetable ingestion might approach those associated with soil ingestion for other COCs including arsenic, beryllium, and nickel. The rest of the COC metals are either not taken up well by plants or are much less toxic than the previously discussed elements.

In keeping with the screening approach of this assessment, many of the behavioral assumptions that have been made in estimating contaminant exposures and doses have been generic, that is, they are not based on site-specific information regarding actual behavior of the exposed populations. As discussed in Section 7.2, the assumptions used are generally in line with the conservative "default" assumptions defined by USEPA for use in risk assessments for Superfund sites and combustion sources. The basic approach to exposure assessment was to define exposure conditions at the site for a hypothetical long-time resident whose behavior patterns were such as to overestimate potential exposures and risks for actual residents. For example, while it is likely that some individuals in the neighborhood across the river from the Kondirator have resided in the neighborhood for 30 years or more, including childhood, it is likely that only a very small proportion have done so. None of the residents will spend 24 hours per day, 350 days per year outdoors receiving inhalation exposure to Kondirator particulates, and few, if any, will actually experience exposure to contaminated soil as frequently as 285 days per year or ingest as much as 100 mg/day (200 mg/day for children) during outdoor activities. Similarly conservative assumptions are made regarding the other exposure pathways, which ensure that exposure estimates greatly overestimate actual exposures for actual residents.

For the air pathway, it is likely that inhalation exposures are substantially overestimated compared to the exposure conditions for a typical resident of the study area. It was conservatively assumed that residents were continuously exposed to outdoor air concentrations, even though a typical resident spends many hours a day inside where air conditions are predicted to be much lower. For the soil pathway, the combined effect of the multiple conservative assumptions could easily overestimate representative COC exposures and doses by a factor of 10 or more, compared to a typical individual. In the case of the fish ingestion pathway, there is a substantial level of uncertainty in the amount and frequency of fish ingestion, and this uncertainty could result in either an overestimation or underestimation of COC exposures. However, all of the risk estimates calculated for the fish ingestion pathway are more than 100 times lower than the levels associated with the occurrence of adverse health effects. Thus, no credible increase in any of the exposure parameters would change the overall conclusion that the fish ingestion pathway is not likely to be associated with adverse health effects.

Another source of uncertainty in the soil exposure estimates is the assumption that the particulates emitted from the Kondirator would be deposited in the top 2 centimeters of soil (about 0.7 inches), and would stay in the surface soil through the entire exposure period. There is very little consensus among risk assessors about the most reasonable value to use for soil mixing depth. This parameter is highly variable and site-specific, depending on the nature of the soil, the physical and chemical properties of contaminants, and the extent to which soils are disturbed, mixed, or leached, by rainfall, animal burrowing, root growth, or human activities. Values between 1 and 20 centimeters have been proposed for use in similar risk assessments. The assumption of 2 centimeters for soil mixing depth in this assessment is a reasonable but probably rather conservative compromise, and is consistent with the recommendation made by the Minnesota Department of Health (Messing 1994).

A similar situation exists in the case of the sediment exposure pathway. The assumptions made regarding the sediment mixing depth and bulk density (which effect estimates of sediment COC concentrations) are that these values could vary greatly over time or spatially throughout the area of the river where exposures occur, depending upon flow conditions, sediment loading, and human activities, such as dredging or barge traffic. Thus the estimates of sediment concentrations of COCs are quite uncertain. These assumptions are identified in Table 10-1 as having a "low" effect on the overall uncertainty in the risk estimates, however, because the health risk estimates for the sediment pathway are far below levels of regulatory concern, even with the conservative assumptions that have been made regarding exposure conditions.

The final source of uncertainty in exposure and/or dose estimates identified in the table is the assumption of 100% relative bioavailability of COCs from the Kondirator particulate in the HHRA. This assumption implies that all of the elements in the particulate will ultimately become available in a form that can be absorbed by receptors over the course of the exposure period. The basis for this assumption, discussed in detail in Section 8.3, is simply that the known corrosion behavior of carbon steel and related alloys is such that fine particulates would be expected to corrode very rapidly in surface water or soil environments. It is assumed that this corrosion would result in the release of all of the COC elements in a form that is bioavailable to humans, although it is possible that the corroded materials (primarily oxides and hydroxides) might not be fully bioavailable. Alternatively, it is possible that the some of the COCs could be released from the particulates in a form that is more bioavailable to humans than the compound that was used in developing the toxicity criteria for the COCs. For this reason, the assumption of 100% bioavailability is characterized as most likely resulting in a low to moderate level of uncertainty in risk estimates, and actual doses and risks might be either over- or under-estimated.

10.6 UNCERTAINTIES ASSOCIATED WITH TOXICOLOGICAL EVALUATION AND RISK ESTIMATION

Within the screening level assessment, the sources of the greatest uncertainty are probably the toxicologic models and toxicologic criteria values used to develop quantitative estimates of potential risk. The following discussion briefly addresses some general technical issues associated with the toxicologic models used in the HHRA, followed by some specific issues associated with the toxicologic criteria for the four COCs that are identified as being associated with in the greatest potential risk in this assessment. The COCs include the three carcinogenic COCs chromium, arsenic, and beryllium, as well as manganese, exposures to which are associated with the highest potential for adverse noncancer effects.

Failure to Consider Background Exposures and Risks. Several reviewers of interim deliverables have noted that the failure to add the natural and man-made background concentrations of COCs in environmental media into the exposure and risk calculations may have resulted in risk estimates that are substantially lower than those that would be generated if the background concentrations were included in the calculations. This is a valid point; in fact, typical naturally occurring background concentrations of a number of elements in soils, when evaluated using the simple screening levels employed in this analysis, can be associated with potential risks which exceed the 10^{-5} Tolerable Cancer Risk level, or in hazard quotients that exceed 1. This most commonly occurs for arsenic, beryllium, chromium, and cadmium (all carcinogenic by inhalation) and occasionally for the noncarcinogenic elements mercury, manganese, antimony, and cobalt. In addition, "background" concentrations of lead in soils in industrial areas and near heavily traveled roads sometimes approach levels that may be hazardous by themselves or in combination with potential exposures from other sources.

The decision whether to include background concentrations in the risk calculations is a complex judgment, involving both policy and technical issues. Background concentrations were not added into the quantitative risk calculations in this screening assessment (with the exception of lead) for two primary reasons. First, excluding background concentrations greatly simplifies the assessment (a major consideration due to resource constraints), and excluding background provides an unambiguous characterization of the effects associated with the Kondirator alone. Second, for soils and air, the media where background concentrations were of the most concern, there were few or no local background data available. It seemed the best use of analytical resources to characterize the impacts of the Kondirator alone, and to leave the question of how to address background exposures and risks to a more detailed analysis, if policy makers decide that one is warranted.

Nonthreshold Cancer Risk Model. As discussed in Section 8.1, the method used to evaluate cancer risks in this assessment employs a linear dose-response model, which assumes that every incremental dose of a potentially carcinogenic COC results in a constant increment of risks. Whether or not low-dose linearity is solid for specific classes of carcinogens is the subject of considerable ongoing debate within the toxicological community, and there is a general consensus that the linear model is probably very conservative for most carcinogens. Use of alternate models, which are not restricted to low-dose linearity, can result in low-dose risk estimates that are many orders of magnitude lower than those obtained from the linear model. For this reason, the use of the linear model is identified as introducing a "high" level of uncertainty into the risk estimates and as most likely resulting in a substantial overestimation of risks. This is probably the largest single source of uncertainty in the cancer risk estimates.

Noncancer Risk Characterization Model. The model used to evaluate the potential for adverse noncancer risks is also quite uncertain. In this case, the uncertainty arises both from the model itself and from the methods used to derive the toxicity criteria (RfDs and RfCs) for the various COCs. As noted in Section 8.1, the derivation of RfDs and RfCs involves the use of uncertainty factors that compensate for a lack of data regarding specific types of effects in humans. The less data, and the lower its quality, the greater number of uncertainty factors used to derive the RfC or RfD. Thus, a given toxicity value may possess a greater or lesser degree of conservatism, depending on data quality, not on the known toxic characteristics of the COC in question. In addition, the magnitude of the uncertainty factors may not always be indicative of the overall level of uncertainty in conclusions regarding the occurrence of adverse effects. This varying and unknown level of conservatism introduces a substantial degree of uncertainty into the noncancer risk characterization. Generally, the overall effect of using this approach is to provide a high level of assurance that exposures and doses regimes below RfC and RfD values are very unlikely to be associated with adverse effects. Conversely, when exposures or dose levels exceed RfCs or RfDs, it may be difficult to draw firm conclusions as to whether adverse effects actually occur. This is not a major source of uncertainty in the Kondirator HHRA, because all of the estimated exposures and doses are below levels of concern indicated by the RfD and RfC values.

Risks from Multiple Contaminant Exposures. Throughout the HHRA, it is assumed that the effect of multiple contaminant exposures, for a given pathway, would be additive. That is, the sum of the cancer risks for a given pathway is assumed to be equal to the sum of the cancer risks associated with exposure to the individual COCs, and a hazard index (the sum of the hazard quotients for individual COCs) is used to evaluate potential adverse noncancer risks for exposures to more than one COC. While toxicologic interactions between multiple chemical exposures is a well-known phenomenon, there is very little information available related to such interactions at low doses, and very little information is available associated with interactions between the specific mix of COCs addressed in this assessment. Thus it is not possible to quantify potential effects of either positive or negative interactions of multiple COC exposures. Potential interactions between multiple pollutant exposures are thus identified as a low-to-moderate source of uncertainty in the risk estimates that could result in either an over- or under-estimation of risks.

Unavailability of Toxicity Criteria for Some COCs. As noted in Section 8.2, USEPA-derived toxicity criteria are not available for a number of the COCs emitted from the Kondirator. There is thus the potential for underestimation of total risks. This factor has, however, been identified as a source of a low level of uncertainty in the risk estimates for several reasons. First, toxicity criteria are available for almost all of the most toxic COCs and for all of the carcinogenic COCs. In addition, most of the COCs for which toxicity criteria are not available are emitted in very low amounts compared with the emission rates of COCs for which the toxicity is well characterized. A higher proportion of noncarcinogenic COCs lack inhalation RfCs than lack ingestion RfDs, so the potential for underestimation of adverse noncancer effects through the inhalation pathway is greater than for the ingestion pathways.

Arsenic Ingestion Slope Factor. Potential exposure to arsenic accounts for just less than half the cancer risk associated with the soil ingestion pathway. The carcinogenicity of ingested inorganic arsenic has been a matter of controversy for many years. Arsenic is classified by EPA as a known human carcinogen (Group A) by the oral route. There are several sources of uncertainty regarding arsenic's carcinogenic potency, however, including the fact that the dose-response curve may be less than linear at low doses, causing the slope factor to overestimate potential risk at lower doses, and that arsenic may be an essential human nutrient (USEPA 1988). Also, a 1988 memorandum from the USEPA Administrator cited in IRIS (1994) regarding arsenic stated that "risk managers must recognize and consider the qualities and uncertainties of risk estimates. The uncertainties associated with ingested inorganic arsenic are such that estimates could be modified downwards as much as an order of magnitude, relative to risk estimates associated with most other carcinogens." The basis of this statement is the fact that the primary response in the epidemiology studies used to derive the oral unit risk for arsenic was skin tumors, which can be detected and treated. It should be noted, however, that arsenic-induced skin cancer is more frequently lethal than other forms of skin cancer (e.g., sun-induced skin cancer) as it causes multiple-site tumors, affects the squamous cells rather than the basal cells of the skin, and occurs in less detectable areas of the body (on the trunk and buttocks rather than the face and neck). Moreover, the occurrence of internal tumors (e.g., of lung, liver, bladder, and kidney) has been recently noted in several studies of patients with arsenic-induced skin cancer (ATSDR 1991). Given the occurrence of internal cancers as well as skin cancer in association with arsenic ingestion, modification of the risk estimate downward may not be appropriate.

It is clear from the preceding discussion that the risk estimate for arsenic by the ingestion route is associated with a high degree of uncertainty.

Beryllium Ingestion Slope Factor. Potential exposures to beryllium account for more than half of both the adult and child's estimated soil ingestion cancer risks. As with arsenic, considerable uncertainty is associated with any potential risks estimated for beryllium because of the uncertainty in the derivation of the ingestion pathway cancer slope factor, but for different reasons. The ingestion slope factor for beryllium was derived from a lifetime animal bioassay in which beryllium was orally administered (IRIS 1994). Neither the incidence of any single tumor or the incidence of total tumors was significantly increased in treated animals compared to controls. However, USEPA used the data for total tumors, which were not significantly increased (i.e., negative data), to derive the cancer slope factor. The justification for use of statistically insignificant data was that beryllium, when injected, produced tumors at the site of the injection. While this may be the case, these data are not relevant to evaluating potential risks from oral exposure. Use of the negative data is in conflict with USEPA guidelines for carcinogen assessment (USEPA 1986), which state that the data selected for dose response analysis should be statistically and toxicologically relevant.

These uncertainties associated with derivation of the cancer slope factor and with the oral-route carcinogenicity of beryllium, should be considered when interpreting estimated potential risks associated with beryllium exposures. Given that the toxicologic study used to derive the slope factor showed no statistically significant increase in cancer risks in treated animals, it is possible that the "true" carcinogenic potency of beryllium by ingestion could be much lower than estimated, and perhaps even zero. It is therefore very likely the cancer risks associated with ingestion of beryllium emitted from the Kondirator are greatly overestimated.

Manganese Reference Concentration. The ratio of the long-term air concentration of manganese in particulates emitted from the Kondirator to the USEPA RfC, approaches 1.0, giving the impression that air exposures to manganese, especially when combined with potential exposures from other sources, could be associated with adverse noncancer effects (Messing 1994). It is likely that the actual potential for adverse health effects associated with potential exposures to manganese is not as high as indicated by this calculation. This is because the RfC value (0.05 $\mu g/m^3$) is probably much too conservative, given the nature of the toxicologic data supporting the value. A recent review of the RfC for manganese (Crump et al. 1994) calls into question the methods used to derive the value. The major criticisms of the RfC value include—

- Exposure data from the epidemiologic study used to derive the RfC were not interpreted correctly, and the USEPA interpretation overestimates potential risks associated with low-level manganese exposures;
- Data from the same epidemiologic study can be used to derive a NOAEL for manganese exposure, rather than the LOAEL derived by USEPA, obviating the need for one of the three tenfold uncertainty factors used in calculating the RfC;
- USEPA's use of an additional uncertainty factor to adjust for differences in duration of exposure and chemical form is also not justified, and;
- The extremely low inhalation RfC for manganese is entirely inconsistent with its low systemic toxicity by other administration pathways, since the critical toxic effects are similar, and the extent of systemic absorption of ingested and inhaled manganese are also quite similar.

The authors of the critique suggest that an RfC value in the neighborhood of 3.0 $\mu g/m^3$ would be scientifically defensible, rather than USEPA's value.

These arguments suggest that the potential for adverse effects associated with manganese exposures is considerably lower than that suggested by the calculated exposure/RfC ratio, even when exposures from other sources are taken into account.

Chromium Speciation. Potential exposure to chromium accounts for almost 50% of the total cancer risk associated with the inhalation pathway. While uncertainty in the cancer slope factor and dose-response model for this contaminant is probably typical of that for many other contaminants, an additional source of uncertainty in the assessment is the assumption that 10% of the total chromium is present in hexavalent form (Cr+6). This assumption is important because only the hexavalent form of chromium is known to be carcinogenic in humans. If in fact a smaller or greater proportion of the emitted chromium were hexavalent, then the estimated cancer risk could be reduced or increased by corresponding amounts.

The assumption that 10% of the chromium would be hexavalent was made in the absence of definitive data. As a constituent of carbon steel, chromium is likely to be present in lower oxidation states, and it is unlikely that a substantial proportion of the chromium would be oxidized to the chromate (hexavalent) form after release to the environment. Under normal conditions in soil, air, and surface water, the dominant form of chromium is the trivalent (+3) state

(Cotton and Wilkinson 1962). Also, even in more oxidized particulates from combustion sources, experience indicates that only a very small proportion of total chromium exists in the hexavalent state. Siebert and Alston-Guiden (1991), for example found that an average of only 3.4% of chromium in particulates emitted from a number of hazardous and medical waste incinerators was hexavalent. Other investigators (Canter and Gloyna 1968) have found that hexavalent chromium emitted into uncontaminated surface water may persist for substantial periods of time, but that in the presence of particulate and sunlight, rapid reduction to trivalent chromium occurs.

For these reasons, the assumption of 10% hexavalent chromium in the Kondirator particulate is believed to be reasonable, but conservative. This assumption could be an important source of uncertainty in the assessment, however. If all of the chromium in the particulates were hexavalent (which is most unlikely), the estimated inhalation risk due to chromium would be 10 times higher. If none of the chromium were hexavalent, then there would be no inhalation pathway cancer risk associated with chromium exposures.

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APPENDIX A

AIR QUALITY AND DEPOSITION MODELING SUMMARY

APPENDIX A.1

DESCRIPTION OF AIR QUALITY AND DEPOSITION MODELING METHODS AND RESULTS

Source: Barr Engineering

A. SUMMARY

Installation of the Kondirator will result in air emissions from the two pollution control device stacks and fugitives from raw material unloading. Ambient air quality impacts will consist of particulate emissions from these sources. Modeled ambient air particulate concentrations (including background concentrations) resulting from Kondirator emissions do not exceed the National Ambient Air Quality Standards ("NAAQS") for particulate matter 10 microns and smaller ("PM_{10}"). Total suspended particulate ("TSP") concentrations resulting from Kondirator emissions do not exceed primary or secondary Minnesota Ambient Air Quality Standards ("MAAQS") for TSP. Modeling results are summarized in Table 24.1 below.

TABLE 24.1
SUMMARY OF PARTICULATE MODELING

Pollutant	Modeled Ambient Conc. $\mu g/m^3$	Background Ambient Conc. $\mu g/m^3$	Total Ambient Conc. $\mu g/m^3$	NAAQS Primary $\mu g/m^3$	NAAQS Secondary $\mu g/m^3$	MAAQS Primary $\mu g/m^3$	MAAQS Secondary $\mu g/m^3$
PM_{10}							
Annual	1.1	21.1	22.2	50	50	NA	NA
24-hr	10.1	49.0	59.1	150	150	NA	NA
TSP							
Annual	3.2	42.0	45.2	NA	NA	75	60
24-hr	26.5	107.0	133.5	NA	NA	260	150

C. EFFECTS ON AIR QUALITY

Ambient air concentrations of particulate matter emitted from the Kondirator and associated operations were estimated using the Industrial Source Complex-Short Term 2 (ISCST2) dispersion model. Maximum 24-hour and annual average concentrations of both particulate matter of 10 microns or less ("PM_{10}") and total suspended particulates ("TSP") were estimated using hourly meteorological data collected at the Minneapolis-St. Paul office of the National Weather Service ("NWS") for the years 1987-1991. Upper air data and surface temperatures collected at the St. Cloud, Minnesota office of the National Weather Service for the period 1987-1991 were used to calculate mixing heights.

Two primary sources of emissions were modeled: stack emissions from the Kondirator dust control system and the cascade cleaning system; and fugitive emissions from unloading activities.

Stack parameters stated in the April 1991 MPCA Air Emission Facility Permit Application prepared by HDR Engineering and shown in Table 24.4 were used in the modeling.

TABLE 24.4
STACK PARAMETERS

	Kondirator Dust Control Stack	Cascade Cleaning System Stack
Stack Height (feet)	62	60
Stack Diameter (inches)	42	24
Stack Flow Rate (acfm)	35,300	7000
Stack Temperature (Fahrenheit)	68	68

Particulate emission rates for the Kondirator Dust Control System stack and the Cascade Cleaning System stack were developed using data presented in Table 2 of the December 1990 MPCA Air Emission Facility Permit Application and information provided by Osborne Engineering regarding the pollution control equipment efficiencies. Based on this information, the emission rates shown in Table 24.5 were used in the modeling.

TABLE 24.5
STACK EMISSION RATES

Particle Size (microns)	Kondirator Dust Control System Stack Emission Rate (lb/hr)[a]
>80	0.0
40-80	0.0
20-40	0.6
10-20	1.4
<10	4.0
Total	6.1
Particle Size (microns)	**Cascade Cleaning System Stack Emission Rate (lb/hr)[a]**
>12,700	0.0
40-12,700	2.96
30-40	0.53
<30	0.39
Total	3.88

[a] Based on throughput of 100 tons per hour.

Using the particle size distributions presented above, PM_{10} was modeled assuming emission rates of 4.0 lb/hr and 0.39 lb/hr, respectively, for the dust control system stack and the cascade cleaning system stack. TSP was modeled assuming emission rates of 6.1 lb/hr and 3.88 lb/hr, respectively, for the two stacks. The modeling analysis conservatively considered PM_{10} to encompass all particles smaller than 30 microns emitted from the Cascade Cleaning System. Furthermore, the analysis did not account for scavenging as a result of deposition. In reality, given the specific gravity of any metallic particulates emitted, ambient concentrations would be less than the model predictions due to removal of particulates by gravitational deposition.

Fugitive emissions from raw materials unloading activities were modeled as a volume source. The parameters that were used to model this source are presented in Table 24.6.

TABLE 24.6
FUGITIVE EMISSION MODELING PARAMETERS

Process	Effective Release Height (feet)	Height of Volume Center (feet)	Area (sq. feet)
Unloading	25	12.5	1076

The effective release height was developed by review of plans for the Kondirator and associated processing equipment. The release height was chosen to represent the height from which materials would be dropped during the unloading process. The horizontal dimensions of the modeled volume source were chosen to encompass a representative work area for unloading activities at a given point in time.

Fugitive emissions from other Kondirator processes will be controlled as needed and were not modeled. Several design features of the proposed AIS Kondirator specifically address concerns over fugitive emissions. First, all conveyors associated with the Kondirator will have sidewalls to prevent materials from falling or blowing off the conveyor. Second, the return conveyor from the sieving drum back to the Kondirator will also be enclosed beneath the conveyor belt to prevent material from falling off the conveyor. Third, dust collected by the Kondirator Dust Collection System and the Cascade Cleaning System will be conveyed to enclosed storage bins through enclosed conveyors. Fourth, scrap metal running through the Kondirator is subjected to induced air velocities on the order of 100 feet per second. Typical wind speeds in the Minneapolis-St. Paul area are on the order of 15 feet per second. Particulate matter created or adhered to the raw scrap metal will likely be removed by the pollution control equipment rather than winds blowing across conveyors.

While the potential for fugitive emissions from the Kondirator is apparently limited, fugitive PM_{10} and TSP emissions from raw materials unloading were estimated using ore emission factors from EPA's Factor Information and Retrieval (FIRE) System, Version 2.62 (USEPA, April 1994). These factors were developed for the handling of iron ores. Among materials for which factors exist, iron ore is most similar to the scrap iron and steel handled at the Kondirator facility. The PM_{10} and TSP emissions from raw materials unloading were estimated assuming a processing rate of 100 tons of scrap metal per hour and an 11-hour work day. The emission factors were 0.0012 lb/ton for PM_{10} and 0.0024 lb/ton for TSP. Calculated fugitive emission rates are presented in Table 24.7.

TABLE 24.7
FUGITIVE EMISSION RATES

Process	PM_{10} Emission Rate (lb/hr)[a]	TSP Emission Rate (lb/hr)
Unloading	0.12	0.24

The proposed noise walls and the raw material scrap pile were identified as structures potentially inducing downwash from the Kondirator Dust Control System stack and the Cascade Cleaning System stack. The integral wall adjacent to the Kondirator was evaluated as a structure two feet wide, 33 feet high, and 87 feet long. The free standing wall along the riverbank was evaluated as a structure two feet wide, 30 feet high, and 317 feet long. Also, the raw materials storage pile was evaluated at its maximum potential size, with lateral dimensions of 110 feet by 140 feet and a height of 50 feet. Direction specific downwash data were calculated for use in the modeling analysis.

Model receptors were established on a Cartesian coordinate system with the origin specified at the Kondirator dust control system stack. The regular coordinate system covers a square area and consists of both x-axis and y-axis coordinates (meters) at +/-30, +/-60, +/-90, +/-120, +/-150, +/-180, +/-210, +/-240, +/-270, +/-300, +/-400, +/-500, +/-600, +/-700, +/-800, +/-900, +/-1000, +/-1200, +/-1400, and +/-1600. In addition, receptors were placed on the property boundary of AIS at intervals not exceeding 30 meters. For modeling air concentrations of particulates, the elevation of each receptor was input to ISCST2. No terrain elevations were input for deposition modeling, since ISCST2 requires that terrain data not be input for deposition estimates.

Estimated concentrations were calculated using the Urban Mode dispersion coefficients. The following regulatory defaults were selected by invoking the regulatory default option: final plume rise used at all downwind receptor locations; stack-tip downwash effects included; buoyancy-induced dispersion effects parameterized; default wind profile coefficients assigned; a calm processing routine used to handle concentrations during calm periods; default vertical temperature gradients assigned; a calm processing routine used to handle concentrations during calm periods; default vertical temperature gradients assigned; revised building wake effects procedure selected, invoking either the Huber and Snyder method or the method of Schulman and Scire depending on stack and building dimensions. As stated above, gravitational settling categories were not selected in order to conservatively estimate ambient air concentrations of particulates.

Background TSP and PM_{10} concentrations were developed using ambient air monitoring data obtained from the MPCA for the years 1985 through 1993. MPCA site #0940, located at 143 13th Avenue Northeast, is the ambient air monitoring station located nearest the AIS site. TSP data are collected at this station. The nearest PM_{10} station is MPCA site #0907 located at 4646 Humboldt Avenue North.

Both PM_{10} and TSP was collected at that station through 1989, but only TSP is currently measured there. The ratio of PM_{10} to TSP at 4646 Humboldt Avenue was calculated as 0.458 using the average ratio calculated for the four most recent years of data available (1985 through 1988) when both PM_{10} and TSP were measured. This ratio was used to project PM_{10} concentrations at 143 13th Avenue Northeast based on measured TSP at the site. The highest annual PM_{10} concentration was calculated from annual TSP concentrations from 1991 through 1993. A value of 21.1 $\mu g/m^3$ (TSP concentration of 46 $\mu g/m^3$, 1991 annual arithmetic mean) was estimated as representative of an annual PM_{10} concentration at the AIS site. The appropriate annual background TSP concentration is the annual geometric mean. The highest annual average concentration at 143 13th Avenue Northeast was 42 $\mu g/m^3$, 1991 annual geometric mean.

A 24-hour PM_{10} background concentration was estimated using the highest of the second highest 24-hour TSP concentrations of each year recorded during the three year period 1991 through 1993 at 143 13th Avenue Northeast and multiplying by the PM_{10} to TSP ratio of 0.458. The highest second highest TSP concentration was 107 $\mu g/m^3$. The corresponding highest second highest PM_{10} concentration was 49.0 $\mu g/m^3$.

The highest annual average modeled PM_{10} concentration (without background concentrations) is 1.1 $\mu g/m^3$ occurring along the western boundary of the AIS property. The highest 24-hour modeled PM_{10} concentration (without background) is 10.1 $\mu g/m^3$, occurring just outside the western boundary of the AIS Kondirator facility, to the northwest of the Kondirator Dust Control stack. Total ambient air concentrations are determined by adding the background concentrations to the modeled concentrations. The resulting annual and 24-hour PM_{10} concentrations are 22.2 $\mu g/m^3$ and 59.1 $\mu g/m^3$, respectively. The annual and 24-hour maximum PM_{10} concentrations, including background, are shown in Figure 3 and Figure 4 respectively. Maximum concentrations are listed in Table 24.8. The National Ambient Air Quality Standard for PM_{10} is 50 $\mu g/m^3$ annually and 150 $\mu g/m^3$ on a 24-hour basis.

Table 24.8
MAXIMUM PM$_{10}$ IMPACTS

Year	Time Period	Impact (µg/m^3)	Location (m)		Background (µg/m^3)	Day	Total Impact (µg/m^3)
			East	North			
1987	24-hour	9.7	-91.2	120.0	49.0	7/25	58.7
	Annual	1.1	-91.2	61.9	21.1		22.2
1988	24-hour	9.9	-91.2	32.8	49.0	9/10	58.9
	Annual	1.0	37.3	-120.0	21.1		22.1
1989	24-hour	9.9	-91.2	61.9	49.0	3/10	58.9
	Annual	1.0	-91.2	91.0	21.1		22.1
1990	24-hour	8.5	-91.2	91.0	49.0	11/20	57.5
	Annual	1.0	-91.2	120.0	21.1		22.1
1991	24-hour	10.1	-120.0	90.0	49.0	3/16	59.1
	Annual	1.0	-91.2	61.9	21.1		22.1

The highest average annual modeled TSP concentration is 3.2 µg/m^3, occurring at the same point as the highest PM$_{10}$ impact, to the northwest of the Kondirator stack. The highest 24-hour modeled TSP concentration is 26.5 µg/m^3, occurring along the western property boundary of the facility, northwest of the Kondirator Dust Control stack (at the same location as the highest annual impact). Adding the ambient background concentrations of TSP, the resulting total annual and 24-hour concentrations of TSP are 45.2 µg/m^3 and 133.5 µg/m^3 respectively. The annual and 24-hour maximum TSP concentrations, including background, are shown in Figure 5 and Figure 6 respectively. Maximum concentrations are listed in Table 24.9. The Minnesota Ambient Air Quality Standards for TSP are 75 µg/m^3 (primary) and 60 µg/m^3 (secondary) annual geometric mean concentration, and 260 µg/m^3 (primary) and 150 µg/m^3 (secondary) 24-hour average concentrations.

Table 24.9
MAXIMUM TSP IMPACTS

Year	**Time Period**	**Impact ($\mu g/m^3$)**	**Location (m)**		**Background ($\mu g/m^3$)**	**Day**	**Total Impact ($\mu g/m^3$)**
			East	**North**			
1987	24-hour	24.4	-91.2	120.0	107.0	7/25	131.4
	Annual	3.2	-91.2	61.9	42.0		45.2
1988	24-hour	26.2	-150.0	90.0	107.0	1/18	133.2
	Annual	2.7	35.2	-90.6	42.0		44.7
1989	24-hour	26.5	-91.2	61.9	107.0	3/10	133.5
	Annual	2.8	-91.2	91.0	42.0		44.8
1990	24-hour	23.0	-91.2	-54.4	107.0	9/10	130.0
	Annual	2.6	-91.2	120.0	42.0		44.6
1991	24-hour	26.2	-120.0	90.0	107.0	3/16	133.2
	Annual	2.9	-91.2	61.9	42.0		44.9

The highest modeled annual PM_{10} concentration from Kondirator sources at the nearest residence was 0.42 $\mu g/m^3$. The nearest residences are across the Mississippi River, 1,000 feet (300 meters) east of the proposed location for the Kondirator. The highest 24-hour PM_{10} impact from Kondirator sources on the nearest residences is 4.24 $\mu g/m^3$.

Modeling results are included as Attachment 5 - Ambient Air Concentration Modeling Results. Sources of information are summarized in Attachment 6 - References.

A. DEPOSITION OF STACK AND FUGITIVE EMISSIONS

Total annual deposition of particulates emitted from the Kondirator was estimated using the Industrial Source Complex-Short Term (ISCST2) dispersion model. Total annual deposition (grams particulate matter per square meter) was estimated using the deposition algorithm in the model. Due to the large size and density of the particulates, the ISCST2 deposition algorithm was chosen rather than the Sehmel and Hodgson curves.

Two primary sources of emissions were modeled: stack emissions from the Kondirator Dust Control System and the Cascade Cleaning System; and fugitive emissions from the raw materials unloading activities.

Model input parameters were identical to those used to model ambient air concentrations of total suspended particulates ("TSP"), with the exception that settling velocities, a necessary parameter for calculating deposition, were included with the source input data, and receptor elevations were excluded from the ISCST2 modeling, since ISCST2 does not consider terrain elevations when performing deposition calculations.

Particulate emission rates for the Kondirator Dust Control Stack and the Cascade Cleaning System stack were developed using data presented in Table 2 of the December 1990 MPCA Air Emission Facility Permit Application prepared by HDR Engineering and information proveded by Osborn Engineering regarding the pollution control equipment efficiences.

Using the particle size distributions presented in Table 24.3 above, deposition of particulate matter was modeled assuming emission rates of 6.1 lb/hr and 3.88 lb/hr, respectively, for the Kondirator Dust Control System stack and the Cascade Cleaning System stack.

Stokes' Law was used to calculate the settling velocities of the particles emitted. Settling velocities for particle size categories were conservatively calculated by using the upper limit of the size category to calculate a settling velocity for the category. A density of 500 lb/ft^3 (representative of steel) was used to calculate settling velocities for various particle sizes. Fugitive emissions from Kondirator processes were assumed to fall into two particle size categories: less than 10 microns, and 10 to 30 microns. Calculated settling velocities and mass fraction in each category are presented in Table 25.1.

TABLE 25.1
FUGITIVE EMISSION SETTLING VELOCITIES AND MASS FRACTIONS

	Less than 10 Microns	10 - 30 Microns
Settling Velocity (m/s)	0.0218	0.196
Mass Fraction	0.47	0.53

Emissions from the Kondirator Dust Control System stack and the Cascade Cleaning System stack were, based on vendor data, assumed to fall into three particle size categories. The categories, calculated settling velocities, and mass fraction in each category are summarized in Table 25.2.

TABLE 25.2
STACK EMISSION SETTLING VELOCITIES AND MASS FRACTIONS

Kondirator Dust Control System Stack	**Less than 10 Microns**	**10 - 20 Microns**	**20 - 40 Microns**
Settling Velocity (m/s)	.0218	.0871	.349
Mass Fraction	.67	.23	.10
Cascade Cleaning System Stack			
Settling Velocity (m/s)	.0218	.349	1.39 (assumed size of 80 microns)
Mass Fraction	.07	.17	.76

Dry deposition was estimated using model receptors located within the property boundary of the Kondirator facility. Since ISCST2 does not consider terrain when calculating deposition, no receptor elevations were input to the model. The receptor grid used was a 30-meter resolution grid. Using arithmetic averages of annual onsite deposition, averaging both across years and across onsite receptors, the deposition of particulates onsite was estimated to be 84.9 g/m^3 over the area draining to the stormwater retention pond.

Following guidance by Greg Pratt of the Minnesota Pollution Control Agency ("MPCA"), wet deposition was estimated using model-predicted onsite concentrations and a particulate scavenging ratio for precipitation. [Source: Galloway, et al, The temporal and spatial variability of scavenging ratios for NSS sulfate, nitrate, methanesulfonate and sodium in the atmosphere over the North Atlantic Ocean, Atmos. Env., 1993, pp. 235-250]. According to Galloway, et al (1993) the pollutant concentration in precipitation (nanomoles per kilogram) is equal to the concentration in air (nanomoles per cubic meter), multiplied by a scavenging ratio (unitless), and divided by the density of air (1.17 kg/m^3). Scavenging ratios can range from 267 for compounds such as methane sulfonate to 4098 for the sodium ion (as sodium salts), which is highly soluble in water. For purposes of calculating wet deposition of airborne particulates from Kondirator sources, all particles were assumed to be iron (molecular weight of 55.85 nanograms per nanomole), and a scavenging coefficient of 2,000 was assumed, since the scavenging coefficient of iron was not measured by Galloway, et al. The real scavenging coefficient for iron would be much lower, since iron is not readily soluble in water. Using the average on site modeled TSP concentration of 1.74 μg/m^3, the annual wet deposition of particulates was estimated to be 1.96 g/m^3/yr, only 2.3 percent of the total dry deposition.

A quality assurance check was made on the modeling output to validate the results. The total emitted mass in the model was compared to the deposited mass immediately around the AIS site. Using the site average deposition rate of 75 μg/m^2/yr, the area needed to deposit the total mass of particulates emitted during the period of one year was calculated to be 248,192 m^2, approximately 61 acres. This number is roughly consistent with the 12-acre size of the AIS site.

APPENDIX A.2

ISCST2 MODEL INPUT FILES FOR KONDIRATOR AIR QUALITY MODELING

(1991 Meteorologic Data)

Source: Barr Engineering

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CO STARTING
CO TITLEONE AIS KONDIRATOR TSP EMISSIONS -- 1991 MSP/ST. CLOUD MET DATA
CO MODELOPT DFAULT CONC URBAN
CO AVERTIME 24 PERIOD
CO POLLUTID OTHER
CO TERRHGTS ELEV
CO ELEVUNIT FEET
CO RUNORNOT RUN
CO ERRORFIL AIS91T.ERR
CO FINISHED
SO STARTING
SO LOCATION 32 VOLUME   -13.41    -84.12      246.6
SO SRCPARAM 32 0.030240      3.81     10.00    7.62
SO LOCATION 41 POINT      0.00      0.00      246.9
SO SRCPARAM 41 0.768600     18.89    293.00    18.6300     1.070
SO LOCATION 42 POINT      0.00     10.67      246.9
SO SRCPARAM 42 0.489000     18.29    293.00    11.3180     0.610
SO BUILDHGT 41     .00     .00    9.15   10.00   10.00   10.00
SO BUILDHGT 41   10.00   10.00   10.00   10.00   10.00   10.00
SO BUILDHGT 41   10.00   10.00   10.00     .00     .00     .00
SO BUILDHGT 41     .00     .00    9.15   10.00   10.00   10.00
SO BUILDHGT 41   10.00   10.00   10.00   10.00   10.00   10.00
SO BUILDHGT 41   10.00   10.00   10.00     .00     .00     .00
SO BUILDWID 41     .00     .00   48.84   17.51   20.71   23.27
SO BUILDWID 41   25.13   26.22   26.52   26.22   25.13   23.27
SO BUILDWID 41   20.71   17.51   13.79     .00     .00     .00
SO BUILDWID 41     .00     .00   48.84   17.51   20.71   23.27
SO BUILDWID 41   25.13   26.22   26.52   26.22   25.13   23.27
SO BUILDWID 41   20.71   17.51   13.79     .00     .00     .00
SO BUILDHGT 42     .00     .00     .00    9.15    9.15    9.15
SO BUILDHGT 42   10.00   10.00   10.00   10.00   10.00   10.00
SO BUILDHGT 42   10.00   10.00   10.00   10.00     .00     .00
SO BUILDHGT 42     .00     .00     .00    9.15    9.15    9.15
SO BUILDHGT 42   10.00   10.00   10.00   10.00   10.00   10.00
SO BUILDHGT 42   10.00   10.00   10.00   10.00     .00     .00
SO BUILDWID 42     .00     .00     .00   62.57   74.41   83.98
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SO BUILDWID 42   20.71   17.51   13.79    9.64     .00     .00
SO BUILDWID 42     .00     .00     .00   62.57   74.41   83.98
SO BUILDWID 42   25.13   26.22   26.52   26.22   25.13   23.27
SO BUILDWID 42   20.71   17.51   13.79    9.64     .00     .00
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SO EMISFACT 42 HROFDY 0.0000 0.0000 0.0000 0.0000
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP AREA 32
SO SRCGROUP STACKS 41 42
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE DISCCART          -91.2  -141.6     812
RE DISCCART          -91.2  -112.5     813
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RE DISCCART          -63.1   207.3     814
RE DISCCART          -35.1   207.3     813
RE DISCCART             -7   207.3     812
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RE DISCCART	1400	1000	851
RE DISCCART	1600	1000	852
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RE DISCCART	0	270	810
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RE DISCCART	150	270	800
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RE DISCCART	-270	240	819
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RE DISCCART      600  -1000    830
RE DISCCART      700  -1000    825
RE DISCCART      800  -1000    829
RE DISCCART      900  -1000    833
RE DISCCART     1000  -1000    835
RE DISCCART     1200  -1000    840
RE DISCCART     1400  -1000    850
RE DISCCART     1600  -1000    845
RE DISCCART    -1600  -1200    860
RE DISCCART    -1400  -1200    858
RE DISCCART    -1200  -1200    855
RE DISCCART    -1000  -1200    849
RE DISCCART     -800  -1200    834
RE DISCCART     -600  -1200    827
RE DISCCART     -400  -1200    824
RE DISCCART     -200  -1200    822
RE DISCCART        0  -1200    800
RE DISCCART      200  -1200    805
RE DISCCART      400  -1200    812
RE DISCCART      600  -1200    824
RE DISCCART      800  -1200    833
RE DISCCART     1000  -1200    835
RE DISCCART     1200  -1200    839
RE DISCCART     1400  -1200    847
RE DISCCART     1600  -1200    847
RE DISCCART    -1600  -1400    859
RE DISCCART    -1400  -1400    855
RE DISCCART    -1200  -1400    851
RE DISCCART    -1000  -1400    840
RE DISCCART     -800  -1400    829
RE DISCCART     -600  -1400    827
RE DISCCART     -400  -1400    824
RE DISCCART     -200  -1400    822
RE DISCCART        0  -1400    800
RE DISCCART      200  -1400    802
RE DISCCART      400  -1400    808
RE DISCCART      600  -1400    819
RE DISCCART      800  -1400    831
RE DISCCART     1000  -1400    835
RE DISCCART     1200  -1400    838
RE DISCCART     1400  -1400    843
RE DISCCART     1600  -1400    845
RE DISCCART    -1600  -1600    858
RE DISCCART    -1400  -1600    855
RE DISCCART    -1200  -1600    851
RE DISCCART    -1000  -1600    835
RE DISCCART     -800  -1600    828
RE DISCCART     -600  -1600    825
RE DISCCART     -400  -1600    825
RE DISCCART     -200  -1600    825
RE DISCCART        0  -1600    800
RE DISCCART      200  -1600    800
RE DISCCART      400  -1600    803
RE DISCCART      600  -1600    812
RE DISCCART      800  -1600    830
RE DISCCART     1000  -1600    837
RE DISCCART     1200  -1600    843
RE DISCCART     1400  -1600    842
RE DISCCART     1600  -1600    838
RE FINISHED
ME STARTING
```

```
ME INPUTFIL C:\RJC\KONDIRAT\MET\MSPSTC91.BIN UNFORM
ME ANEMHGHT    6.100 METERS
ME SURFDATA 14922 1991 SURFNAME
ME UAIRDATA 14926 1991 UAIRNAME
ME STARTEND 1991 1 1 1 1991 12 31 24
ME WINDCATS   1.54   3.09   5.14   8.23   10.80
ME FINISHED
OU STARTING
OU RECTABLE 24 FIRST SECOND
OU PLOTFILE 24 ALL FIRST C:\RJC\KONDIRAT\NEW\ISC\AIS91T.GPH 70
OU PLOTFILE PERIOD ALL C:\RJC\KONDIRAT\NEW\ISC\AIS91TA.GPH 71
OU FINISHED

•••••••••••••••••••••••••••••••••••••
••• SETUP Finishes Successfully •••
•••••••••••••••••••••••••••••••••••••
```

```
*** ISCST2 - VERSION 93109 ***   *** AIS KONDIRATOR TSP EMISSIONS -- 1991 MSP/ST. CLOUD MET DATA      ***      07/07/94
                 ***                                                        ***      23:47:26
                                                                                     PAGE  1
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV         DFAULT

                              ***     MODEL SETUP OPTIONS SUMMARY      ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

**Model Is Setup For Calculation of Average CONCentration Values.

**Model Uses URBAN Dispersion.

**Model Uses Regulatory DEFAULT Options:
        1. Final Plume Rise.
        2. Stack-tip Downwash.
        3. Buoyancy-induced Dispersion.
        4. Use Calms Processing Routine.
        5. Not Use Missing Data Processing Routine.
        6. Default Wind Profile Exponents.
        7. Default Vertical Potential Temperature Gradients.
        8. "Upper Bound" Values for Supersquat Buildings.
        9. No Exponential Decay for URBAN/Non-SO2

**Model Accepts Receptors on ELEV Terrain.

**Model Assumes No FLAGPOLE Receptor Heights.

**Model Calculates  1 Short Term Average(s) of:  24-HR
   and Calculates PERIOD Averages

**This Run Includes:    3 Source(s);      3 Source Group(s); and     986 Receptor(s)

**The Model Assumes A Pollutant Type of:  OTHER

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
       Model Outputs Tables of PERIOD Averages by Receptor
       Model Outputs Tables of Highest Short Term Values by Receptor (RECTABLE Keyword)
       Model Outputs External File(s) of High Values for Plotting (PLOTFILE Keyword)

**NOTE:  The Following Flags May Appear Following CONC Values:  c for Calm Hours
                                                                m for Missing Hours
                                                                b for Both Calm and Missing Hours

**Misc. Inputs:  Anem. Hgt. (m) =     6.10 ;    Decay Coef. =    .0000    ;    Rot. Angle =      .0
             Emission Units = GRAMS/SEC                         ;  Emission Rate Unit Factor =    .10000E+07
             Output Units   = MICROGRAMS/M**3

**Input Runstream File: ais91t.dat                    ;  **Output Print File: ais91t.lst
**Detailed Error/Message File:   AIS91T.ERR
```

```
*** ISCST2 - VERSION 93109 ***   *** AIS KONDIRATOR TSP EMISSIONS -- 1991 MSP/ST. CLOUD MET DATA        ***      07/07/94
              ***                                                    ***     23:47:26
                                                                             PAGE  2
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT


                         *** POINT SOURCE DATA ***

        NUMBER EMISSION RATE                BASE    STACK  STACK   STACK    STACK   BUILDING EMISSION RATE
 SOURCE   PART. (USER UNITS)    X       Y    ELEV.   HEIGHT  TEMP.  EXIT VEL. DIAMETER  EXISTS  SCALAR VARY
  ID      CATS.          (METERS) (METERS) (METERS) (METERS) (DEG.K)  (M/SEC)  (METERS)          BY         .
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 41         0  .76860E+00      .0      .0  246.9   18.89  293.00   18.63    1.07    YES   HROFDY
 42         0  .48900E+00      .0    10.7  246.9   18.29  293.00   11.32     .61    YES   HROFDY
```

```
*** ISCST2 - VERSION 93109 ***    *** AIS KONDIRATOR TSP EMISSIONS -- 1991 MSP/ST. CLOUD MET DATA        ***        07/07/94
                  ***                                                 ***        23:47:26
                                                                                 PAGE  3
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT


                                   *** VOLUME SOURCE DATA ***

         NUMBER EMISSION RATE                    BASE    RELEASE    INIT.     INIT.  EMISSION RATE
 SOURCE    PART. (USER UNITS)     X        Y      ELEV.   HEIGHT      SY        SZ    SCALAR VARY
   ID      CATS.              (METERS) (METERS) (METERS) (METERS) (METERS) (METERS)       BY
-------------------------------------------------------------------

 32          0   .30240E-01    -13.4    -84.1   246.6     3.81    10.00     7.62 HROFDY
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT


                          *** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID                                SOURCE IDs


AREA     32     ,

STACKS   41     , 42     ,

ALL      32     , 41     , 42     ,
```

```
*** ISCST2 - VERSION 93109 ***    *** AIS KONDIRATOR TSP EMISSIONS -- 1991 MSP/ST. CLOUD MET DATA         ***        07/07/94
           ***                                                   ***      23:47:26
                                                                          PAGE  5
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                         *** DIRECTION SPECIFIC BUILDING DIMENSIONS ***


SOURCE ID: 41
 IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK
   1   .0,   .0, 0    2   .0,   .0, 0    3  9.2,  48.8, 0    4 10.0,  17.5, 0    5 10.0,  20.7, 0    6 10.0,  23.3, 0
   7 10.0,  25.1, 0    8 10.0,  26.2, 0    9 10.0,  26.5, 0   10 10.0,  26.2, 0   11 10.0,  25.1, 0   12 10.0,  23.3, 0
  13 10.0,  20.7, 0   14 10.0,  17.5, 0   15 10.0,  13.8, 0   16   .0,   .0, 0   17   .0,   .0, 0   18   .0,   .0, 0
  19   .0,   .0, 0   20   .0,   .0, 0   21  9.2,  48.8, 0   22 10.0,  17.5, 0   23 10.0,  20.7, 0   24 10.0,  23.3, 0
  25 10.0,  25.1, 0   26 10.0,  26.2, 0   27 10.0,  26.5, 0   28 10.0,  26.2, 0   29 10.0,  25.1, 0   30 10.0,  23.3, 0
  31 10.0,  20.7, 0   32 10.0,  17.5, 0   33 10.0;  13.8, 0   34   .0,   .0, 0   35   .0,   .0, 0   36   .0,   .0, 0


SOURCE ID: 42
 IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK  IFV  BH    BW  WAK
   1   .0,   .0, 0    2   .0,   .0, 0    3   .0,   .0, 0    4  9.2,  62.6, 0    5  9.2,  74.4, 0    6  9.2,  84.0, 0
   7 10.0,  25.1, 0    8 10.0,  26.2, 0    9 10.0,  26.5, 0   10 10.0,  26.2, 0   11 10.0,  25.1, 0   12 10.0,  23.3, 0
  13 10.0,  20.7, 0   14 10.0,  17.5, 0   15 10.0,  13.8, 0   16 10.0,   9.6, 0   17   .0,   .0, 0   18   .0;   .0, 0
  19   .0,   .0, 0   20   .0,   .0, 0   21   .0,   .0, 0   22  9.2,  62.6, 0   23  9.2,  74.4, 0   24  9.2,  84.0, 0
  25 10.0,  25.1, 0   26 10.0,  26.2, 0   27 10.0,  26.5, 0   28 10.0,  26.2, 0   29 10.0,  25.1, 0   30 10.0,  23.3, 0
  31 10.0,  20.7, 0   32 10.0,  17.5, 0   33 10.0,  13.8, 0   34 10.0,   9.6, 0   35   .0,   .0, 0   36   .0,   .0, 0
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                * SOURCE EMISSION RATE SCALARS WHICH VARY FOR EACH HOUR OF THE DAY *

   HOUR   SCALAR     HOUR   SCALAR     HOUR   SCALAR     HOUR   SCALAR     HOUR   SCALAR     HOUR   SCALAR
 -------------------------------------------------------------------


 SOURCE ID = 32      ; SOURCE TYPE =   VOLUME :
     1  .00000E+00    2  .00000E+00 ,  3  .00000E+00    4  .00000E+00    5  .00000E+00    6  .00000E+00
     7  .00000E+00    8  .10000E+01    9  .10000E+01   10  .10000E+01   11  .10000E+01   12  .10000E+01
    13  .10000E+01   14  .10000E+01   15  .10000E+01   16  .10000E+01   17  .10000E+01   18  .10000E+01
    19  .00000E+00   20  .00000E+00   21  .00000E+00   22  .00000E+00   23  .00000E+00   24  .00000E+00

 SOURCE ID = 41      ; SOURCE TYPE =   POINT  :
     1  .00000E+00    2  .00000E+00    3  .00000E+00    4  .00000E+00    5  .00000E+00    6  .00000E+00
     7  .00000E+00    8  .10000E+01    9  .10000E+01   10  .10000E+01   11  .10000E+01   12  .10000E+01
    13  .10000E+01   14  .10000E+01   15  .10000E+01   16  .10000E+01   17  .10000E+01   18  .10000E+01
    19  .00000E+00   20  .00000E+00   21  .00000E+00   22  .00000E+00   23  .00000E+00   24  .00000E+00

 SOURCE ID = 42      ; SOURCE TYPE =   POINT  :
     1  .00000E+00    2  .00000E+00    3  .00000E+00    4  .00000E+00    5  .00000E+00    6  .00000E+00
     7  .00000E+00    8  .10000E+01    9  .10000E+01   10  .10000E+01   11  .10000E+01   12  .10000E+01
    13  .10000E+01   14  .10000E+01   15  .10000E+01   16  .10000E+01   17  .10000E+01   18  .10000E+01
    19  .00000E+00   20  .00000E+00   21  .00000E+00   22  .00000E+00   23  .00000E+00   24  .00000E+00
```

```
*** MODELING OPTIONS USED: CONC   URBAN  ELEV        DFAULT

                              *** DISCRETE CARTESIAN RECEPTORS ***
                               (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                           (METERS)

 (    -91.2,   -141.6,    247.5,      .0);     (    -91.2,   -112.5,    247.8,      .0);
 (    -91.2,    -83.5,    248.1,      .0);     (    -91.2,    -54.4,    248.1,      .0);
 (    -91.2,    -25.3,    248.1,      .0);     (    -91.2,      3.7,    248.1,      .0);
 (    -91.2,     32.8,    248.1,      .0);     (    -91.2,     61.9,    248.1,      .0);
 (    -91.2,     91.0,    247.8,      .0);     (    -91.2,    120.0,    247.8,      .0);
 (    -91.2,    149.1,    248.1,      .0);     (    -91.2,    178.2,    248.4,      .0);
 (    -91.2,    207.3,    248.4,      .0);     (    -63.1,    207.3,    248.1,      .0);
 (    -35.1,    207.3,    247.8,      .0);     (     -7.0,    207.3,    247.5,      .0);
 (     21.1,    207.3,    247.2,      .0);     (     22.1,    186.5,    246.6,      .0);
 (     23.2,    165.8,    246.6,      .0);     (     26.5,    145.0,    246.6,      .0);
 (     29.9,    124.1,    246.6,      .0);     (     31.3,    108.5,    246.6,      .0);
 (     31.3,     94.0,    246.6,      .0);     (     28.8,     69.4,    246.6,      .0);
 (     29.0,     47.1,    246.6,      .0);     (     29.2,     24.8,    246.6,      .0);
 (     29.4,      2.4,    246.6,      .0);     (     28.8,     -2.4,    246.6,      .0);
 (     30.9,    -31.8,    246.6,      .0);     (     33.0,    -61.2,    246.6,      .0);
 (     35.2,    -90.6,    246.6,      .0);     (     37.3,   -120.0,    246.6,      .0);
 (     39.4,   -149.3,    246.6,      .0);     (     41.6,   -178.7,    246.6,      .0);
 (     34.8,   -172.4,    246.6,      .0);     (     12.5,   -172.4,    246.6,      .0);
 (     -9.8,   -172.4,    246.6,      .0);     (     -9.8,   -170.7,    246.6,      .0);
 (    -36.9,   -170.7,    246.9,      .0);     (    -64.1,   -170.7,    246.9,      .0);
 (    -91.2,   -170.7,    247.2,      .0);     (  -1600.0,   1600.0,    271.9,      .0);
 (  -1400.0,   1600.0,    271.3,      .0);     (  -1200.0,   1600.0,    268.8,      .0);
 (  -1000.0,   1600.0,    267.6,      .0);     (   -800.0,   1600.0,    266.1,      .0);
 (   -600.0,   1600.0,    260.6,      .0);     (   -400.0,   1600.0,    253.0,      .0);
 (   -200.0,   1600.0,    243.8,      .0);     (       .0,   1600.0,    254.5,      .0);
 (    200.0,   1600.0,    253.3,      .0);     (    400.0,   1600.0,    254.5,      .0);
 (    600.0,   1600.0,    256.0,      .0);     (    800.0,   1600.0,    257.6,      .0);
 (   1000.0,   1600.0,    260.0,      .0);     (   1200.0,   1600.0,    260.0,      .0);
 (   1400.0,   1600.0,    258.8,      .0);     (   1600.0,   1600.0,    258.8,      .0);
 (  -1600.0,   1400.0,    277.7,      .0);     (  -1400.0,   1400.0,    274.0,      .0);
 (  -1200.0,   1400.0,    277.4,      .0);     (  -1000.0,   1400.0,    275.2,      .0);
 (   -800.0,   1400.0,    278.0,      .0);     (   -600.0,   1400.0,    265.2,      .0);
 (   -400.0,   1400.0,    253.0,      .0);     (   -200.0,   1400.0,    243.8,      .0);
 (       .0,   1400.0,    249.9,      .0);     (    200.0,   1400.0,    255.4,      .0);
 (    400.0,   1400.0,    256.0,      .0);     (    600.0,   1400.0,    256.3,      .0);
 (    800.0,   1400.0,    257.3,      .0);     (   1000.0,   1400.0,    259.1,      .0);
 (   1200.0,   1400.0,    259.1,      .0);     (   1400.0,   1400.0,    260.0,      .0);
 (   1600.0,   1400.0,    259.7,      .0);     (  -1600.0,   1200.0,    283.2,      .0);
 (  -1400.0,   1200.0,    281.9,      .0);     (  -1200.0,   1200.0,    278.0,      .0);
 (  -1000.0,   1200.0,    278.0,      .0);     (   -800.0,   1200.0,    284.4,      .0);
 (   -600.0,   1200.0,    271.6,      .0);     (   -400.0,   1200.0,    259.1,      .0);
 (   -200.0,   1200.0,    243.8,      .0);     (       .0,   1200.0,    243.8,      .0);
 (    200.0,   1200.0,    256.0,      .0);     (    400.0,   1200.0,    256.3,      .0);
 (    600.0,   1200.0,    256.6,      .0);     (    800.0,   1200.0,    256.9,      .0);
 (   1000.0,   1200.0,    257.6,      .0);     (   1200.0,   1200.0,    259.1,      .0);
```

```
*** MODELING OPTIONS USED: CONC   URBAN  ELEV        DFAULT

                         *** DISCRETE CARTESIAN RECEPTORS ***
                           (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                      (METERS)

 (   1400.0,   1200.0,    259.7,      .0);     (   1600.0,   1200.0,    259.1,      .0);
 (  -1600.0,   1000.0,    284.4,      .0);     (  -1400.0,   1000.0,    286.8,      .0);
 (  -1200.0,   1000.0,    281.9,      .0);     (  -1000.0,   1000.0,    278.3,      .0);
 (   -900.0,   1000.0,    277.4,      .0);     (   -800.0,   1000.0,    275.8,      .0);
 (   -700.0,   1000.0,    273.4,      .0);     (   -600.0,   1000.0,    271.3,      .0);
 (   -500.0,   1000.0,    265.5,      .0);     (   -400.0,   1000.0,    256.0,      .0);
 (   -300.0,   1000.0,    249.0,      .0);     (   -200.0,   1000.0,    247.2,      .0);
 (   -100.0,   1000.0,    243.8,      .0);     (       .0,   1000.0,    243.8,      .0);
 (    100.0,   1000.0,    245.4,      .0);     (    200.0,   1000.0,    253.0,      .0);
 (    300.0,   1000.0,    253.9,      .0);     (    400.0,   1000.0,    254.8,      .0);
 (    500.0,   1000.0,    255.7,      .0);     (    600.0,   1000.0,    256.3,      .0);
 (    700.0,   1000.0,    256.3,      .0);     (    800.0,   1000.0,    256.6,      .0);
 (    900.0,   1000.0,    257.6,      .0);     (   1000.0,   1000.0,    259.4,      .0);
 (   1200.0,   1000.0,    259.4,      .0);     (   1400.0,   1000.0,    259.4,      .0);
 (   1600.0,   1000.0,    259.7,      .0);     (  -1000.0,    900.0,    277.4,      .0);
 (   -900.0,    900.0,    274.3,      .0);     (   -800.0,    900.0,    274.9,      .0);
 (   -700.0,    900.0,    270.7,      .0);     (   -600.0,    900.0,    268.2,      .0);
 (   -500.0,    900.0,    263.7,      .0);     (   -400.0,    900.0,    256.6,      .0);
 (   -300.0,    900.0,    246.9,      .0);     (   -200.0,    900.0,    246.9,      .0);
 (   -100.0,    900.0,    243.8,      .0);     (       .0,    900.0,    243.8,      .0);
 (    100.0,    900.0,    243.8,      .0);     (    200.0,    900.0,    250.9,      .0);
 (    300.0,    900.0,    251.5,      .0);     (    400.0,    900.0,    251.8,      .0);
 (    500.0,    900.0,    252.4,      .0);     (    600.0,    900.0,    252.7,      .0);
 (    700.0,    900.0,    254.5,      .0);     (    800.0,    900.0,    256.3,      .0);
 (    900.0,    900.0,    257.6,      .0);     (   1000.0,    900.0,    259.1,      .0);
 (  -1600.0,    800.0,    277.1,      .0);     (  -1400.0,    800.0,    283.5,      .0);
 (  -1200.0,    800.0,    277.7,      .0);     (  -1000.0,    800.0,    277.4,      .0);
 (   -900.0,    800.0,    278.0,      .0);     (   -800.0,    800.0,    271.3,      .0);
 (   -700.0,    800.0,    271.3,      .0);     (   -600.0,    800.0,    268.2,      .0);
 (   -500.0,    800.0,    263.7,      .0);     (   -400.0,    800.0,    257.6,      .0);
 (   -300.0,    800.0,    252.4,      .0);     (   -200.0,    800.0,    251.5,      .0);
 (   -100.0,    800.0,    243.8,      .0);     (       .0,    800.0,    243.8,      .0);
 (    100.0,    800.0,    243.8,      .0);     (    200.0,    800.0,    250.5,      .0);
 (    300.0,    800.0,    251.2,      .0);     (    400.0,    800.0,    252.1,      .0);
 (    500.0,    800.0,    253.3,      .0);     (    600.0,    800.0,    256.0,      .0);
 (    700.0,    800.0,    256.0,      .0);     (    800.0,    800.0,    256.9,      .0);
 (    900.0,    800.0,    257.6,      .0);     (   1000.0,    800.0,    259.1,      .0);
 (   1200.0,    800.0,    259.7,      .0);     (   1400.0,    800.0,    258.5,      .0);
 (   1600.0,    800.0,    258.5,      .0);     (  -1000.0,    700.0,    272.8,      .0);
 (   -900.0,    700.0,    271.3,      .0);     (   -800.0,    700.0,    268.2,      .0);
 (   -700.0,    700.0,    270.1,      .0);     (   -600.0,    700.0,    267.3,      .0);
 (   -500.0,    700.0,    262.7,      .0);     (   -400.0,    700.0,    255.7,      .0);
 (   -300.0,    700.0,    252.1,      .0);     (   -200.0,    700.0,    250.9,      .0);
 (   -100.0,    700.0,    243.8,      .0);     (       .0,    700.0,    243.8,      .0);
 (    100.0,    700.0,    243.8,      .0);     (    200.0,    700.0,    249.9,      .0);
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                         *** DISCRETE CARTESIAN RECEPTORS ***
                          (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                     (METERS)

 (    300.0,   700.0,   250.9,    .0);     (    400.0,   700.0,   251.8,    .0);
 (    500.0,   700.0,   253.6,    .0);     (    600.0,   700.0,   252.7,    .0);
 (    700.0,   700.0,   253.0,    .0);     (    800.0,   700.0,   255.7,    .0);
 (    900.0,   700.0,   256.0,    .0);     (   1000.0,   700.0,   258.5,    .0);
 (  -1600.0,   600.0,   274.3,    .0);     (  -1400.0,   600.0,   271.6,    .0);
 (  -1200.0,   600.0,   269.7,    .0);     (  -1000.0,   600.0,   268.2,    .0);
 (   -900.0,   600.0,   267.0,    .0);     (   -800.0,   600.0,   266.1,    .0);
 (   -700.0,   600.0,   265.8,    .0);     (   -600.0,   600.0,   264.6,    .0);
 (   -500.0,   600.0,   262.1,    .0);     (   -400.0,   600.0,   255.4,    .0);
 (   -300.0,   600.0,   249.0,    .0);     (   -200.0,   600.0,   248.1,    .0);
 (   -100.0,   600.0,   245.4,    .0);     (      .0,   600.0,   243.8,    .0);
 (    100.0,   600.0,   243.8,    .0);     (    200.0,   600.0,   243.8,    .0);
 (    300.0,   600.0,   250.2,    .0);     (    400.0,   600.0,   252.1,    .0);
 (    500.0,   600.0,   253.0,    .0);     (    600.0,   600.0,   252.4,    .0);
 (    700.0,   600.0,   253.3,    .0);     (    800.0,   600.0,   255.4,    .0);
 (    900.0,   600.0,   256.0,    .0);     (   1000.0,   600.0,   258.2,    .0);
 (   1200.0,   600.0,   259.7,    .0);     (   1400.0,   600.0,   260.0,    .0);
 (   1600.0,   600.0,   259.1,    .0);     (  -1000.0,   500.0,   270.1,    .0);
 (   -900.0,   500.0,   270.1,    .0);     (   -800.0,   500.0,   266.4,    .0);
 (   -700.0,   500.0,   264.6,    .0);     (   -600.0,   500.0,   264.0,    .0);
 (   -500.0,   500.0,   260.0,    .0);     (   -400.0,   500.0,   254.5,    .0);
 (   -300.0,   500.0,   249.6,    .0);     (   -200.0,   500.0,   248.1,    .0);
 (   -100.0,   500.0,   247.2,    .0);     (      .0,   500.0,   243.8,    .0);
 (    100.0,   500.0,   243.8,    .0);     (    200.0,   500.0,   244.1,    .0);
 (    300.0,   500.0,   250.9,    .0);     (    400.0,   500.0,   252.1,    .0);
 (    500.0,   500.0,   252.4,    .0);     (    600.0,   500.0,   252.4,    .0);
 (    700.0,   500.0,   253.3,    .0);     (    800.0,   500.0,   254.5,    .0);
 (    900.0,   500.0,   256.0,    .0);     (   1000.0,   500.0,   257.9,    .0);
 (  -1600.0,   400.0,   274.6,    .0);     (  -1400.0,   400.0,   274.3,    .0);
 (  -1200.0,   400.0,   272.5,    .0);     (  -1000.0,   400.0,   273.7,    .0);
 (   -900.0,   400.0,   274.3,    .0);     (   -800.0,   400.0,   269.7,    .0);
 (   -700.0,   400.0,   266.1,    .0);     (   -600.0,   400.0,   265.2,    .0);
 (   -500.0,   400.0,   260.6,    .0);     (   -400.0,   400.0,   254.5,    .0);
 (   -300.0,   400.0,   249.6,    .0);     (   -200.0,   400.0,   248.7,    .0);
 (   -100.0,   400.0,   247.5,    .0);     (      .0,   400.0,   243.8,    .0);
 (    100.0,   400.0,   243.8,    .0);     (    200.0,   400.0,   243.8,    .0);
 (    300.0,   400.0,   250.5,    .0);     (    400.0,   400.0,   251.8,    .0);
 (    500.0,   400.0,   252.1,    .0);     (    600.0,   400.0,   252.7,    .0);
 (    700.0,   400.0,   253.6,    .0);     (    800.0,   400.0,   254.5,    .0);
 (    900.0,   400.0,   255.4,    .0);     (   1000.0,   400.0,   256.3,    .0);
 (   1200.0,   400.0,   259.1,    .0);     (   1400.0,   400.0,   259.1,    .0);
 (   1600.0,   400.0,   259.1,    .0);     (  -1000.0,   300.0,   276.8,    .0);
 (   -900.0,   300.0,   275.2,    .0);     (   -800.0,   300.0,   272.2,    .0);
 (   -700.0,   300.0,   266.7,    .0);     (   -600.0,   300.0,   262.7,    .0);
 (   -500.0,   300.0,   258.5,    .0);     (   -400.0,   300.0,   253.6,    .0);
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```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                              *** DISCRETE CARTESIAN RECEPTORS ***
                               (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                          (METERS)

 (  -300.0,    300.0,    249.6,      .0);      (  -270.0,    300.0,    249.3,      .0);
 (  -240.0,    300.0,    249.0,      .0);      (  -210.0,    300.0,    248.7,      .0);
 (  -180.0,    300.0,    248.4,      .0);      (  -150.0,    300.0,    248.1,      .0);
 (  -120.0,    300.0,    247.8,      .0);      (   -90.0,    300.0,    247.5,      .0);
 (   -60.0,    300.0,    247.2,      .0);      (   -30.0,    300.0,    246.9,      .0);
 (      .0,    300.0,    246.9,      .0);      (    30.0,    300.0,    243.8,      .0);
 (    60.0,    300.0,    243.8,      .0);      (    90.0,    300.0,    243.8,      .0);
 (   120.0,    300.0,    243.8,      .0);      (   150.0,    300.0,    243.8,      .0);
 (   180.0,    300.0,    243.8,      .0);      (   210.0,    300.0,    243.8,      .0);
 (   240.0,    300.0,    244.1,      .0);      (   270.0,    300.0,    250.2,      .0);
 (   300.0,    300.0,    250.5,      .0);      (   400.0,    300.0,    251.2,      .0);
 (   500.0,    300.0,    252.1,      .0);      (   600.0,    300.0,    253.0,      .0);
 (   700.0,    300.0,    253.6,      .0);      (   800.0,    300.0,    254.5,      .0);
 (   900.0,    300.0,    255.1,      .0);      (  1000.0,    300.0,    255.7,      .0);
 (  -300.0,    270.0,    249.9,      .0);      (  -270.0,    270.0,    249.6,      .0);
 (  -240.0,    270.0,    249.3,      .0);      (  -210.0,    270.0,    249.0,      .0);
 (  -180.0,    270.0,    248.7,      .0);      (  -150.0,    270.0,    248.4,      .0);
 (  -120.0,    270.0,    248.1,      .0);      (   -90.0,    270.0,    247.8,      .0);
 (   -60.0,    270.0,    247.5,      .0);      (   -30.0,    270.0,    247.2,      .0);
 (      .0,    270.0,    246.9,      .0);      (    30.0,    270.0,    243.8,      .0);
 (    60.0,    270.0,    243.8,      .0);      (    90.0,    270.0,    243.8,      .0);
 (   120.0,    270.0,    243.8,      .0);      (   150.0,    270.0,    243.8,      .0);
 (   180.0,    270.0,    243.8,      .0);      (   210.0,    270.0,    243.8,      .0);
 (   240.0,    270.0,    243.8,      .0);      (   270.0,    270.0,    249.9,      .0);
 (   300.0,    270.0,    250.2,      .0);      (  -300.0,    240.0,    249.9,      .0);
 (  -270.0,    240.0,    249.6,      .0);      (  -240.0,    240.0,    249.3,      .0);
 (  -210.0,    240.0,    249.0,      .0);      (  -180.0,    240.0,    248.7,      .0);
 (  -150.0,    240.0,    248.4,      .0);      (  -120.0,    240.0,    248.1,      .0);
 (   -90.0,    240.0,    247.8,      .0);      (   -60.0,    240.0,    247.5,      .0);
 (   -30.0,    240.0,    247.2,      .0);      (      .0,    240.0,    246.9,      .0);
 (    30.0,    240.0,    243.8,      .0);      (    60.0,    240.0,    243.8,      .0);
 (    90.0,    240.0,    243.8,      .0);      (   120.0,    240.0,    243.8,      .0);
 (   150.0,    240.0,    243.8,      .0);      (   180.0,    240.0,    243.8,      .0);
 (   210.0,    240.0,    243.8,      .0);      (   240.0,    240.0,    243.8,      .0);
 (   270.0,    240.0,    249.9,      .0);      (   300.0,    240.0,    250.2,      .0);
 (  -300.0,    210.0,    249.9,      .0);      (  -270.0,    210.0,    249.6,      .0);
 (  -240.0,    210.0,    249.3,      .0);      (  -210.0,    210.0,    249.0,      .0);
 (  -180.0,    210.0,    248.7,      .0);      (  -150.0,    210.0,    248.4,      .0);
 (  -120.0,    210.0,    248.1,      .0);      (   -90.0,    210.0,    247.8,      .0);
 (   -60.0,    210.0,    247.5,      .0);      (   -30.0,    210.0,    247.2,      .0);
 (      .0,    210.0,    246.9,      .0);      (    30.0,    210.0,    243.8,      .0);
 (    60.0,    210.0,    243.8,      .0);      (    90.0,    210.0,    243.8,      .0);
 (   120.0,    210.0,    243.8,      .0);      (   150.0,    210.0,    243.8,      .0);
 (   180.0,    210.0,    243.8,      .0);      (   210.0,    210.0,    243.8,      .0);
 (   240.0,    210.0,    244.1,      .0);      (   270.0,    210.0,    248.4,      .0);
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```
                         *** DISCRETE CARTESIAN RECEPTORS ***
                          (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                     (METERS)

 (   300.0,   210.0,   250.2,     .0);     ( -1600.0,   200.0,   283.5,     .0);
 ( -1400.0,   200.0,   278.9,     .0);     ( -1200.0,   200.0,   280.1,     .0);
 ( -1000.0,   200.0,   276.1,     .0);     (  -900.0,   200.0,   273.4,     .0);
 (  -800.0,   200.0,   271.3,     .0);     (  -700.0,   200.0,   266.4,     .0);
 (  -600.0,   200.0,   261.5,     .0);     (  -500.0,   200.0,   256.6,     .0);
 (  -400.0,   200.0,   253.3,     .0);     (   400.0,   200.0,   251.5,     .0);
 (   500.0,   200.0,   252.1,     .0);     (   600.0,   200.0,   253.3,     .0);
 (   700.0,   200.0,   253.6,     .0);     (   800.0,   200.0,   254.5,     .0);
 (   900.0,   200.0,   255.1,     .0);     (  1000.0,   200.0,   255.7,     .0);
 (  1200.0,   200.0,   258.2,     .0);     (  1400.0,   200.0,   259.1,     .0);
 (  1600.0,   200.0,   260.0,     .0);     (  -300.0,   180.0,   250.5,     .0);
 (  -270.0,   180.0,   249.6,     .0);     (  -240.0,   180.0,   249.3,     .0);
 (  -210.0,   180.0,   249.0,     .0);     (  -180.0,   180.0,   248.7,     .0);
 (  -150.0,   180.0,   248.4,     .0);     (  -120.0,   180.0,   248.1,     .0);
 (    30.0,   180.0,   243.8,     .0);     (    60.0,   180.0,   243.8,     .0);
 (    90.0,   180.0,   243.8,     .0);     (   120.0,   180.0,   243.8,     .0);
 (   150.0,   180.0,   243.8,     .0);     (   180.0,   180.0,   243.8,     .0);
 (   210.0,   180.0,   243.8,     .0);     (   240.0,   180.0,   244.1,     .0);
 (   270.0,   180.0,   246.9,     .0);     (   300.0,   180.0,   250.2,     .0);
 (  -300.0,   150.0,   249.9,     .0);     (  -270.0,   150.0,   249.6,     .0);
 (  -240.0,   150.0,   249.3,     .0);     (  -210.0,   150.0,   249.0,     .0);
 (  -180.0,   150.0,   248.7,     .0);     (  -150.0,   150.0,   248.4,     .0);
 (  -120.0,   150.0,   248.1,     .0);     (    30.0,   150.0,   243.8,     .0);
 (    60.0,   150.0,   243.8,     .0);     (    90.0,   150.0,   243.8,     .0);
 (   120.0,   150.0,   243.8,     .0);     (   150.0,   150.0,   243.8,     .0);
 (   180.0,   150.0,   243.8,     .0);     (   210.0,   150.0,   243.8,     .0);
 (   240.0,   150.0,   243.8,     .0);     (   270.0,   150.0,   246.9,     .0);
 (   300.0,   150.0,   250.2,     .0);     (  -300.0,   120.0,   249.9,     .0);
 (  -270.0,   120.0,   249.6,     .0);     (  -240.0,   120.0,   249.3,     .0);
 (  -210.0,   120.0,   249.0,     .0);     (  -180.0,   120.0,   248.7,     .0);
 (  -150.0,   120.0,   248.4,     .0);     (  -120.0,   120.0,   248.1,     .0);
 (    60.0,   120.0,   243.8,     .0);     (    90.0,   120.0,   243.8,     .0);
 (   120.0,   120.0,   243.8,     .0);     (   150.0,   120.0,   243.8,     .0);
 (   180.0,   120.0,   243.8,     .0);     (   210.0,   120.0,   243.8,     .0);
 (   240.0,   120.0,   243.8,     .0);     (   270.0,   120.0,   246.9,     .0);
 (   300.0,   120.0,   250.2,     .0);     ( -1000.0,   100.0,   276.8,     .0);
 (  -900.0,   100.0,   271.9,     .0);     (  -800.0,   100.0,   271.0,     .0);
 (  -700.0,   100.0,   266.1,     .0);     (  -600.0,   100.0,   260.6,     .0);
 (  -500.0,   100.0,   255.7,     .0);     (  -400.0,   100.0,   253.3,     .0);
 (   400.0,   100.0,   251.2,     .0);     (   500.0,   100.0,   252.1,     .0);
 (   600.0,   100.0,   253.0,     .0);     (   700.0,   100.0,   253.6,     .0);
 (   800.0,   100.0,   254.5,     .0);     (   900.0,   100.0,   255.1,     .0);
 (  1000.0,   100.0,   255.7,     .0);     (  -300.0,    90.0,   249.9,     .0);
 (  -270.0,    90.0,   249.6,     .0);     (  -240.0,    90.0,   249.3,     .0);
 (  -210.0,    90.0,   249.0,     .0);     (  -180.0,    90.0,   248.7,     .0);
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```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                         *** DISCRETE CARTESIAN RECEPTORS ***
                          (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                    (METERS)

 (   -150.0,     90.0,    248.4,      .0);      (   -120.0,     90.0,    248.1,      .0);
 (     60.0,     90.0,    243.8,      .0);      (     90.0,     90.0,    243.8,      .0);
 (    120.0,     90.0,    243.8,      .0);      (    150.0,     90.0,    243.8,      .0);
 (    180.0,     90.0,    243.8,      .0);      (    210.0,     90.0,    243.8,      .0);
 (    240.0,     90.0,    244.1,      .0);      (    270.0,     90.0,    246.9,      .0);
 (    300.0,     90.0,    250.2,      .0);      (   -300.0,     60.0,    249.9,      .0);
 (   -270.0,     60.0,    249.6,      .0);      (   -240.0,     60.0,    249.3,      .0);
 (   -210.0,     60.0,    249.0,      .0);      (   -180.0,     60.0,    248.7,      .0);
 (   -150.0,     60.0,    248.4,      .0);      (   -120.0,     60.0,    248.1,      .0);
 (     30.0,     60.0,    243.8,      .0);      (     60.0,     60.0,    243.8,      .0);
 (     90.0,     60.0,    243.8,      .0);      (    120.0,     60.0,    243.8,      .0);
 (    150.0,     60.0,    243.8,      .0);      (    180.0,     60.0,    243.8,      .0);
 (    210.0,     60.0,    243.8,      .0);      (    240.0,     60.0,    244.1,      .0);
 (    270.0,     60.0,    246.9,      .0);      (    300.0,     60.0,    250.2,      .0);
 (   -300.0,     30.0,    249.9,      .0);      (   -270.0,     30.0,    249.6,      .0);
 (   -240.0,     30.0,    249.3,      .0);      (   -210.0,     30.0,    249.0,      .0);
 (   -180.0,     30.0,    248.7,      .0);      (   -150.0,     30.0,    248.4,      .0);
 (   -120.0,     30.0,    248.1,      .0);      (     30.0,     30.0,    243.8,      .0);
 (     60.0,     30.0,    243.8,      .0);      (     90.0,     30.0,    243.8,      .0);
 (    120.0,     30.0,    243.8,      .0);      (    150.0,     30.0,    243.8,      .0);
 (    180.0,     30.0,    243.8,      .0);      (    210.0,     30.0,    243.8,      .0);
 (    240.0,     30.0,    244.1,      .0);      (    270.0,     30.0,    246.9,      .0);
 (    300.0,     30.0,    250.2,      .0);      (  -1600.0,       .0,    278.9,      .0);
 (  -1400.0,       .0,    277.4,      .0);      (  -1200.0,       .0,    274.3,      .0);
 (  -1000.0,       .0,    272.8,      .0);      (   -900.0,       .0,    270.4,      .0);
 (   -800.0,       .0,    268.2,      .0);      (   -700.0,       .0,    263.3,      .0);
 (   -600.0,       .0,    259.4,      .0);      (   -500.0,       .0,    255.4,      .0);
 (   -400.0,       .0,    253.6,      .0);      (   -300.0,       .0,    249.9,      .0);
 (   -270.0,       .0,    249.6,      .0);      (   -240.0,       .0,    249.3,      .0);
 (   -210.0,       .0,    249.0,      .0);      (   -180.0,       .0,    248.7,      .0);
 (   -150.0,       .0,    248.4,      .0);      (   -120.0,       .0,    248.1,      .0);
 (     60.0,       .0,    243.8,      .0);      (     90.0,       .0,    243.8,      .0);
 (    120.0,       .0,    243.8,      .0);      (    150.0,       .0,    243.8,      .0);
 (    180.0,       .0,    243.8,      .0);      (    210.0,       .0,    243.8,      .0);
 (    240.0,       .0,    244.1,      .0);      (    270.0,       .0,    249.9,      .0);
 (    300.0,       .0,    250.2,      .0);      (    400.0,       .0,    251.2,      .0);
 (    500.0,       .0,    252.1,      .0);      (    600.0,       .0,    253.3,      .0);
 (    700.0,       .0,    253.6,      .0);      (    800.0,       .0,    254.5,      .0);
 (    900.0,       .0,    255.4,      .0);      (   1000.0,       .0,    255.4,      .0);
 (   1200.0,       .0,    257.9,      .0);      (   1400.0,       .0,    259.7,      .0);
 (   1600.0,       .0,    259.4,      .0);      (   -300.0,    -30.0,    250.2,      .0);
 (   -270.0,    -30.0,    249.6,      .0);      (   -240.0,    -30.0,    249.3,      .0);
 (   -210.0,    -30.0,    249.0,      .0);      (   -180.0,    -30.0,    248.7,      .0);
 (   -150.0,    -30.0,    248.4,      .0);      (   -120.0,    -30.0,    248.1,      .0);
 (     60.0,    -30.0,    243.8,      .0);      (     90.0,    -30.0,    243.8,      .0);
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV       DFAULT


                        *** DISCRETE CARTESIAN RECEPTORS ***
                         (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                    (METERS)

 (   120.0,   -30.0,   243.8,    .0);     (   150.0,   -30.0,   243.8,    .0);
 (   180.0,   -30.0,   243.8,    .0);     (   210.0,   -30.0,   243.8,    .0);
 (   240.0,   -30.0,   244.1,    .0);     (   270.0,   -30.0,   248.4,    .0);
 (   300.0,   -30.0,   250.2,    .0);     (  -300.0,   -60.0,   249.9,    .0);
 (  -270.0,   -60.0,   249.6,    .0);     (  -240.0,   -60.0,   249.3,    .0);
 (  -210.0,   -60.0,   249.0,    .0);     (  -180.0,   -60.0,   248.7,    .0);
 (  -150.0,   -60.0,   248.4,    .0);     (  -120.0,   -60.0,   248.1,    .0);
 (    60.0,   -60.0,   243.8,    .0);     (    90.0,   -60.0,   243.8,    .0);
 (   120.0,   -60.0,   243.8,    .0);     (   150.0,   -60.0,   243.8,    .0);
 (   180.0,   -60.0,   243.8,    .0);     (   210.0,   -60.0,   243.8,    .0);
 (   240.0,   -60.0,   244.1,    .0);     (   270.0,   -60.0,   245.4,    .0);
 (   300.0,   -60.0,   249.9,    .0);     (  -300.0,   -90.0,   249.9,    .0);
 (  -270.0,   -90.0,   249.6,    .0);     (  -240.0,   -90.0,   249.3,    .0);
 (  -210.0,   -90.0,   249.0,    .0);     (  -180.0,   -90.0,   248.7,    .0);
 (  -150.0,   -90.0,   248.4,    .0);     (  -120.0,   -90.0,   248.1,    .0);
 (    60.0,   -90.0,   243.8,    .0);     (    90.0,   -90.0,   243.8,    .0);
 (   120.0,   -90.0,   243.8,    .0);     (   150.0,   -90.0,   243.8,    .0);
 (   180.0,   -90.0,   243.8,    .0);     (   210.0,   -90.0,   243.8,    .0);
 (   240.0,   -90.0,   244.1,    .0);     (   270.0,   -90.0,   246.9,    .0);
 (   300.0,   -90.0,   250.2,    .0);     ( -1000.0,  -100.0,   271.3,    .0);
 (  -900.0,  -100.0,   267.6,    .0);     (  -800.0,  -100.0,   266.7,    .0);
 (  -700.0,  -100.0,   262.7,    .0);     (  -600.0,  -100.0,   259.1,    .0);
 (  -500.0,  -100.0,   255.1,    .0);     (  -400.0,  -100.0,   253.6,    .0);
 (   400.0,  -100.0,   251.2,    .0);     (   500.0,  -100.0,   252.1,    .0);
 (   600.0,  -100.0,   253.3,    .0);     (   700.0,  -100.0,   253.9,    .0);
 (   800.0,  -100.0,   254.8,    .0);     (   900.0,  -100.0,   255.4,    .0);
 (  1000.0,  -100.0,   256.0,    .0);     (  -300.0,  -120.0,   249.6,    .0);
 (  -270.0,  -120.0,   249.3,    .0);     (  -240.0,  -120.0,   249.0,    .0);
 (  -210.0,  -120.0,   248.7,    .0);     (  -180.0,  -120.0,   248.4,    .0);
 (  -150.0,  -120.0,   248.1,    .0);     (  -120.0,  -120.0,   247.8,    .0);
 (    60.0,  -120.0,   243.8,    .0);     (    90.0,  -120.0,   243.8,    .0);
 (   120.0,  -120.0,   243.8,    .0);     (   150.0,  -120.0,   243.8,    .0);
 (   180.0,  -120.0,   243.8,    .0);     (   210.0,  -120.0,   243.8,    .0);
 (   240.0,  -120.0,   244.1,    .0);     (   270.0,  -120.0,   248.4,    .0);
 (   300.0,  -120.0,   250.2,    .0);     (  -300.0,  -150.0,   249.9,    .0);
 (  -270.0,  -150.0,   249.6,    .0);     (  -240.0,  -150.0,   249.3,    .0);
 (  -210.0,  -150.0,   249.0,    .0);     (  -180.0,  -150.0,   248.7,    .0);
 (  -150.0,  -150.0,   248.4,    .0);     (  -120.0,  -150.0,   248.1,    .0);
 (    60.0,  -150.0,   243.8,    .0);     (    90.0,  -150.0,   243.8,    .0);
 (   120.0,  -150.0,   243.8,    .0);     (   150.0,  -150.0,   243.8,    .0);
 (   180.0,  -150.0,   243.8,    .0);     (   210.0,  -150.0,   243.8,    .0);
 (   240.0,  -150.0,   244.1,    .0);     (   270.0,  -150.0,   248.4,    .0);
 (   300.0,  -150.0,   250.2,    .0);     (  -300.0,  -180.0,   249.9,    .0);
 (  -270.0,  -180.0,   249.6,    .0);     (  -240.0,  -180.0,   249.3,    .0);
 (  -210.0,  -180.0,   249.0,    .0);     (  -180.0,  -180.0,   248.7,    .0);
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                              *** DISCRETE CARTESIAN RECEPTORS ***
                               (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                          (METERS)

 (  -150.0,   -180.0,    248.4,      .0);       (  -120.0,   -180.0,    248.1,      .0);
 (   -90.0,   -180.0,    247.8,      .0);       (   -60.0,   -180.0,    247.5,      .0);
 (   -30.0,   -180.0,    247.2,      .0);       (      .0,   -180.0,    246.9,      .0);
 (    30.0,   -180.0,    246.9,      .0);       (    60.0,   -180.0,    243.8,      .0);
 (    90.0,   -180.0,    243.6,      .0);       (   120.0,   -180.0,    243.8,      .0);
 (   150.0,   -180.0,    243.8,      .0);       (   180.0,   -180.0,    243.8,      .0);
 (   210.0,   -180.0,    243.8,      .0);       (   240.0,   -180.0,    244.1,      .0);
 (   270.0,   -180.0,    248.4,      .0);       (   300.0,   -180.0,    250.2,      .0);
 ( -1600.0,   -200.0,    277.4,      .0);       ( -1400.0,   -200.0,    275.2,      .0);
 ( -1200.0,   -200.0,    273.4,      .0);       ( -1000.0,   -200.0,    271.3,      .0);
 (  -900.0,   -200.0,    268.2,      .0);       (  -800.0,   -200.0,    270.4,      .0);
 (  -700.0,   -200.0,    263.0,      .0);       (  -600.0,   -200.0,    259.1,      .0);
 (  -500.0,   -200.0,    255.4,      .0);       (  -400.0,   -200.0,    253.6,      .0);
 (   400.0,   -200.0,    250.9,      .0);       (   500.0,   -200.0,    252.1,      .0);
 (   600.0,   -200.0,    253.0,      .0);       (   700.0,   -200.0,    253.9,      .0);
 (   800.0,   -200.0,    254.8,      .0);       (   900.0,   -200.0,    255.7,      .0);
 (  1000.0,   -200.0,    256.0,      .0);       (  1200.0,   -200.0,    259.4,      .0);
 (  1400.0,   -200.0,    259.7,      .0);       (  1600.0,   -200.0,    258.8,      .0);
 (  -300.0,   -210.0,    250.9,      .0);       (  -270.0,   -210.0,    250.2,      .0);
 (  -240.0,   -210.0,    249.9,      .0);       (  -210.0,   -210.0,    249.6,      .0);
 (  -180.0,   -210.0,    249.3,      .0);       (  -150.0,   -210.0,    248.7,      .0);
 (  -120.0,   -210.0,    248.4,      .0);       (   -90.0,   -210.0,    247.8,      .0);
 (   -60.0,   -210.0,    247.5,      .0);       (   -30.0,   -210.0,    247.2,      .0);
 (      .0,   -210.0,    246.9,      .0);       (    30.0,   -210.0,    245.4,      .0);
 (    60.0,   -210.0,    243.8,      .0);       (    90.0,   -210.0,    243.8,      .0);
 (   120.0,   -210.0,    243.8,      .0);       (   150.0,   -210.0,    243.8,      .0);
 (   180.0,   -210.0,    243.8,      .0);       (   210.0,   -210.0,    243.8,      .0);
 (   240.0,   -210.0,    243.8,      .0);       (   270.0,   -210.0,    244.1,      .0);
 (   300.0,   -210.0,    250.2,      .0);       (  -300.0,   -240.0,    250.5,      .0);
 (  -270.0,   -240.0,    250.2,      .0);       (  -240.0,   -240.0,    249.9,      .0);
 (  -210.0,   -240.0,    249.6,      .0);       (  -180.0,   -240.0,    249.0,      .0);
 (  -150.0,   -240.0,    248.7,      .0);       (  -120.0,   -240.0,    248.4,      .0);
 (   -90.0,   -240.0,    248.1,      .0);       (   -60.0,   -240.0,    247.8,      .0);
 (   -30.0,   -240.0,    247.5,      .0);       (      .0,   -240.0,    247.2,      .0);
 (    30.0,   -240.0,    245.4,      .0);       (    60.0,   -240.0,    243.8,      .0);
 (    90.0,   -240.0,    243.8,      .0);       (   120.0,   -240.0,    243.8,      .0);
 (   150.0,   -240.0,    243.8,      .0);       (   180.0,   -240.0,    243.8,      .0);
 (   210.0,   -240.0,    243.8,      .0);       (   240.0,   -240.0,    243.8,      .0);
 (   270.0,   -240.0,    244.1,      .0);       (   300.0,   -240.0,    250.2,      .0);
 (  -300.0,   -270.0,    250.5,      .0);       (  -270.0,   -270.0,    250.2,      .0);
 (  -240.0,   -270.0,    249.9,      .0);       (  -210.0,   -270.0,    249.6,      .0);
 (  -180.0,   -270.0,    249.3,      .0);       (  -150.0,   -270.0,    248.7,      .0);
 (  -120.0,   -270.0,    248.4,      .0);       (   -90.0,   -270.0,    248.1,      .0);
 (   -60.0,   -270.0,    247.8,      .0);       (   -30.0,   -270.0,    247.5,      .0);
 (      .0,   -270.0,    247.2,      .0);       (    30.0,   -270.0,    244.1,      .0);
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV       DFAULT

                         *** DISCRETE CARTESIAN RECEPTORS ***
                         (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                     (METERS)

 (     60.0,   -270.0,   243.8,      .0);      (     90.0,   -270.0,   243.8,      .0);
 (    120.0,   -270.0,   243.8,      .0);      (    150.0,   -270.0,   243.8,      .0);
 (    180.0,   -270.0,   243.8,      .0);      (    210.0,   -270.0,   243.8,      .0);
 (    240.0,   -270.0,   243.8,      .0);      (    270.0,   -270.0,   244.1,      .0);
 (    300.0,   -270.0,   250.2,      .0);      (  -1000.0,   -300.0,   272.8,      .0);
 (   -900.0,   -300.0,   274.6,      .0);      (   -800.0,   -300.0,   277.4,      .0);
 (   -700.0,   -300.0,   261.2,      .0);      (   -600.0,   -300.0,   256.3,      .0);
 (   -500.0,   -300.0,   254.5,      .0);      (   -400.0,   -300.0,   253.0,      .0);
 (   -300.0,   -300.0,   251.8,      .0);      (   -270.0,   -300.0,   250.9,      .0);
 (   -240.0,   -300.0,   250.2,      .0);      (   -210.0,   -300.0,   249.6,      .0);
 (   -180.0,   -300.0,   249.3,      .0);      (   -150.0,   -300.0,   249.0,      .0);
 (   -120.0,   -300.0,   248.7,      .0);      (    -90.0,   -300.0,   248.4,      .0);
 (    -60.0,   -300.0,   248.1,      .0);      (    -30.0,   -300.0,   247.8,      .0);
 (       .0,   -300.0,   247.5,      .0);      (     30.0,   -300.0,   245.4,      .0);
 (     60.0,   -300.0,   243.8,      .0);      (     90.0,   -300.0,   243.8,      .0);
 (    120.0,   -300.0,   243.8,      .0);      (    150.0,   -300.0,   243.8,      .0);
 (    180.0,   -300.0,   243.8,      .0);      (    210.0,   -300.0,   243.8,      .0);
 (    240.0,   -300.0,   243.8,      .0);      (    270.0,   -300.0,   244.1,      .0);
 (    300.0,   -300.0,   251.5,      .0);      (    400.0,   -300.0,   252.7,      .0);
 (    500.0,   -300.0,   251.8,      .0);      (    600.0,   -300.0,   253.3,      .0);
 (    700.0,   -300.0,   253.9,      .0);      (    800.0,   -300.0,   254.5,      .0);
 (    900.0,   -300.0,   255.4,      .0);      (   1000.0,   -300.0,   256.6,      .0);
 (  -1600.0,   -400.0,   272.8,      .0);      (  -1400.0,   -400.0,   273.1,      .0);
 (  -1200.0,   -400.0,   277.4,      .0);      (  -1000.0,   -400.0,   274.3,      .0);
 (   -900.0,   -400.0,   269.7,      .0);      (   -800.0,   -400.0,   264.6,      .0);
 (   -700.0,   -400.0,   260.0,      .0);      (   -600.0,   -400.0,   255.7,      .0);
 (   -500.0,   -400.0,   253.3,      .0);      (   -400.0,   -400.0,   252.4,      .0);
 (   -300.0,   -400.0,   251.8,      .0);      (   -200.0,   -400.0,   250.9,      .0);
 (   -100.0,   -400.0,   249.6,      .0);      (       .0,   -400.0,   250.2,      .0);
 (    100.0,   -400.0,   243.8,      .0);      (    200.0,   -400.0,   243.8,      .0);
 (    300.0,   -400.0,   253.0,      .0);      (    400.0,   -400.0,   253.0,      .0);
 (    500.0,   -400.0,   251.5,      .0);      (    600.0,   -400.0,   253.0,      .0);
 (    700.0,   -400.0,   253.9,      .0);      (    800.0,   -400.0,   254.8,      .0);
 (    900.0,   -400.0,   255.4,      .0);      (   1000.0,   -400.0,   256.3,      .0);
 (   1200.0,   -400.0,   258.8,      .0);      (   1400.0,   -400.0,   260.0,      .0);
 (   1600.0,   -400.0,   258.8,      .0);      (  -1000.0,   -500.0,   273.1,      .0);
 (   -900.0,   -500.0,   268.5,      .0);      (   -800.0,   -500.0,   263.0,      .0);
 (   -700.0,   -500.0,   258.5,      .0);      (   -600.0,   -500.0,   255.4,      .0);
 (   -500.0,   -500.0,   253.6,      .0);      (   -400.0,   -500.0,   252.7,      .0);
 (   -300.0,   -500.0,   252.1,      .0);      (   -200.0,   -500.0,   251.5,      .0);
 (   -100.0,   -500.0,   250.9,      .0);      (       .0,   -500.0,   250.2,      .0);
 (    100.0,   -500.0,   243.8,      .0);      (    200.0,   -500.0,   243.8,      .0);
 (    300.0,   -500.0,   253.0,      .0);      (    400.0,   -500.0,   253.0,      .0);
 (    500.0,   -500.0,   251.2,      .0);      (    600.0,   -500.0,   252.7,      .0);
 (    700.0,   -500.0,   253.6,      .0);      (    800.0,   -500.0,   254.5,      .0);
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```
*** MODELING OPTIONS USED: CONC   URBAN  ELEV        DFAULT

                              *** DISCRETE CARTESIAN RECEPTORS ***
                              (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                          (METERS)

 (    900.0,   -500.0,    255.4,      .0);      (   1000.0,   -500.0,    256.0,      .0);
 (  -1600.0,   -600.0,    271.3,      .0);      (  -1400.0,   -600.0,    268.5,      .0);
 (  -1200.0,   -600.0,    271.3,      .0);      (  -1000.0,   -600.0,    271.6,      .0);
 (   -900.0,   -600.0,    266.7,      .0);      (   -800.0,   -600.0,    261.2,      .0);
 (   -700.0,   -600.0,    257.6,      .0);      (   -600.0,   -600.0,    255.1,      .0);
 (   -500.0,   -600.0,    253.6,      .0);      (   -400.0,   -600.0,    252.4,      .0);
 (   -300.0,   -600.0,    251.8,      .0);      (   -200.0,   -600.0,    251.2,      .0);
 (   -100.0,   -600.0,    250.5,      .0);      (       .0,   -600.0,    249.9,      .0);
 (    100.0,   -600.0,    243.8,      .0);      (    200.0,   -600.0,    243.8,      .0);
 (    300.0,   -600.0,    250.5,      .0);      (    400.0,   -600.0,    253.3,      .0);
 (    500.0,   -600.0,    252.4,      .0);      (    600.0,   -600.0,    252.1,      .0);
 (    700.0,   -600.0,    252.7,      .0);      (    800.0,   -600.0,    253.9,      .0);
 (    900.0,   -600.0,    255.7,      .0);      (   1000.0,   -600.0,    256.0,      .0);
 (   1200.0,   -600.0,    259.4,      .0);      (   1400.0,   -600.0,    258.5,      .0);
 (   1600.0,   -600.0,    258.5,      .0);      (  -1000.0,   -700.0,    268.8,      .0);
 (   -900.0,   -700.0,    263.3,      .0);      (   -800.0,   -700.0,    260.0,      .0);
 (   -700.0,   -700.0,    255.4,      .0);      (   -600.0,   -700.0,    253.0,      .0);
 (   -500.0,   -700.0,    252.4,      .0);      (   -400.0,   -700.0,    251.8,      .0);
 (   -300.0,   -700.0,    251.5,      .0);      (   -200.0,   -700.0,    251.2,      .0);
 (   -100.0,   -700.0,    250.9,      .0);      (       .0,   -700.0,    250.2,      .0);
 (    100.0,   -700.0,    243.8,      .0);      (    200.0,   -700.0,    243.8,      .0);
 (    300.0,   -700.0,    250.2,      .0);      (    400.0,   -700.0,    252.7,      .0);
 (    500.0,   -700.0,    253.6,      .0);      (    600.0,   -700.0,    253.6,      .0);
 (    700.0,   -700.0,    252.7,      .0);      (    800.0,   -700.0,    253.3,      .0);
 (    900.0,   -700.0,    254.5,      .0);      (   1000.0,   -700.0,    255.7,      .0);
 (  -1600.0,   -800.0,    274.9,      .0);      (  -1400.0,   -800.0,    269.4,      .0);
 (  -1200.0,   -800.0,    263.3,      .0);      (  -1000.0,   -800.0,    264.9,      .0);
 (   -900.0,   -800.0,    261.8,      .0);      (   -800.0,   -800.0,    259.1,      .0);
 (   -700.0,   -800.0,    254.8,      .0);      (   -600.0,   -800.0,    252.7,      .0);
 (   -500.0,   -800.0,    252.1,      .0);      (   -400.0,   -800.0,    251.5,      .0);
 (   -300.0,   -800.0,    251.2,      .0);      (   -200.0,   -800.0,    250.9,      .0);
 (   -100.0,   -800.0,    250.5,      .0);      (       .0,   -800.0,    244.1,      .0);
 (    100.0,   -800.0,    243.8,      .0);      (    200.0,   -800.0,    243.8,      .0);
 (    300.0,   -800.0,    249.0,      .0);      (    400.0,   -800.0,    253.0,      .0);
 (    500.0,   -800.0,    253.0,      .0);      (    600.0,   -800.0,    253.9,      .0);
 (    700.0,   -800.0,    253.0,      .0);      (    800.0,   -800.0,    253.0,      .0);
 (    900.0,   -800.0,    256.0,      .0);      (   1000.0,   -800.0,    255.1,      .0);
 (   1200.0,   -800.0,    257.6,      .0);      (   1400.0,   -800.0,    259.1,      .0);
 (   1600.0,   -800.0,    257.6,      .0);      (  -1000.0,   -900.0,    262.1,      .0);
 (   -900.0,   -900.0,    260.0,      .0);      (   -800.0,   -900.0,    256.0,      .0);
 (   -700.0,   -900.0,    254.8,      .0);      (   -600.0,   -900.0,    253.6,      .0);
 (   -500.0,   -900.0,    253.3,      .0);      (   -400.0,   -900.0,    253.3,      .0);
 (   -300.0,   -900.0,    252.4,      .0);      (   -200.0,   -900.0,    251.5,      .0);
 (   -100.0,   -900.0,    250.5,      .0);      (       .0,   -900.0,    243.8,      .0);
 (    100.0,   -900.0,    243.8,      .0);      (    200.0,   -900.0,    243.8,      .0);
```

```
                         *** DISCRETE CARTESIAN RECEPTORS ***
                          (X-COORD, Y-COORD, ZELEV, ZFLAG)
                                     (METERS)

 (    300.0,   -900.0,   248.4,     .0);     (    400.0,   -900.0,   250.9,     .0);
 (    500.0,   -900.0,   251.5,     .0);     (    600.0,   -900.0,   253.3,     .0);
 (    700.0,   -900.0,   253.0,     .0);     (    800.0,   -900.0,   253.0,     .0);
 (    900.0,   -900.0,   253.9,     .0);     (   1000.0,   -900.0,   254.8,     .0);
 (  -1600.0,  -1000.0,   266.1,     .0);     (  -1400.0,  -1000.0,   264.9,     .0);
 (  -1200.0,  -1000.0,   261.8,     .0);     (  -1000.0,  -1000.0,   260.0,     .0);
 (   -900.0,  -1000.0,   259.1,     .0);     (   -800.0,  -1000.0,   255.4,     .0);
 (   -700.0,  -1000.0,   254.8,     .0);     (   -600.0,  -1000.0,   254.5,     .0);
 (   -500.0,  -1000.0,   253.9,     .0);     (   -400.0,  -1000.0,   253.3,     .0);
 (   -300.0,  -1000.0,   252.4,     .0);     (   -200.0,  -1000.0,   251.5,     .0);
 (   -100.0,  -1000.0,   250.5,     .0);     (       .0,  -1000.0,   243.8,     .0);
 (    100.0,  -1000.0,   243.8,     .0);     (    200.0,  -1000.0,   243.8,     .0);
 (    300.0,  -1000.0,   248.4,     .0);     (    400.0,  -1000.0,   249.3,     .0);
 (    500.0,  -1000.0,   251.2,     .0);     (    600.0,  -1000.0,   253.0,     .0);
 (    700.0,  -1000.0,   251.5,     .0);     (    800.0,  -1000.0,   252.7,     .0);
 (    900.0,  -1000.0,   253.9,     .0);     (   1000.0,  -1000.0,   254.5,     .0);
 (   1200.0,  -1000.0,   256.0,     .0);     (   1400.0,  -1000.0,   259.1,     .0);
 (   1600.0,  -1000.0,   257.6,     .0);     (  -1600.0,  -1200.0,   262.1,     .0);
 (  -1400.0,  -1200.0,   261.5,     .0);     (  -1200.0,  -1200.0,   260.6,     .0);
 (  -1000.0,  -1200.0,   258.8,     .0);     (   -800.0,  -1200.0,   254.2,     .0);
 (   -600.0,  -1200.0,   252.1,     .0);     (   -400.0,  -1200.0,   251.2,     .0);
 (   -200.0,  -1200.0,   250.5,     .0);     (       .0,  -1200.0,   243.8,     .0);
 (    200.0,  -1200.0,   245.4,     .0);     (    400.0,  -1200.0,   247.5,     .0);
 (    600.0,  -1200.0,   251.2,     .0);     (    800.0,  -1200.0,   253.9,     .0);
 (   1000.0,  -1200.0,   254.5,     .0);     (   1200.0,  -1200.0,   255.7,     .0);
 (   1400.0,  -1200.0,   258.2,     .0);     (   1600.0,  -1200.0,   258.2,     .0);
 (  -1600.0,  -1400.0,   261.8,     .0);     (  -1400.0,  -1400.0,   260.6,     .0);
 (  -1200.0,  -1400.0,   259.4,     .0);     (  -1000.0,  -1400.0,   256.0,     .0);
 (   -800.0,  -1400.0,   252.7,     .0);     (   -600.0,  -1400.0,   252.1,     .0);
 (   -400.0,  -1400.0,   251.2,     .0);     (   -200.0,  -1400.0,   250.5,     .0);
 (       .0,  -1400.0,   243.8,     .0);     (    200.0,  -1400.0,   244.4,     .0);
 (    400.0,  -1400.0,   246.3,     .0);     (    600.0,  -1400.0,   249.6,     .0);
 (    800.0,  -1400.0,   253.3,     .0);     (   1000.0,  -1400.0,   254.5,     .0);
 (   1200.0,  -1400.0,   255.4,     .0);     (   1400.0,  -1400.0,   256.9,     .0);
 (   1600.0,  -1400.0,   257.6,     .0);     (  -1600.0,  -1600.0,   261.5,     .0);
 (  -1400.0,  -1600.0,   260.6,     .0);     (  -1200.0,  -1600.0,   259.4,     .0);
 (  -1000.0,  -1600.0,   254.5,     .0);     (   -800.0,  -1600.0,   252.4,     .0);
 (   -600.0,  -1600.0,   251.5,     .0);     (   -400.0,  -1600.0,   251.5,     .0);
 (   -200.0,  -1600.0,   251.5,     .0);     (       .0,  -1600.0,   243.8,     .0);
 (    200.0,  -1600.0,   243.8,     .0);     (    400.0,  -1600.0,   244.8,     .0);
 (    600.0,  -1600.0,   247.5,     .0);     (    800.0,  -1600.0,   253.0,     .0);
 (   1000.0,  -1600.0,   255.1,     .0);     (   1200.0,  -1600.0,   256.9,     .0);
 (   1400.0,  -1600.0,   256.6,     .0);     (   1600.0,  -1600.0,   255.4,     .0);
```

```
*** MODELING OPTIONS USED: CONC  URBAN  ELEV        DFAULT

                    * SOURCE-RECEPTOR COMBINATIONS LESS THAN 1.0 METER OR 3*ZLB *
                       IN DISTANCE. CALCULATIONS MAY NOT BE PERFORMED.


                    SOURCE       - - RECEPTOR LOCATION - -       DISTANCE
                     ID       XR (METERS)  YR (METERS)        (METERS)
                    - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

                    41              29.4        2.4          29.50
                    41              28.8       -2.4          28.90
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV        DFAULT

                         *** METEOROLOGICAL DAYS SELECTED FOR PROCESSING ***
                                        (1=YES; 0=NO)

       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 1111111111 1111111111 1111111111 1111111111
       1111111111 111111

            METEOROLOGICAL DATA PROCESSED BETWEEN START DATE:  91  1  1  1
                                        AND END DATE:  91 12 31 24

     NOTE:  METEOROLOGICAL DATA ACTUALLY PROCESSED WILL ALSO DEPEND ON WHAT IS INCLUDED IN THE DATA FILE.


                   *** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES ***
                                       (METERS/SEC)

                         1.54,   3.09,   5.14,   8.23,   10.80,

                               *** WIND PROFILE EXPONENTS ***


     STABILITY                        WIND SPEED CATEGORY
     CATEGORY       1            2            3            4            5            6
       A      .15000E+00   .15000E+00   .15000E+00   .15000E+00   .15000E+00   .15000E+00
       B      .15000E+00   .15000E+00   .15000E+00   .15000E+00   .15000E+00   .15000E+00
       C      .20000E+00   .20000E+00   .20000E+00   .20000E+00   .20000E+00   .20000E+00
       D      .25000E+00   .25000E+00   .25000E+00   .25000E+00   .25000E+00   .25000E+00
       E      .30000E+00   .30000E+00   .30000E+00   .30000E+00   .30000E+00   .30000E+00
       F      .30000E+00   .30000E+00   .30000E+00   .30000E+00   .30000E+00   .30000E+00

                    *** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
                              (DEGREES KELVIN PER METER)


     STABILITY                        WIND SPEED CATEGORY
     CATEGORY       1            2            3            4            5            6
       A      .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00
       B      .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00
       C      .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00
       D      .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00
       E      .20000E-01   .20000E-01   .20000E-01   .20000E-01   .20000E-01   .20000E-01
       F      .35000E-01   .35000E-01   .35000E-01   .35000E-01   .35000E-01   .35000E-01
```

```
*** MODELING OPTIONS USED:  CONC   URBAN  ELEV         DFAULT


               *** THE FIRST  24 HOURS OF METEOROLOGICAL DATA ***

        FILE: C:\RJC\KONDIRAT\MET\MSPSTC91.BIN          FORMAT: UNFORM
        SURFACE STATION NO.:  14922               UPPER AIR STATION NO.:  14926
                  NAME: SURFNAME                               NAME: UAIRNAME
                  YEAR:  1991                              YEAR:  1991

                            FLOW   SPEED  TEMP    STAB   MIXING HEIGHT (M)
        YEAR  MONTH  DAY  HOUR   VECTOR  (M/S)   (K)   CLASS   RURAL    URBAN
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

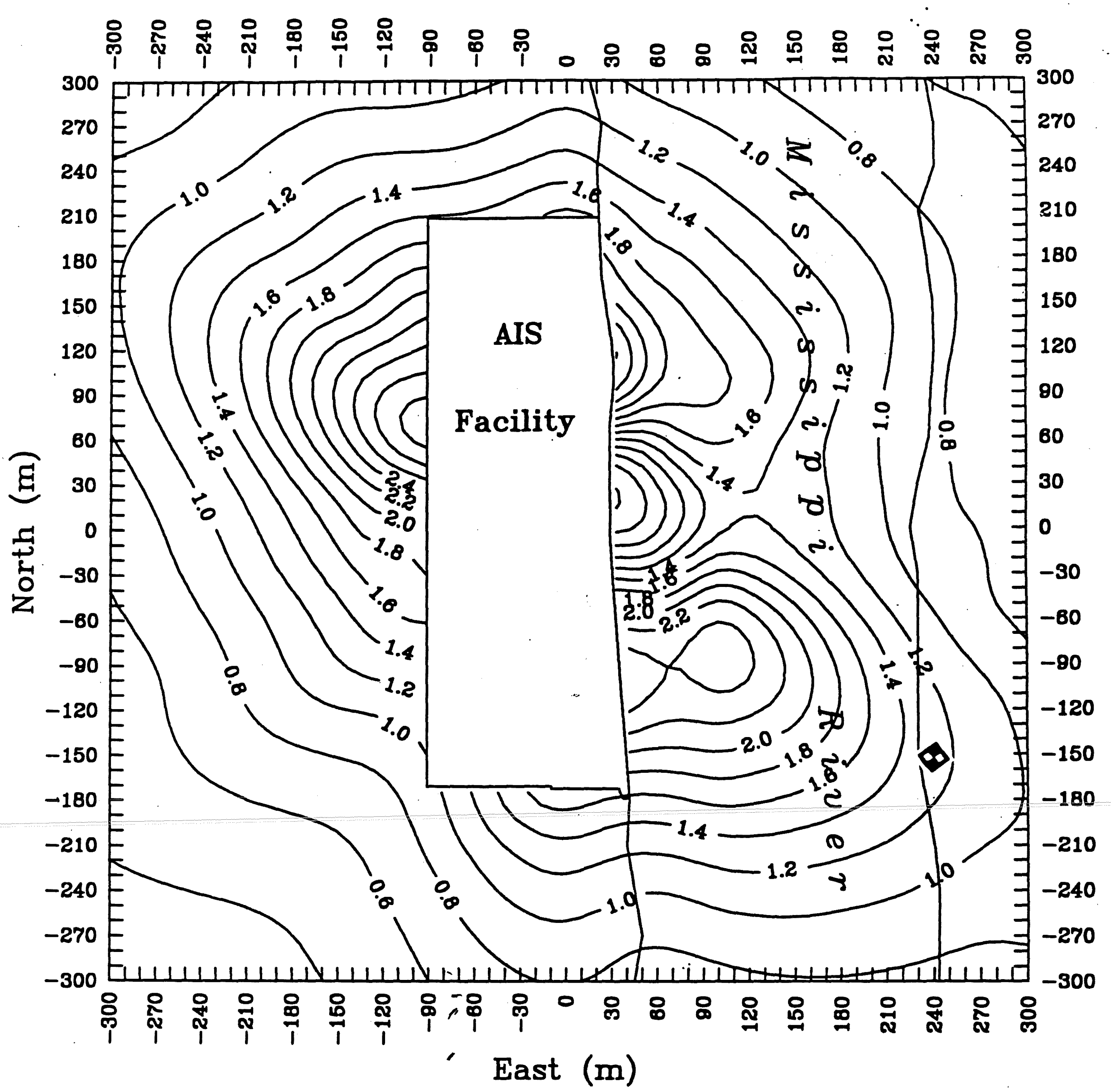

         91     1     1     1      1.0   3.09   263.7     5      336.7    219.0
         91     1     1     2      8.0   4.63   262.6     5      331.0    219.0
         91     1     1     3      4.0   4.63   262.6     5      325.2    219.0
         91     1     1     4      3.0   5.14   262.6     5      319.5    219.0
         91     1     1     5    353.0   5.66   262.6     4      313.7    313.7
         91     1     1     6    352.0   4.63   262.0     5      308.0    219.0
         91     1     1     7     15.0   6.17   263.1     4      302.2    302.2
         91     1     1     8     13.0   4.63   263.7     4      296.5    296.5
         91     1     1     9     47.0   4.63   264.8     4      290.7    290.7
         91     1     1    10     81.0   5.14   265.9     4      285.0    285.0
         91     1     1    11     94.0   4.12   267.6     4      279.2    279.2
         91     1     1    12    136.0   4.63   268.1     4      273.5    273.5
         91     1     1    13    133.0   5.14   268.7     4      267.7    267.7
         91     1     1    14    129.0   6.69   269.3     4      262.0    262.0
         91     1     1    15    132.0   7.72   268.1     4      262.0    262.0
         91     1     1    16    134.0   8.23   265.9     4      262.0    262.0
         91     1     1    17    121.0   8.75   264.8     4      267.2    267.2
         91     1     1    18    137.0   8.75   262.6     4      280.0    280.0
         91     1     1    19    134.0   8.75   260.9     4      292.9    292.9
         91     1     1    20    127.0   7.20   259.3     4      305.7    305.7
         91     1     1    21    140.0   6.69   258.1     4      318.6    318.6
         91     1     1    22    152.0   8.23   256.5     4      331.4    331.4
         91     1     1    23    150.0   7.20   255.9     4      344.3    344.3
         91     1     1    24    130.0   6.69   254.8     4      357.1    357.1


*** NOTES:  STABILITY CLASS 1=A, 2=B, 3=C, 4=D, 5=E AND 6=F.
        FLOW VECTOR IS DIRECTION TOWARD WHICH WIND IS BLOWING.
```

APPENDIX A.3

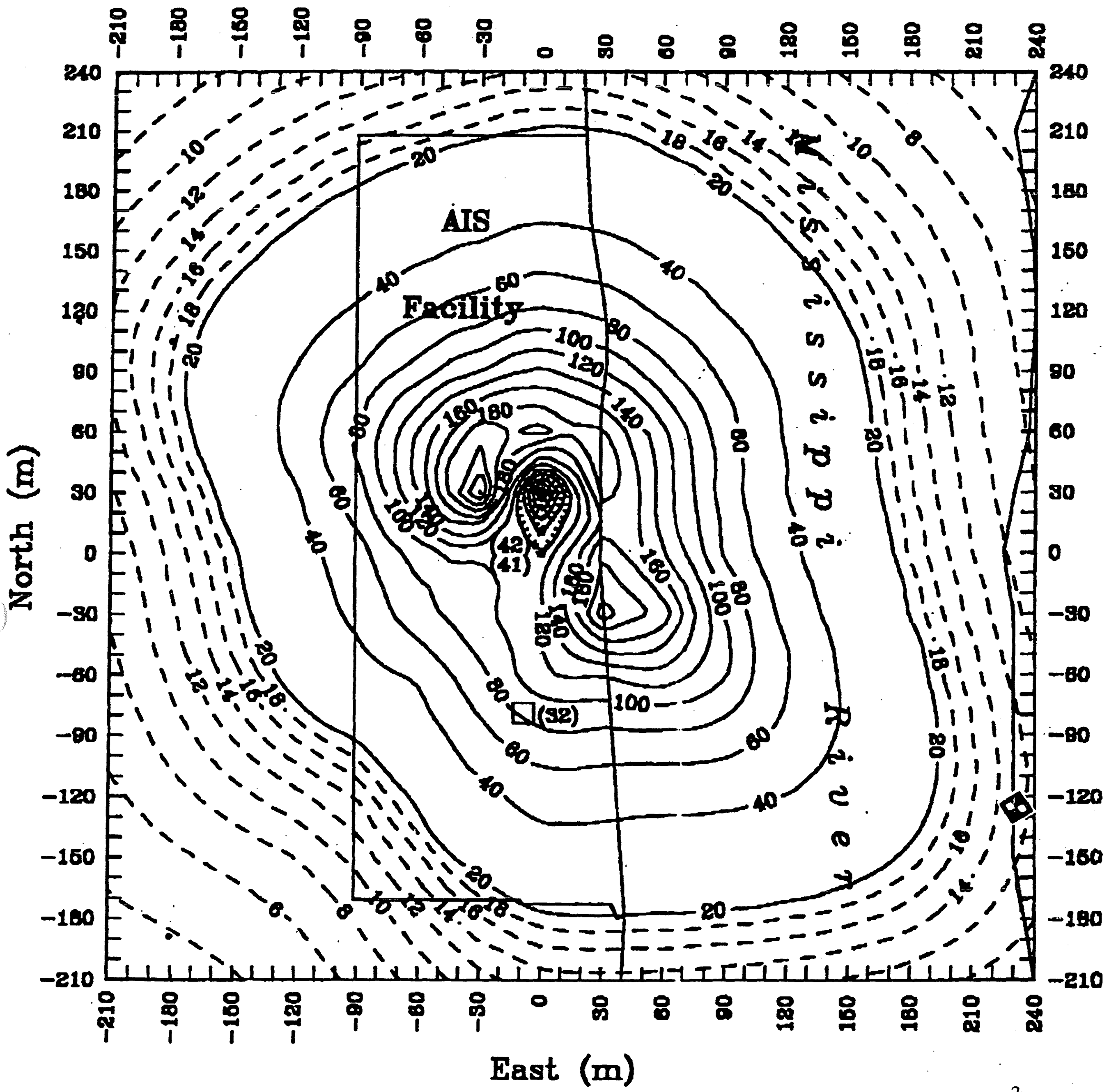
LONG-TERM TSP AIR QUALITY AND DEPOSITION MODELING RESULTS

Source: Barr Engineering



◆ Indicated Isopleth (1.3 ug/m^3) was used as the risk assessment air concentration (Table 4-3).

Maximum Annual Modeled TSP Concentrations ($\mu g/m^3$) from Kondirator Project Sources Only 1987 through 1991 Meteorological Data.



◆ Indicated Isopleth (13.0 g/m^2) was used as the risk assessment particulate deposition rate (Table 4-3).

Average Annual Modeled Particulate Deposition (g/m^2) from American Iron and Supply Sources, 1987 through 1991 Meteorological Data.

APPENDIX B

MODELS USED TO ESTIMATE EXPOSURE CONCENTRATIONS

TABLE OF CONTENTS

B. PROCEDURES AND EQUATIONS USED TO ESTIMATE EXPOSURE CONCENTRATIONS IN ENVIRONMENTAL MEDIA

The purpose of this Appendix is to provide the information necessary to allow the reader of this document to reproduce all of the calculations which ICF KE performed to derive estimated COC concentrations in environmental media (air, surface soil, surface water, sediment, and fish tissue). The following sections of this appendix discuss each step in the analysis, presenting all the equations used, all of the input data, and the results of all calculations. A flow chart of the organization of this appendix is shown in Figure B-1. The estimated COC concentrations are used to estimate human health and ecological risks. The equations and calculations used to estimate human and ecological risks are presented in Appendix C.

B.1 IDENTIFICATION OF CONSTITUENTS OF CONCERN (COCS)

The first step in the analysis was to identify substances that could be emitted from the Kondirator during its operation. The approach taken was to identify all of the scrap metals which might be processed by the Kondirator and identify all of the constituent elements of each of the feed materials. Information on the identities of the scrap metals and on the composition of each of the feed metals was provided by the Applicant (Draft EAW 1994). The sources of the elemental composition data for the scrap metals were Material Safety Data Sheets (MSDSs) provided by Resource Consultants (1991). The feed materials identified by the Applicant and the elements identified as being present in one or more of the feed materials are shown in Table B-1. No organic substances were identified as COCs because the feed material to the Kondirator will consist predominantly of uncoated materials. The process of identifying COCs is described in more detail in Sections 2.1 and 2.2 of the Human Health Risk Assessment (HHRA) and the Ecological Risk Assessment (ERA).

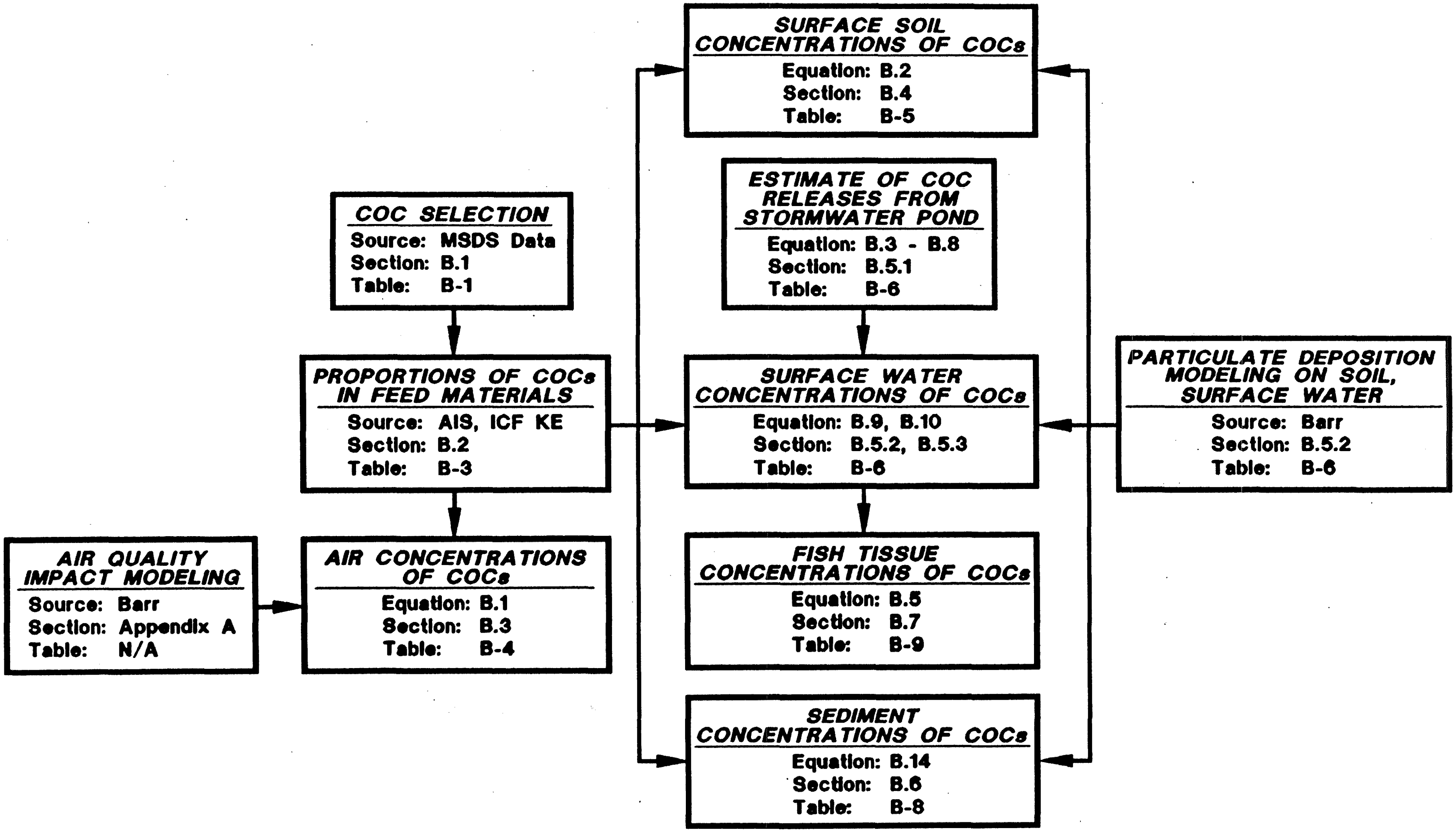
B.2 ESTIMATION OF THE PROPORTIONS (CONCENTRATIONS) OF METALS IN KONDIRATOR FEED MATERIALS

The next step in the analysis was to estimate the concentrations (proportions) of the individual COCs in the scrap metals that would be processed in the Kondirator. This was done by first estimating the approximate proportions of each of the individual scrap metals (carbon steel, stainless steel, aluminum, galvanized steel, cast iron, iron, brass, and copper) that would be processed over time. Then, the estimated proportions of the various scrap metals in the Kondirator feed materials and the estimated proportions of the COC elements in each scrap metal are combined to give a weighted-average concentration (proportion) of each COC in the feed materials.

The Applicant and ICF Kaiser both developed estimates of the proportions of the individual scrap metals that would be processed in the Kondirator, as shown in the Table B-2. The ICF KE estimates differ from those of the Applicant in that slightly larger proportion of the scrap metals going to the Kondirator were assumed to be nonferrous than was assumed by the applicant. ICF KE also assumed that the input to the Kondirator would consist of 99% scrap metal, while the Applicant assumed that 5% of the feed materials would be soil and other nonmetallic materials. Since the nonferrous metals generally tend to have higher concentrations of the more toxic COC elements than carbon steel and other ferrous scrap, ICF KE's approach resulted in a slightly more

FIGURE B-1

KONDIRATOR SCREENING LEVEL RISK ASSESSMENT FLOW CHART OF APPENDIX B CONCENTRATION CALCULATIONS



ICF KAISER

KONDIFC1.DWG
05/10/95

TABLE B-1 SELECTION OF CONSTITUENTS OF CONCERN

Potential Feed Material	PRESENT IN FEED MATERIAL? (a)								SELECTED AS COC? (b)
	Carbon Steel	Stainless Steel	Aluminum	Galvanized Steel	Cast Iron	Iron	Brass	Copper	
ALUMINUM	yes	yes	yes	yes	yes	yes	yes	yes	yes
ANTIMONY	no	no	yes	no	no	no	yes	no	yes
ARSENIC	yes	yes	no	yes	yes	yes	yes	yes	yes
BERYLLIUM	no	no	yes	no	no	no	no	yes	yes
BORON	yes	yes	no	yes	yes	yes	no	no	yes
CADMIUM	no	no	yes	no	no	no	no	yes	yes
CALCIUM	yes	yes	no	yes	yes	yes	no	no	yes
CARBON	yes	yes	no	yes	yes	yes	no	no	yes
CHROMIUM	yes	yes	yes	yes	yes	yes	no	yes	yes
COBALT	yes	yes	yes	yes	yes	yes	no	yes	yes
COPPER	yes	yes	yes	yes	yes	yes	yes	yes	yes
IRON	yes	yes	yes	yes	yes	yes	yes	yes	yes
LEAD	yes	yes	yes	yes	yes	yes	yes	yes	yes
LITHIUM	no	no	yes	no	no	no	no	no	yes
MAGNESIUM	no	no	yes	no	no	no	yes	no	yes
MANGANESE	yes	yes	yes	yes	no	no	no	no	yes
MERCURY	no	no	no	no	no	no	no	no	no
MOLYBDENUM	yes	yes	no	yes	yes	yes	no	no	yes
NICKEL	yes	yes	yes	yes	yes	yes	yes	yes	yes
NIOBIUM	yes	yes	no	yes	yes	yes	no	no	yes
SILICON	yes	yes	yes	yes	yes	yes	yes	no	yes
SILVER	no	no	yes	no	no	no	yes	yes	yes
TIN	yes	yes	yes	yes	yes	yes	yes	yes	yes
TITANIUM	yes	yes	no	yes	yes	yes	no	no	yes
TUNGSTEN	no	yes	no	no	no	no	no	no	yes
VANADIUM	yes	yes	yes	yes	yes	yes	no	no	yes
ZINC	no	no	yes	yes	no	no	yes	no	yes
ZIRCONIUM	yes	yes	no	yes	yes	yes	no	no	yes

(a) Source of elemental composition data is the MSDS data (Resource Consultants 1991). "No" indicates maximum concentration = 0.0%. "Yes" indicates maximum concentration > 0.0%.

(b) Elemental composition evaluated as shown in Table B-3 and Table 2-1.

Table B-2. Assumed Proportions of Individual Scrap Metals in Kondirator Feed Materials

Feed Material	Assumed by Applicant (%)	Assumed by ICF KE (%)
Carbon steel	90	90
Stainless steel	2	2
Aluminum	2	2
Galvanized steel	([a])	1
Cast iron	([a])	1
Iron	([a])	1
Brass	([a])	1
Copper	([a])	1
Nonmetallic	5	0

[a] Applicant assumed that the sum of these 5 metals would be 1% of the total waste feed (Draft EAW).

conservative estimate of risks for these metals than would have been obtained using the Applicant's estimates of feed material composition.

ICF KE developed two separate estimates of the elemental concentrations, using the MSDS data supplied by the Applicant. First, a simple weighted-average set of metal concentrations was calculated by multiplying the proportions of the individual scrap metals in the feed by the maximum concentrations of the individual metals in each feed metal, and totaling the results to give an estimate of the concentration of each metal weighted across all of the Kondirator feed materials. The results of this calculation are shown in Table B-3 in the column labeled "Weighted Average Composition". The total of the estimated metals concentrations (at the bottom of this column) exceeds 100 percent because the MSDS data gives ranges of metals compostions for many of the elements, and the sums of these maximum elemental concentrations in the individual scrap metals also exceed 100 percent.

The second estimate of concentrations was derived by ICF Kaiser using professional judgement and a qualitative assessment of the toxicity of the various elements. This estimate was derived by first "normalizing" the total of the estimated metals concentrations to 99 percent (the total proportion of scrap metal in the feed materials) and then adjusting the composition of some of the more toxic metals upward slightly so that the total elemental composition was again equal to 100 percent. The upward adjustments in the concentrations of the individual metals were all less than 7 percent. The results of these calculations are referred to as "Toxicity Adjusted Composition" shown in the second column of Table 3-2.

Finally, the concentrations of the individual metals used in the estimation of exposures were derived by taking the greater of the Weighted Average Concentrations or the Toxicity Adjusted Concentrations. This approach provided a small additional degree of conservatism in the estimates of risk and exposure. The values are shown in the last column of Table B-3.

B.3 ESTIMATION OF COC CONCENTRATIONS IN AIR

The concentrations of the individual COCs in air that could result from Kondirator operations were calculated by multiplying the estimated Total Suspended Particulate (TSP) concentration at the receptor location by the proportions of the individual COCs in the feed materials:

$$C_a = \mathrm{TSP} \times \mathrm{COC} \qquad \text{Eq. (B–1)}$$

where

C_a = long-term concentration of COC in air ($\mu g/m^3$),
TSP = estimated TSP concentration (1.3 $\mu g/m^3$), and
COC = estimated average proportion of COC in feed materials (unitless, Table B–3).

The TSP concentrations were estimated by Barr Engineering, using the USEPA ISCST2 model (Barr 1994). The input and output data from the ISCST2 model are summarized in Appendix A. The assumptions used in the air quality modeling are discussed in detail in Section 4.1. The maximum annual average (TSP) concentration from the 5-year modeling period for the residential receptor location at the eastern shoreline of the Mississippi (UTM 230E, -120N) were used to estimate COC exposure concentrations. The estimated maximum annual average TSP concentration at this location due to the Kondirator emissions was 1.3 $\mu g/m^3$. The estimated proportions of COCs in the Kondirator feed materials are shown in Table B–3. The resulting estimates of long-term air

TABLE B-3. PROPORTIONS OF CONSTITUENTS OF CONCERN IN FEED MATERIALS USED IN THE RISK ASSESSMENT

Constituents of Concern	Estimated Feed Metal Elemental Composition (a)		
	Weighted Average Concentration (a)	Toxicity Adjusted Concentration (b)	COC Concentration Used in Risk Assessment (c)
Aluminum	1.69%	1.76%	1.76%
Antimony	0.03%	0.02%	0.03%
Arsenic	0.12%	0.11%	0.12%
Beryllium	0.05%	0.05%	0.05%
Boron	0.10%	0.10%	0.10%
Cadmium	0.08%	0.08%	0.08%
Calcium	0.10%	0.09%	0.10%
Carbon	1.97%	1.84%	1.97%
Chromium	0.67%	0.71%	0.71%
Cobalt	0.42%	0.44%	0.44%
Copper	1.84%	1.42%	1.84%
Iron	90.17%	87.10%	90.17%
Lead	0.38%	0.37%	0.38%
Lithium	0.35%	0.08%	0.08%
Magnesium	0.35%	0.22%	0.35%
Manganese	1.96%	2.04%	2.04%
Molybdenum	0.29%	0.31%	0.31%
Nickel	0.94%	0.96%	0.96%
Niobium	0.10%	0.09%	0.10%
Silicon	0.71%	0.60%	0.71%
Silver	0.05%	0.04%	0.05%
Tin	0.59%	0.59%	0.59%
Titanium	0.10%	0.09%	0.10%
Tungsten	0.40%	0.39%	0.40%
Vanadium	0.21%	0.22%	0.22%
Zinc	0.74%	0.19%	0.74%
Zirconium	0.10%	0.09%	0.10%
Total Metals	104.22%	100.00%	104.46%

(a) Source of elemental composition data is the MSDS data (Resource Consultants 1991). The proportions of individual scrap metals which are used to estimate these weighted averages are shown in Table B-2.

(b) Concentrations are derived by "normalizing" total metals concentrations to be equal to 99 percent, then adjusting concentrations of several COCs, based on toxicity, so that total metals concentration is 100 percent

(c) Values used for risk assessment are equal to the greater of the estimates in the previous two columns.

TABLE B-4. ANNUAL AVERAGE AIR CONCENTRATIONS CALCULATED AT THE SHORELINE

Constituents of Concern	Feed Material Composition (a)	Annual Average Air Concentration of COCs at the Shoreline (ug/m^3) (b)
Aluminum	1.76%	0.023
Antimony	0.03%	0.0004
Arsenic	0.12%	0.0015
Beryllium	0.05%	0.0007
Boron	0.10%	0.0012
Cadmium	0.08%	0.0010
Calcium	0.10%	0.0012
Carbon	1.97%	0.026
Chromium	0.71%	0.009
Cobalt	0.44%	0.006
Copper	1.84%	0.024
Iron	90.17%	1.17
Lead	0.38%	0.0049
Lithium	0.08%	0.0010
Magnesium	0.35%	0.0046
Manganese	2.04%	0.027
Molybdenum	0.31%	0.0040
Nickel	0.96%	0.012
Niobium	0.10%	0.0012
Silicon	0.71%	0.009
Silver	0.05%	0.0007
Tin	0.59%	0.008
Titanium	0.10%	0.0012
Tungsten	0.40%	0.005
Vanadium	0.22%	0.003
Zinc	0.74%	0.010
Zirconium	0.10%	0.0012

(a) From Table B-3.

(b) Calculated by multiplying the annual average TSP concentration of 1.3 ug/m^3 at the eastern shoreline residential receptor (UTM coordinates 230E, -120N) by the elemental metal composition, equation B-1. The TSP value was estimated by Barr Engineering (See Appendix A).

concentrations of the individual COCs are shown in the last column of Table B–4. These values are used as inputs to the inhalation pathway exposure and risk equations in Appendix C.2 and Table C-2.

B.4 ESTIMATION OF COC CONCENTRATIONS IN SURFACE SOIL

The increases in COC concentrations in residential area soil that could be associated with Kondirator emissions were estimated to evaluate risks associated with the soil ingestion pathway in the HHRA and ERA. The annual deposition of particulate onto soil was calculated by multiplying the estimated maximum annual TSP deposition rate at the residential receptor by the proportion of each COC in the feed materials. The long-term TSP deposition rate for the eastern shoreline residential receptor location was calculated by Barr Engineering (1994) to be 13.0 g/m^2-year.

The increase in COC concentration in soil that could be associated with the Kondirator emissions was calculated as follows:

$$C_{soil}=\frac{(DEP)(COC)(FL)(x)}{(SD)(BD)} \qquad \text{Eq. (B–2)}$$

where

C_{soil} = concentration of chemical in soil after 15 years (mg/kg),
DEP = estimated TSP deposition rate (13.0 g/m^2-yr),
COC = estimated proportion of COC in particulate (unitless, Table B–3),
FL = facility life (15 years),
x = conversion factor (1,000 mg/g),
SD = soil depth of mixing (0.02 m for HHRA, 0.15 m for ERA), and
BD = soil bulk density (1.17×10^3 kg/m^3).

This equation gives the estimated concentration of the various COCs in the top two centimeters of soil at the end of the assumed 15-year Kondirator operating life, assuming no runoff, leaching, or other mechanisms act to reduce the COC concentrations. A soil mixing depth of 2 centimeters was used in the HHRA per MDH comments; a mixing depth of 15 cm was used in the ERA to reflect exposures to terrestrial organisms in the root zone. The estimated concentrations of COCs in surface soils after 15 years are given in Table B–5 and are used to calculate soil ingestion exposures, as shown in Appendix C.3.

B.5 ESTIMATION OF COC CONCENTRATIONS IN SURFACE WATER

B.5.1 Concentrations Due to Stormwater Pond Discharge

The long-term average concentration of each COC in the Mississippi River adjacent to the site was calculated as part of the surface water pathway exposure analysis. The equation used to estimate the concentration of COC in the surface water due to releases from the stormwater pond is (USEPA 1991)

TABLE B–5

Estimated Surface Soil COC Concentrations Resulting from Emissions from the Proposed Kondirator Facility

Constituent	Feed Materials Composition (a)	Maximum Estimated Surface Soil Concentration 2.0 cm Mixing Depth (mg/kg) (b)	Maximum Estimated Surface Soil Concentration 15 cm Mixing Depth (mg/kg) (b)
ALUMINUM	1.76%	146.67	19.56
ANTIMONY	0.03%	2.50	0.33
ARSENIC	0.12%	9.58	1.28
BERYLLIUM	0.05%	4.17	0.56
BORON	0.10%	7.92	1.06
CADMIUM	0.08%	6.67	0.89
CALCIUM	0.10%	7.92	1.06
CARBON	1.97%	164.17	21.89
CHROMIUM	0.71%	59.17	7.89
COBALT	0.44%	36.67	4.89
COPPER	1.84%	153.58	20.48
IRON	90.17%	7,514	1001.89
LEAD	0.38%	31.25	4.17
LITHIUM	0.08%	6.67	0.89
MAGNESIUM	0.35%	29.17	3.89
MANGANESE	2.04%	170.00	22.67
MOLYBDENUM	0.31%	25.83	3.44
NICKEL	0.96%	80.00	10.67
NIOBIUM	0.10%	7.92	1.06
SILICON	0.71%	59.25	7.90
SILVER	0.05%	4.17	0.56
TIN	0.59%	49.17	6.56
TITANIUM	0.10%	7.92	1.06
TUNGSTEN	0.40%	33.33	4.44
VANADIUM	0.22%	18.33	2.44
ZINC	0.74%	61.67	8.22
ZIRCONIUM	0.10%	7.92	1.06

(a) Feed metal composition from Table B–3.

(b) Calculated as shown in equation B–2. TSP depostion at the eastern shoreline receptor (13.0 g/m^2–year) was estimated by Barr Engineering (see Appendix A). Mixing depth of 2 cm was used for exposure estimation in the HHRA.

(c) Calculated as described in note (b), but using a mixing depth of 15 cm; these concentrations are used for exposure assessment in the ERA.

$$c_s = \frac{c_{so} q_s W}{q_u \left(\frac{\pi D_y L_m}{u} \right)^{0.5}} \qquad \text{Eq. (B-3)}$$

where

c_s = metal-specific concentration in the Mississippi River at complete mixing (μg/l),
c_{so} = metal-specific concentration in stormwater outflow (μg/l),
q_s = outflow rate from pond (0.05 m^3/sec, Draft EAW 1994), continuous,
W = width of river (213 m),
q_u = flow rate in the river (91 m^3/sec),
D_y = lateral dispersion coefficient (1.3 m^2/sec),
L_m = mixing distance (1,707 m), and
u = stream velocity (0.11 m/sec).

The estimated discharge rate from the detention pond (q_s) was provided by the Applicant. The flow rate in the river used to estimate COC concentrations is the 7-day low-flow rate reported by the USGS monitoring station in Anoka, MN, in 1993 (USGS 1993).

The concentrations of COCs in the stormwater pond outflow (C_{so}) is calculated by

$$c_{so} = \frac{1}{\beta} \frac{M_{coc} * x}{12 \text{ hours} * q_s} \qquad \text{Eq. (B-4)}$$

where

c_{so} = concentration in stormwater outflow (mg/l)
M_{coc} = mass of chemical discharged from the wet detention pond (g),
q_s = outflow rate from wet detention pond (0.05 m^3/sec),
β = constant (3600 sec/1 hour), and
x = conversion factor (1 m^3/g × 1,000 μg/l).

The masses of COCs in the stormwater outflow (M_{coc}) are calculated by multiplying the total mass of particulate entering the pond per storm event, 117.4 lb = 53.4 kg, as estimated by the Applicant (Draft EAW 1994) by the concentrations of COCs in the Kondirator feed materials (Table B-3) and by the retention efficiency of the pond:

$$M_{coc} = (RO)(COC)(1-r) \qquad \text{Eq. (B-5)}$$

where

RO = total TSP in runoff from design storm event (117.4 lb = 53.4 kg, Draft EAW),
COC = estimated proportion of COC in particulate (unitless), and
r = retention efficiency of the stormwater pond (0.92, unitless, Draft EAW).

The calculated concentrations of COCs in the stormwater outflow, C_{so}, are shown in the second numerical column of Table B-6.

The mixing distance (L_m in equation B-3, 1707 meters) was calculated as follows (USEPA 1991):

$$L_m = \frac{mW^2u}{D_y} \qquad \text{Eq. (B-6)}$$

where

L_m = distance to complete mixing (m),
m = constant (0.4 for a side discharge with <5% concentration gradient),
W = stream width (m),
u = average stream velocity (m/sec), and
D_y = lateral dispersion coefficient (m^2/sec).

The stream width used in equation 5 was 213 meters (Draft EAW 1994), and the average stream velocity (0.11 m/sec) was calculated assuming a rectangular channel with an average depth of 3.7 meters, and the 7-day low-flow volume of 91 m^3/sec.

The lateral dispersion coefficient (D_y) was calculated as

$$D_y = 0.6du^* \pm 50\% \qquad \text{Eq. (B-7)}$$

where

D_y = lateral dispersion coefficient (m^2/sec),
d = stream depth (m), and
u^* = shear velocity (m/sec).

The shear velocity in equation (B-7) was estimated to be

$$u^* = \sqrt{gds} \qquad \text{Eq. (B-8)}$$

where

u^* = shear velocity (m/sec)
d = stream depth (m)
g = gravitational acceleration (9.81 m/sec^2), and
s = average bed slope (m/m).

A site-specific bed slope was not available, therefore, a hypothetical bed slope of 1% was assumed.

The COC concentrations in the Mississippi River resulting from stormwater pond discharges calculated using equation B-3 (with input from equations B-4 through B-8) are summarized in the third numerical column of Table B-6.

B.5.2 COC Concentrations in River Water Due to Particulate Deposition

The deposition of particulates from the Kondirator onto the surface of the river also results in increased concentrations of COCs in the river water. The increase in concentrations due to direct particulate deposition was estimated as follows:

$$C_d = \frac{s(DR*A*COC)}{q_u} \qquad \text{Eq. (B-9)}$$

where

C_d = COC concentration in Mississippi River water due to deposition of Kondirator particulate ($mg/m^3 = \mu g/l$),
s = conversion factor (3.2×10^{-8} years/sec),
DR = TSP deposition rate on river surface (39,750 mg/m2-year),
A = deposition area (213×1707 m = 363,590 m^2),
COC = estimated proportion of COCs in particulate emissions (unitless), and
q_u = 7-day low-flow rate (91 m^3/sec, USGS 1993).

The average TSP deposition rate for the river reach adjacent to the facility (39.75 g/m^2-year = 39,750 mg/m^3), taken from the Applicant's deposition modeling, was used to calculate COC loading to surface water. The deposition area was assumed to be equal to the mixing zone (213 meters × 1707 meters) calculated for the stormwater discharge, as described in the previous section. The low-flow rate of 91 m^3/second for 1993 was also used to calculate the increase in COC concentrations in the river, with an assumption of perfect mixing. The facility lifetime does not enter into this equation because the particulate is assumed to be continuously diluted in the river flow, and COC concentrations do not build up in the water column. The estimated concentrations of COCs in the Mississippi River surface water due to particulate deposition on the river surface are shown in the fourth column of Table B-6. It should be noted that, due to the manual transfer of data, some rounding errors may have been propagated in the surface water analysis summarized in Table B-6. These errors are quite small, and do not significantly affect the result of the risk calculations.

B.5.3 Combined COC Surface Water Concentrations Due to Stormwater Discharge and Particulate Deposition

The combined impact of the stormwater discharges and surface deposition of particulates on COC concentrations in the Mississippi river (C_{tot}) is simply the sum of the two contributions:

$$C_{tot} = C_{so} + C_d \qquad \text{Eq. (B-10)}$$

The estimated combined increments in COC concentrations due to Kondirator emissions are shown in the last column of Table B-6.

The above analyses assume that the particulate matter discharged from the stormwater pond and deposited on the surface of the river would remain suspended in the river. As noted in the following section, it is likely that a proportion of these particulate COCs would actually be deposited into bottom sediment, so that the surface water concentration estimates just described may overestimate the actual water column concentrations and the bioavailable concentrations of COCs.

B.6 COC CONCENTRATIONS IN SEDIMENT

Incremental concentrations of constituents of concern emitted from the Kondirator in sediment were estimated to evaluate the sediment ingestion pathway risks in the HHRA and ERA.

Sediment concentrations were calculated for all of the COCs that could be emitted from the Kondirator.

This analysis was conducted in two steps. First, the proportion of deposited particulate which would be expected to remain suspended in the water column was calculated (B.6.1). Only the fraction which would not remain suspended in water column was assumed to contribute to sediment buildup of COC concentrations. Section B.6.2 then describes the methods used to estimate the sediment COC buildup over times.

B.6.1 Sediment Particle Size and Deposition Analysis

A conservation of energy approach was used to determine the static pressure required to counteract the force due to gravity on a particle entering the Mississippi River. The output of this analysis is an estimate of the largest particle size which would be expected to remain suspended in the river.

For a particle to be suspended in the water column, the lift must be greater than the weight, as measured at the centerline of the cylinder cross-section. The expression for calculating the threshold diameter that the stream velocity could support was (Bertin 1984)—

$$d = \frac{10\,\rho_w U_w^2}{3\,\rho_c g \pi} \qquad \text{Eq. (B-11)}$$

where

d = particle diameter (m),
ρ_c = density of particle (7,860 kg/m^3),
g = gravitational acceleration (9.81 m/sec^2),
π = 3.14159,
P_w = density of water (1,000 kg/m^3), and
U_w = fee-stream velocity of water (0.106 m/sec).

Using the above expression, a threshold particle diameter of 0.2 mm was determined. This is the largest diameter of a particle that would likely stay suspended in the water column of the Mississippi River.

The size distribution of particles emitted from the Kondirator facility ranges from less than 0.01 mm to 500 mm, according to the EAW (Draft EAW 1994). The largest size range listed in the EAW was 0.04 mm to 500 mm, as listed in Table B-7. Only those particles with diameter greater than 0.2 mm would be assumed to fall through the water column and deposit into the sediment. However, since there was not a clear class of particles that were greater than 0.2 mm in diameter, the percentage of particles that reach sediment in the vicinity of the Kondirator was calculated as half of the percentage of particles in the 0.04 to 500 mm size range, or approximately 15% of the total deposited particulate.

B.6.2 Calculation of COC Concentrations in Sediment

The following equation was used to calculate constituent concentrations in river sediment after the 15-year facility life:

Table B–7. Particle Size Distribution of Kondirator Emissions

Source	Size (mm)	Fraction of Total Particulate Mass
Dust Control System	<0.01	0.06
	0.01–0.02	0.14
	0.02–0.04	0.41
Cascade Cleaning System	<0.03	0.04
	0.03–0.04	0.05
	0.04–500	0.30
Total		1.0

Source: Draft EAW (1994).

$$C_s = \frac{(TSP)(COC)(FL)(F)(x)}{(SD)(BD)} \qquad \text{Eq. (B-12)}$$

where

C_s = concentration of constituent in sediment (mg/kg),
TSP = TSP deposition rate over the river (39.75 g/m^2-yr),
COC = COC proportion of total particulate (unitless)
FL = facility life (15 years),
F = proportion of particulate settling onto bottom sediment (0.1478, unitless)
x = conversion factor (1,000 mg/g),
SD = sediment mixing depth (0.15 m), and
BD = sediment bulk density (1.17x10^3 kg/m^3).

As in estimating soil COC concentrations, the emitted constituents were assumed to accumulate over the 15-year facility life, assuming no loss. The depth of mixing used to estimate sediment concentrations was assumed to be 15 cm. The bulk density of 1.17×10^3 kg/m^3 that was used for soil calculations was also assumed for sediment. Both of these values are quite uncertain, and could vary widely over the study area as a result of natural processes (sediment deposition and resuspension, and mixing of sediments by bottom-dwelling organisms) and human activities (barge traffic, dredging).

The results of the sediment COC concentration calculations are shown in the last column of Table B–8. These values are used as inputs to the HHRA sediment exposure and risk calculations (Appendices C.3 and Tables C-5 and C-6). They also serve as inputs to the sediment exposure calculations in the ERA.

B.7 COC CONCENTRATIONS IN FRESHWATER FISH

Fish uptake of contaminants from water is commonly described by a fish:water bioconcentration factor (BCF), which is the ratio of a chemical's concentration in fish tissue to its concentration in water at steady state. Fish:water BCFs are used to estimate fish tissue concentrations for all of the COCs. The BCF values for all of the COCS are shown in Table B–9. Possible alternatives to the BCF approach are discussed in Section 6.1 of the HHRA and ERA.

The concentrations of each COC in fish due to water-column COC exposures were calculated using an equilibrium partitioning model:

$$C_f = (C_{tot})(BCF_{f:w}) \qquad \text{Eq. (B-13)}$$

where

C_f = estimated COC concentration in fish tissue (mg/kg),
C_{tot} = estimated COC concentration in the water due to Kondirator emissions(mg/l)
$BCF_{f:w}$ = fish:water BCF (mg/kg fish tissue per mg/l water) for COC

Total chemical concentrations in the Mississippi River due to Kondirator emissions were estimated using equation B–10 and shown in Table B–6. Possible reductions in chemical concentrations in fish tissue due to processing or cooking were conservatively not taken into account in this approach. In addition, this approach assumes that water is the major source of tissue residues for

TABLE B-8

Estimated Sediment Concentrations Resulting from Emissions from the Proposed Kondirator Facility

Constituents of Concern	Feed Materials Composition (a)	Maximum Estimated Sediment Concentration (C_s) (mg/kg) (b)
Aluminum	1.76%	8.87
Antimony	0.03%	0.15
Arsenic	0.12%	0.58
Beryllium	0.05%	0.25
Boron	0.10%	0.48
Cadmium	0.08%	0.40
Calcium	0.10%	0.48
Carbon	1.97%	9.93
Chromium	0.71%	3.58
Cobalt	0.44%	2.22
Copper	1.84%	9.29
Iron	90.17%	454.31
Lead	0.38%	1.89
Lithium	0.08%	0.40
Magnesium	0.35%	1.76
Manganese	2.04%	10.28
Molybdenum	0.31%	1.56
Nickel	0.96%	4.84
Niobium	0.10%	0.48
Silicon	0.71%	3.58
Silver	0.05%	0.25
Tin	0.59%	2.97
Titanium	0.10%	0.48
Tungsten	0.40%	2.02
Vanadium	0.22%	1.11
Zinc	0.74%	3.73
Zirconium	0.10%	0.48

(a) Feed material compositon estimates come from Table B–3.

(b) The sediment concentrations of COCs after 15 years of facility operation (C_s), are calculated as shown in equation B–12. These values are used in the sediment pathway dose and risk risk calculations in Tables C–5 and C–6.

Table B-9. Bioconcentration Factors Reported for Fish and Estimated Fish Tissue Concentrations Based on Predicted Surface Water Concentrations

Chemical	Bioconcentration Factor (BCF) for Fish	Species/Exposure Conditions[a]	Reference	Fish Tissue Concentration[b] (mg/kg)
Aluminum	147–231	brook trout; whole body, 15-day exposure	Cleveland et. al (1986 in EPA 1988a)	$2x10^{-2}$–$2.5x10^{-2}$
Antimony	not significant	bluegill; whole body, 28-day exposure	Barrows et.al (1980 in EPA 1988b)	—
Arsenic	4	bluegill; whole body	EPA (1978)	$3x10^{-5}$
Beryllium	19	bluegill; whole body, 28-day exposure	EPA (1980)	$6x10^{-5}$
Cadmium	3–7,440	brook trout; muscle tissue, 490-day exposure to mosquito fish; whole body, 26-week exposure	Benoit et al. (1976 in EPA 1985a) Giesy et al. (1977 in Eisler 1985)	$1.4x10^{-5}$–$3.6x10^{-2}$
Chromium	3	rainbow trout; whole body and muscle tissue	EPA (1985b)	$1.3x10^{-4}$
Lead	1–726	plaice; whole body, 96-hour exposure to rainbow trout; whole body, 7-day exposure	Maddock and Taylor (1980 in Eisler 1988) Wong et al. (1981 in Eisler 1988)	$2.2x10^{-5}$–$1.6x10^{-2}$
Manganese	84	unidentified freshwater fish from an African lake	Greichas et al. 1978 in AQUIRE 1990	1×10^{-2}
Nickel	47–106	fathead minnow; whole body, 30-day exposure	Calamari et al. (1982 in EPA 1986a)	$2.7x10^{-3}$–$5x10^{-3}$
Silver	11–150	largemouth bass; muscle tissue, 120-day exposure to bluegill; whole body, 180-day exposure	EPA (1987a) Cearly (1971 in EPA 1987b)	$3.2x10^{-5}$–$4.4x10^{-4}$
Zinc	51–1,000	freshwater fish	EPA (1986b) and EPA (1987b)	$6.6x10^{-4}$–$1.3x10^{-2}$

[a] Whole body concentrations were used whenever available.
[b] Calculated as shown in equation B-13, water concentrations from Table B-6.

these chemicals, and that the contributions from direct sediment ingestion and food ingestion are negligible in comparison.

The estimated concentrations of COCs in fish tissue are shown in the last column of Table B–9. These ranges of values reflect the ranges of BCF values for the various COCs. These fish tissue concentrations serve as inputs to the HHRA fish consumption pathway exposure and risk assessment shown in Appendix C.4 and Tables C-7 and C-8.

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APPENDIX C

SUMMARY OF CALCULATIONS USED TO ESTIMATE CHEMICAL INTAKES AND DOSES

TABLE OF CONTENTS

C. SUMMARY OF CALCULATIONS USED TO ESTIMATE CHEMICAL INTAKES AND DOSES

C.1 INTRODUCTION

This appendix presents the equations that were used to derive inhalation exposure concentrations and chemical dose estimates for the exposure pathways selected for evaluation in the human health risk assessment. In addition, the equations used to estimate cancer risks for each of the pathways are presented, and the results of the dose and risk estimates are presented in tabular form.

The inputs to the equations for all of the pathways are the exposure concentration estimates which were derived as described in Appendix B. In the discussion which follows, the specific equations and tables where these inputs can be found are identified.

The terminology used in this appendix is consistent with USEPA's (1992) "Guidelines for Exposure Assessment." In accordance with the 1992 guidance, inhalation exposure concentrations (IECs) were estimated in units of air concentration, mg/m^3 or $\mu g/m^3$, while ingestion pathway chemical doses were estimated in units of mg chemical/kg body weight-day (mg/kg-day). For the oral pathways of exposure, the doses calculated in this assessment are equivalent to "potential doses." A potential dose is the amount of chemical ingested, and is analogous to the administered dose in a dose-response experiment. An internal dose, also referred to as an absorbed dose, takes into account the amount of chemical absorbed into the body. Following USEPA's (1992) guidance, the dose for noncarcinogens is referred to as an average daily dose (ADD) and it can be either a potential dose (ADD_{pot}) or an internal dose (ADD_{int}). For carcinogens, the dose is referred to as a lifetime average daily dose ($LADD_{pot}$ or $LADD_{int}$).

For the oral exposure pathways, chemical doses were estimated for two age groups, young children and adults. Dose and risk estimates were developed for each age group separately and, in the case of cancer risks, lifetime risks were estimated by adding the risks for each age group. Only the age-group-specific risk calculations are documented in this Appendix. Additive risks for child and adult receptors are provided in Table 9-1 of the HHRA. For noncarcinogens, addition of hazard quotient values (indicators of risk) is not appropriate across age groups, because the potential for adverse noncancer effects in a given age group is a function of exposure and dose for that age group, not averaged or accumulated over a lifetime. Thus, hazard quotients are presented separately for each age group.

The equations that were used to derive doses for each exposure pathway and to calculate risks are presented below. Table C-1 provides a summary of the parameter values used to estimate exposures doses and risks. The rational for selection of specific parameter values is discussed in more detail in Section 7.3.

C.2 INHALATION OF FACILITY EMISSIONS

Exposures associated with inhalation of COCs emitted from the Kondirator facility are calculated using the following equation:

Table C-1. Rationale for Selection of Exposure Parameter Values

Parameter	Value Used in the Assessment	Comment/Alternatives Value
Body weight (adult, all pathways)	70 kg	Standard Default Value recommended by USEPA (1989), value of 60 kg representing female receptors is sometimes used.
Body weight (child 1-6 years old, all pathways)	15 kg	Standard USEPA Default Value, near the national mean body weight for this age group (both sexes)
Exposure duration (inhalation)	15 yr facility operating life (adult); 6 yr (child)	Value for adults corresponds to facility lifetime provided by Applicant; value for children corresponds to duration of age group
Exposure frequency (inhalation)	350 days/yr	USEPA (1989) Default value, generally considered to be conservative
Exposure time (inhalation)	24 hr/day	Default value, may greatly overstate duration of outdoor particulate inhalation exposure
Exposure duration (soil ingestion, fish ingestion)	24 yr (adult); 6 yr (child)	USEPA (1989) default value; Combined adult and child exposure durations correspond to approximately 95th percentile national housing tenure; probably a conservative estimate of local average residential tenure
Exposure frequency (soil and sediment ingestion	285 days/yr (adult and child)	Corresponds to approximate annual average number of days with maximum temperature greater than 32 F in Minneapolis (see text); it is assumed that on colder days, soil/sediment contact would not occur
Soil/sediment ingestion rate	200 mg/day (child); 100 mg/day (adult)	USEPA (1989) Default Value; generally considered to be conservative estimates of average soil ingestion by these age groups; sediment ingestion might be expected to be even lower
Relative bioavailability (all ingestion pathways)	1.0 (100%, all COCs)	It is assumed that all of the COCs in the Kondirator particulate would become available for uptake by humans or biota during the exposure period; see Section 8.4
Exposure frequency (fish ingestion)	365 days/yr	Corresponds to subsistence fisher; probably a very conservative estimate for recreational fish consumers
Fish ingestion rate	30 g/day (adult); 10 g/day (child)	Values typical of daily fish ingestion in Great Lakes Region (Ruffle et al. 1994), these values are somewhat greater than recommended USEPA default values.
Exposure averaging time (all pathways)	Exposure period (for noncarcinogens) 70 yr (for carcinogens)	USEPA (1989) default values; toxicity parameters are defined to be consistent with these exposure averaging periods

$$IEC = C_a * \frac{EF}{365} * \frac{ED}{AT} \qquad \text{Eq. (C–1)}$$

where

IEC = inhalation exposure concentration (μg/m^3)
C_a = chemical concentration in air (μg/m^3)
EF = exposure frequency (350 days/year)
ED = duration of exposure (15 years, facility lifetime), and
AT = averaging time (70 year lifetime for carcinogens, 15 years for noncarcinogens).

Note that IECs are calculated differently for chemicals exhibiting carcinogenic versus noncarcinogenic effects. In the former case, exposure is extrapolated over a lifetime while in the latter case, IECs are estimated over the actual duration of exposure.

The exposure parameter values used in equation C–1 are appropriate for adults. Inhalation pathway exposures and risks are not calculated separately for children, because the procedures used by the USEPA to derive cancer Unit Risk and RfC values are derived based on physiological models derived for adults.

Cancer risks are estimated for the inhalation pathway as——

$$Risk = IEC * UR \qquad \text{Eq. (C–2)}$$

where

Risk = Estimated lifetime incremental cancer risk associated with exposure to COC,
IEC = Inhalation exposure concentration (ug/m^3, from equation C-1),
UR = USEPA inhalation pathway cancer Unit Risk value for the COC (ug/m3)$^{-1}$ from Table 8–2.

The potential for adverse noncancer health events due to inhalation of particulate COCs are characterized using the following equation:

$$HQ = IEC/RfC \qquad \text{Eq. (C–3)}$$

where

HQ = Hazard Quotient (unitless),
IEC = Inhalation exposure concentration (mg/m^3, from equation B-1),
RfC = USEPA Inhalation pathway RfC value (mg/m^3), from Table 8–2.

As discussed in Section 8.1, hazard quotient values are an indicator of potential adverse effects; an HQ value less than 1.0 for a given exposure indicates with a high degree of assurance that adverse effects are not likely to occur. A value greater than 1.0 indicates that the dose level exceeds a value which may be associated with adverse effect, but does not provide an estimate of the probability or severity of the effect.

Note that the concentration units for the Unit Risk and RfC values differ in the two equations (milligrams per cubic meter versus micrograms per cubic meter) because USEPA issues the Rfc values in the latter units. The conversions of the IEC calculations into the appropriate values are performed on the spreadsheets used to characterize risks (air concentrations in $\mu g/m^3$ are divided by 1,000). The results of the inhalation pathway IEC and risk calculations are summarized in Table C-2.

C.3 INCIDENTAL INGESTION OF SOIL AND SEDIMENT

Potential COC doses due to incidental ingestion of carcinogenic contaminants in soil and sediment were estimated separately for adults and children by the following equation:

$$LADD_{pot} = \frac{C_s * Z}{LT} * \frac{IR_{i(s)} * EF_{i(s)} * ED_i * Bio}{BW_i} * days \qquad \text{Eq. (C–4)}$$

where

$LADD_{pot}$ = potential lifetime average daily dose (mg/kg-day),
C_s = chemical concentration in soil or sediment (mg/kg, from Table B.4-1),
Z = conversion factor (kg/10^6 mg),
$IR_{i(s)}$ = daily incidental soil or sediment ingestion rate in age period i (mg/day, Table C-1),
$EF_{i(s)}$ = frequency of soil or sediment contact exposure events in age period i (days/yr, Table C-1),
ED_i = exposure duration in age period i (yrs, Table C-1),
Bio[1] = relative oral bioavailability factor (unitless), assumed to be equal to 1.0 for all COCs
BW_i = average body weight in age period i (kg, Table C-1), and
LT = number of days in lifetime of 70 years (365 days/yr*70 yrs).
Days = conversion factor (365 days/yr).

To calculate COC doses for children, a body weight (15 kg) and soil/sediment ingestion rate (200 mg/day) appropriate to this age group were used. For adults, a body weight of 70 kg and a soil ingestion rate of 100 mg/day were used (Table C–1). This method estimates doses for either children or adults, averaged over a full lifetime, even though exposures occur for less than a full lifetime. For children, the exposure duration is assumed to be six years (the full duration in the age range 1-6 years), whereas for adults, the exposure duration is assumed to be the facility operating life of 15 years.

For noncarcinogens, potential doses from soil and sediment ingestion were calculated as follows:

$$ADD_{pot} = \frac{C_s * Z}{AT} * \frac{IR_{i(s)} * EF_{i(s)} * ED_i * Bio}{BW_i} \qquad \text{Eq. (C–5)}$$

where

ADD_{pot} = average daily dose (mg/kg-day), and
AT = averaging time (ΣED_i in days).

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[1] Note that the *relative* oral bioavailability factor (Bio) reflects the *ratio* of a chemical's bioavailability from a soil (particulate) matrix to its bioavailability from the vehicle used in the relevant toxicity study.

TABLE C–2

Risk Calculations for Inhalation of Air Emissions from the Kondirator Facility by Residents Living Across the River from the Facility (adults)

Exposure Assessment Equation:

IEC = Ca x (EF/365) x (ED/AT)

IEC = Inhalation Exposure Concentration (ug/m3)
Ca = Annual average air COC concentration (ug/m3)
EF = exposure frequency (350 days/year)
ED = duration of exposure (15 years, facility lifetime), and
AT = averaging time
lifetime for carcinogens (70 years)
duration of exposure for noncarcinogens (15 years)

Risk Characterization Equations:

Cancer Risk = IEC x UR

Hazard Quotient = IEC / RfC

Unit Risk = USEPA Unit Risk Value (Table 8–2)
RfC = USEPA Reference Concentration (Table 8–2)

1. Cancer Risk Estimation

Constituents Exhibiting Potential Carcinogenic Effects	Annual Average Air Concentrations of COCs, Ca (ug/m3) (a)	Inhalation Exposure Concentrations (IECs, ug/m3)	USEPA Unit Risk $(ug/m3)^{-1}$	Weight–of–Evidence (b)	Estimated Incremental Lifetime Cancer Risk (c)
ARSENIC	0.0015	0.0003	0.0043	A	1E–06
BERYLLIUM	0.0007	0.0001	0.0024	B2	3E–07
CADMIUM	0.0010	0.0002	0.0018	B1	4E–07
CHROMIUM, as Cr(VI)	0.0092	0.0002 (d)	0.012	A	2E–06
NICKEL	0.012	0.0026	0.0002	A	6E–07

TOTAL RISK					5E–06 (e)

2. Noncancer Hazard Index Calculation

Constituents Exhibiting Potential Noncarcinogenic Effects	Annual Average Air Concentrations of COCs, Ca (ug/m3) (a)	Inhalation Exposure Concentrations (IECs, ug/m3)	USEPA Reference Concentrations (RfC) (ug/m3) [Uncertainty Factor] (f)	Target Organ (g)	Hazard Quotient (c)
BORON	0.0012	0.0012	20 [100]	Respiratory Tract	6E–05
MANGANESE	0.027	0.025	0.05 [1,000]	CNS	5E–01

SCREENING HAZARD INDEX (h)					5E–01

(a) Calculated using Equation B–1.
(b) USEPA weight of evidence criteria are described in Section 8.1 of the HHRA
(c) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001, or a cancer risk of one in one hundred thousand.
(d) The available unit risk value for chromium is based on chromium VI. Therefore, the estimated exposure for total chromium is assumed to be 10% chromium VI, as discussed in the Section 8.3.
(e) Calculated by summing the cancer risks for all carcinogenic COCs.
(f) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.
(g) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.
(h) Calculated by summing hazard quotients for all COCs, irrespective of target organs affected. A value less than one is interpreted to indicate little potential for adverse effects to occur.

The exposure durations for children and adults are the same in this equation as in the cancer risk estimation. In the case of noncarcinogens, however, the time over which average dose estimates are developed (AT) is equal to the duration of exposure, rather than to a lifetime.

The relative oral bioavailability factor (Bio) in both dose estimation equations for oral doses accounts for a chemical's potentially reduced bioavailability in an environmental medium compared to the vehicle tested in a toxicity study. In regards to soil and sediment ingestion calculations, it represents the ratio of the chemical's bioavailability from a soil or sediment matrix, to its bioavailability from the vehicle used in the relevant toxicity study. In this assessment, a value of 1.0 has been used for all constituents of concern, consistent with the conservative assumption that all COCs are absorbed as efficiently from soil as from the administration vehicle in the toxicity tests. The rationale for the selection of this value is discussed on Section 8.3.

The potential cancer risks associated with ingestion of COCs in soil or sediment is estimated using the following equation:

$$\text{Risk} = \text{LADD} * \text{CSF} \qquad \text{Eq. (C–6)}$$

where

Risk = lifetime incremental cancer risk associated with COC ingestion,
LADD = lifetime average (potential) daily dose of COC (mg/kd-day, from equation C-4),
CSF = the USEPA ingestion pathway Cancer Slope Factor for the COC (mg/kg-day)$^{-1}$, Table 8-1.

The potential for adverse noncancer effects associated with ingestion exposures to COCs is estimated as—

$$\text{HQ} = \text{ADD/RfD} \qquad \text{Eq. (C–7)}$$

where

HQ = hazard quotient (unitless),
ADD = average (potential) daily dose over the exposure period (mg/kg-day, from equation C-5),
RfD = the USEPA ingestion pathway Reference Dose (mg/kg-day, from Table 8-1).

The hazard quotient values derived using Equation C-7 are interpreted in the same fashion as HQ values for the inhalation pathway, as discussed above. The ADD, LADD, cancer risk, and noncancer hazard quotient calculations for soil ingestion are summarized in Tables C-3 and C-4. Risk calculations for children are shown in Table C-3, and the corresponding calculations for adults are shown in Table C-4. The risk calculations for sediment ingestion are summarized in Tables C-5 and C-6.

C.4 INGESTION OF FRESHWATER FISH

As discussed in Section 6-1, none of the COCs which were identified as having significant potential to bioaccumulate in fish tissue are believed to be carcinogens by the ingestion pathway.

TABLE C–3 Risk Calculations for Incidental Ingestion of Soil by a Child Resident Living Across the River from the Kondirator Facility

LADDpot = (Cs x IR x EF x ED x Bio x Conv)/(AT x BW)

LADDpot = potential lifetime average daily dose (mg/kg–day)
Cs = chemical concentration in soil after 15 years (mg/kg)
IR = daily incidental soil ingestion rate for child (200 mg/day)
EF = frequency of soil exposure events for child (285 days/year)
ED = exposure duration for child (6 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for 1–6 year old (15 kg)
AT = average lifetime (365 days/year x 70 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

ADDpot = (Cs x IR x EF x ED x Bio x Conv)/(AT x BW)

ADDpot = potential average daily dose (mg/kg–day)
Cs = chemical concentration in soil after 15 years (mg/kg)
IR = daily incidental soil ingestion rate for child (200 mg/day)
EF = frequency of soil exposure events for child (285 days/year)
ED = exposure duration for child (6 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for 1–6 year old (15 kg)
AT = averaging time (365 days/year x 6 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

1. Cancer Risk Estimation

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Soil Concentration (Cs, mg/kg) (a)	Potential Lifetime Average Daily Dose (LADDpot) (mg/kg–day)	USEPA Cancer Slope Factor (CSF) $(mg/kg–day)^{-1}$	Weight–of–Evidence (b)	Estimated Incremental Lifetime Cancer Risk = LADDpot x CSF (c)
ARSENIC	9.58	$9\text{x}10^{-6}$	1.75	A	1E–05
BERYLLIUM	4.17	$4\text{x}10^{-6}$	4.3	B2	2E–05

TOTAL RISK					3E–05 (d)

2. Noncancer Risk Estimation

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Soil Concentration (Cs, mg/kg) (a)	Potential Average Daily Dose (ADD) (mg/kg–day)	Reference Dose (RfD) (mg/kg–day) [Uncertainty Factor](e)	Target Organ (f)	Hazard Quotient = ADDpot / RfD (c)
ANTIMONY	2.50	$3\text{x}10^{-5}$	0.0004 [1,000]	Blood Chemistry	7E–02
ARSENIC	9.58	$1\text{x}10^{-4}$	0.0003 [3]	Skin	3E–01
BERYLLIUM	4.17	$4\text{x}10^{-5}$	0.005 [100]	None Observed	9E–03
BORON	7.92	$8\text{x}10^{-5}$	0.09 [100]	Testicular	9E–04
CADMIUM	6.67	$7\text{x}10^{-5}$	0.001 [10]	Kidney	7E–02
CHROMIUM, as Cr(III)	59.17	$5.5\text{x}10^{-4}$ (g)	1 [1,000]	Liver	6E–04
CHROMIUM, as Cr(VI)	59.17	$6.2\text{x}10^{-5}$ (g)	0.005 [500]	CNS	1E–02
COPPER	153.58	$2\text{x}10^{-3}$	0.037 [1]	GI Irritation	4E–02
MANGANESE	170.00	$2\text{x}10^{-3}$	0.14 [1]	CNS	1E–02
MOLYBDENUM	25.83	$3\text{x}10^{-4}$	0.005 [30]	Blood Chemistry	5E–02
NICKEL	80.00	$8\text{x}10^{-4}$	0.02 [300]	Decreased BW	4E–02
SILVER	4.17	$4\text{x}10^{-5}$	0.005 [3]	Argyria	9E–03
TIN	49.17	$5\text{x}10^{-4}$	0.6 [3,000]	Liver/Kidney	9E–04
VANADIUM	18.33	$2\text{x}10^{-4}$	0.007 [100]	None Observed	3E–02
ZINC	61.67	$6\text{x}10^{-4}$	0.3 [3]	Blood Chemistry	2E–03

SCREENING HAZARD INDEX (h)					7E–01

(a) Soil concentrations calculated as shown in Table B–5.

(b) USEPA weight of evidence criteria are described in Section 8.1 of the HHRA

(c) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001, or a cancer risk of one in one hundred thousand.

(d) Calculated by summing the cancer risks for all carcinogenic COCs.

(e) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.

(f) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.

(g) The available CSF and RfD values for chromium are based on chromium VI. Therefore, the estimated exposure for total chromium is assumed to be 10% chromium VI, as discussed in the Section 8.3.

(h) Calculated by summing hazard quotients for all COCs, irrespective of the target organs affected. A value less than one is interpreted to indicate little potential for adverse effects to occur.

TABLE C–4 Risk Calculations for Incidental Ingestion of Soil by an Adult Resident Living Across the River from the Kondirator Facility

LADDpot = (Cs x IR x EF x ED x Conv)/(AT x BW) x Bio

LADDpot = potential lifetime average daily dose (mg/kg–day)
Cs = chemical concentration in soil after 15 years (mg/kg)
IR = daily incidental soil ingestion rate for adult (100 mg/day)
EF = frequency of soil exposure events for adult (285 days/year)
ED = exposure duration for adult (24 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for an adult (70 kg)
AT = average lifetime (365 days/year x 70 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

ADDpot = (Cs x IR x EF x ED x Conv)/(AT x BW) x Bio

ADDpot = potential average daily dose (mg/kg–day)
Cs = chemical concentration in soil after 15 years (mg/kg)
IR = daily incidental soil ingestion rate for adult (100 mg/day)
EF = frequency of soil exposure events for adult (285 days/year)
ED = exposure duration for adult (24 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for an adult (70 kg)
AT = averaging time (365 days/year x 24 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

1. Cancer Risk Estimation

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Soil Concentration (Cs, mg/kg) (a)	Potential Lifetime Average Daily Dose (LADDpot) (mg/kg–day)	USEPA Cancer Slope Factor (CSF) $(mg/kg-day)^{-1}$	Weight–of–Evidence (b)	Estimated Incremental Lifetime Cancer Risk = LADDpot X CSF (c)
ARSENIC	9.58	$4x10^{-6}$	1.75	A	6E–06
BERYLLIUM	4.17	$2x10^{-6}$	4.3	B2	7E–06

TOTAL RISK					1E–05 (d)

2. Noncancer Risk Estimation

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Soil Concentration (Cs, mg/kg) (a)	Potential Average Daily Dose (ADD) (mg/kg–day)	Reference Dose (RfD) (mg/kg–day) [Uncertainty Factor](e)	Target Organ (f)	Hazard Quotient = ADDpot / RfD (c)
ANTIMONY	2.50	$3x10^{-6}$	0.0004 [1,000]	Blood Chemistry	7E–03
ARSENIC	9.58	$1x10^{-5}$	0.0003 [3]	Skin	4E–02
BERYLLIUM	4.17	$5x10^{-6}$	0.005 [100]	None Observed	9E–04
BORON	7.92	$9x10^{-6}$	0.09 [100]	Testicular	1E–04
CADMIUM	6.67	$7x10^{-6}$	0.001 [10]	Kidney	7E–03
CHROMIUM, as Cr(III)	59.17	$5.9x10^{-5}$ (g)	1 [1,000]	Liver	6E–05
CHROMIUM, as Cr(VI)	59.17	$6.6x10^{-6}$ (g)	0.005 [500]	CNS	1E–03
COPPER	153.58	$2x10^{-4}$	0.037 [1]	GI Irritation	5E–03
MANGANESE	170.00	$2x10^{-4}$	0.14 [1]	CNS	1E–03
MOLYBDENUM	25.83	$3x10^{-5}$	0.005 [30]	Blood Chemistry	6E–03
NICKEL	80.00	$9x10^{-5}$	0.02 [300]	Decreased BW	4E–03
SILVER	4.17	$5x10^{-6}$	0.005 [3]	Argyria	9E–04
TIN	49.17	$5x10^{-5}$	0.6 [3,000]	Liver/Kidney	9E–05
VANADIUM	18.33	$2x10^{-5}$	0.007 [100]	None Observed	3E–03
ZINC	61.67	$7x10^{-5}$	0.3 [3]	Blood Chemistry	2E–04

SCREENING HAZARD INDEX (h)					7E–02

(a) Soil concentrations calculated as shown in Table B.7–1.
(b) USEPA weight of evidence criteria are described in Section 8.1 of the HHRA
(c) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001, or a cancer risk of one in one hundred thousand.
(d) Calculated by summing the cancer risks for all carcinogenic COCs.
(e) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.
(f) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.
(d) The available CSF and RfD values for chromium are based on chromium VI. Therefore, the estimated exposure for total chromium is assumed to be 10% chromium VI, as discussed in the Section 8.3.
(h) Calculated by summing hazard quotients for all COCs, irrespective of the target organs affected. A value less than one is interpreted to indicate little potential for adverse effects to occur.

TABLE C–5 Risk Calculations for Incidental Ingestion of Mississippi River Sediment by a Child Resident Using the River for Recreation

LADDpot = (Cs x IR x EF x ED x Bio x Conv)/(AT x BW)

LADDpot = potential lifetime average daily dose (mg/kg–day)
Cs = chemical concentration in sediment after 15 years (mg/kg)
IR = daily incidental sediment ingestion rate for child (200 mg/day)
EF = frequency of sediment exposure events for child (285 days/year)
ED = exposure duration for child (6 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for 1–6 year old (15 kg)
AT = average lifetime (365 days/year x 70 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

ADDpot = (Cs x IR x EF x ED x Bio x Conv)/(AT x BW)

ADDpot = potential average daily dose (mg/kg–day)
Cs = chemical concentration in sediment after 15 years (mg/kg)
IR = daily incidental sediment ingestion rate for child (200 mg/day)
EF = frequency of sediment exposure events for child (285 days/year)
ED = exposure duration for child (6 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for 1–6 year old (15 kg)
AT = averaging time (365 days/year x 6 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

1. Cancer Risk Calculations

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Sediment Concentration (Cs, mg/kg) (a)	Potential Lifetime Average Daily Dose (LADDpot) (mg/kg–day)	USEPA Cancer Slope Factor (CSF) (mg/kg–day)$^{-1}$	Weight–of–Evidence (b)	Estimated Incremental Lifetime Cancer Risk = LADDpot X CSF (c)
ARSENIC	0.58	5x10^{-7}	1.75	A	9E–07
BERYLLIUM	0.25	2x10^{-7}	4.3	B2	1E–06

TOTAL RISK					2E–06 (d)

2. Noncancer Risk Estimation

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Sediment Concentration (Cs, mg/kg) (a)	Potential Average Daily Dose (ADD) (mg/kg–day)	Reference Dose (RfD) (mg/kg–day) [Uncertainty Factor](e)	Target Organ (f)	Hazard Quotient = ADDpot / RfD (c)
ANTIMONY	0.15	2x10^{-6}	0.0004 [1,000]	Blood Chemistry	4E–03
ARSENIC	0.58	6x10^{-6}	0.0003 [3]	Skin	2E–02
BERYLLIUM	0.25	3x10^{-6}	0.005 [100]	None Observed	5E–04
BORON	0.48	5x10^{-6}	0.09 [100]	Testicular	6E–05
CADMIUM	0.40	4x10^{-6}	0.001 [10]	Kidney	4E–03
CHROMIUM, as Cr(III)	3.58	3.4x10^{-5} (g)	1 [1,000]	Liver	3E–05
CHROMIUM, as Cr(VI)	3.58	3.7x10^{-6} (g)	0.005 [500]	CNS	7E–04
COPPER	9.29	1x10^{-4}	0.037 [1]	GI Irritation	3E–03
MANGANESE	10.28	1x10^{-4}	0.14 [1]	CNS	8E–04
MOLYBDENUM	1.56	2x10^{-5}	0.0050 [30]	Blood Chemistry	3E–03
NICKEL	4.84	5x10^{-5}	0.02 [300]	Decreased BW	3E–03
SILVER	0.25	3x10^{-6}	0.005 [3]	Argyria	5E–04
TIN	2.97	3x10^{-5}	0.6 [3,000]	Liver/Kidney	5E–05
VANADIUM	1.11	1x10^{-5}	0.007 [100]	None Observed	2E–03
ZINC	3.73	4x10^{-5}	0.3 [3]	Blood Chemistry	1E–04

SCREENING HAZARD INDEX (h)					4E–02

(a) Sediment concentrations calculated as shown in Table B–8.

(b) USEPA weight of evidence criteria are described in Section 8.1 of the HHRA

(c) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001, or a cancer risk of one in one hundred thousand.

(d) Calculated by summing the cancer risks for all carcinogenic COCs.

(e) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.

(f) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.

(g) The available CSF and Rfd values for chromium are based on chromium VI. Therefore, the estimated exposure for total chromium is assumed to be 10% chromium VI, as discussed in the Section 8.3.

(h) Calculated by summing hazard quotients for all COCs, irrespective of the target organs affected. A value less than one is interpreted to indicate little potential for adverse effects to occur.

TABLE C–6 Risk Calculations for Incidental Ingestion of Mississippi River Sediment by an Adult Resident Using the River for Recreation

LADDpot = (Cs x IR x EF x ED x Bio x Conv)/(AT x BW)

LADDpot = potential lifetime average daily dose (mg/kg–day)
Cs = chemical concentration in sediment after 15 years (mg/kg)
IR = daily incidental sediment ingestion rate for adult (100 mg/day)
EF = frequency of sediment exposure events for adult (285 days/year)
ED = exposure duration for adult (24 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for an adult (70 kg)
AT = average lifetime (365 days/year x 70 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

ADDpot = (Cs x IR x EF x ED x Bio x Conv)/(AT x BW)

ADDpot = potential average daily dose (mg/kg–day)
Cs = chemical concentration in sediment after 15 years (mg/kg)
IR = daily incidental sediment ingestion rate for adult (100 mg/day)
EF = frequency of sediment exposure events for adult (285 days/year)
ED = exposure duration for adult (24 years)
Conv = conversion factor (1 kg/1,000,000 mg)
BW = average body weight for an adult (70 kg)
AT = averaging time (365 days/year x 24 years)
Bio = relative oral bioavailability (unitless), assumed to be 1.0

1. Cancer Risk Calculations

Constituents Exhibiting Potential Carcinogenic Effects	Maximum Estimated Sediment Concentration (Cs, mg/kg) (a)	Potential Lifetime Average Daily Dose (LADDpot) (mg/kg–day)	USEPA Cancer Slope Factor (CSF) $(mg/kg-day)^{-1}$	Weight–of–Evidence (b)	Estimated Incremental Lifetime Cancer Risk = LADDpot X CSF (c
ARSENIC	0.58	$2x10^{-7}$	1.75	A	4E–07
BERYLLIUM	0.25	$1x10^{-7}$	4.3	B2	4E–07

TOTAL RISK					8E–07 (d)

2. Noncancer Risk Estimation

Constituents Exhibiting Potential Noncarcinogenic Effects	Maximum Estimated Sediment Concentration (Cs, mg/kg) (a)	Potential Average Daily Dose (ADD) (mg/kg–day)	Reference Dose (RfD) (mg/kg–day) [Uncertainty Factor](e)	Target Organ (f)	Hazard Quotient = ADDpot / RfD (c)
ANTIMONY	0.15	$2x10^{-7}$	0.0004 [1,000]	Blood Chemistry	4E–04
ARSENIC	0.58	$6x10^{-7}$	0.0003 [3]	Skin	2E–03
BERYLLIUM	0.25	$3x10^{-7}$	0.005 [100]	None Observed	6E–05
BORON	0.48	$5x10^{-7}$	0.09 [100]	Testicular	6E–06
CADMIUM	0.40	$4x10^{-7}$	0.001 [10]	Kidney	4E–04
CHROMIUM, as Cr(III)	3.58	$3.6x10^{-6}$ (g)	1 [1,000]	Liver	4E–06
CHROMIUM, as Cr(VI)	3.58	$4.0x10^{-7}$ (g)	0.005 [500]	CNS	8E–05
COPPER	9.29	$1x10^{-5}$	0.037 [1]	GI Irritation	3E–04
MANGANESE	10.28	$1x10^{-5}$	0.14 [1]	CNS	8E–05
MOLYBDENUM	1.56	$2x10^{-6}$	0.005 [30]	Blood Chemistry	3E–04
NICKEL	4.84	$5x10^{-6}$	0.02 [300]	Decreased BW	3E–04
SILVER	0.25	$3x10^{-7}$	0.005 [3]	Argyria	6E–05
TIN	2.97	$3x10^{-6}$	0.6 [3,000]	Liver/Kidney	6E–06
VANADIUM	1.11	$1x10^{-6}$	0.007 [100]	None Observed	2E–04
ZINC	3.73	$4x10^{-6}$	0.3 [3]	Blood Chemistry	1E–05

SCREENING HAZARD INDEX (h)					4E–03

(a) Sediment concentrations calculated as shown in Table B–8.
(b) USEPA weight of evidence criteria are described in Section 8.1 of the HHRA
(c) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001, or a cancer risk of one in one hundred thousand.
(d) Calculated by summing the cancer risks for all carcinogenic COCs.
(e) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.
(f) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.
(g) The available CSF and RfD values for chromium are based on chromium VI. Therefore, the estimated exposure for total chromiun assumed to be 10% chromium VI, as discussed in the Section 8.3.
(h) Calculated by summing hazard quotients for all COCs, irrespective of target organs affected. A value less than one is interpreted to indicate little potential for adverse effects to occur.

Thus, in the case of the fish consumption exposures, only noncancer risk were calculated, For noncarcinogens, the potential COC doses to human receptors (children and adults) from fish consumption were calculated as follows:

$$ADD_{pot} = \frac{C_f * Y}{AT} * \frac{IR_{i(f)} * EF_{i(f)} * ED_i * Bio * (1 - Prep)}{BW_i} \qquad \text{Eq. (C-8)}$$

where

ADD_{pot} = potential average daily dose (mg/kg-day),
C_f = Fish tissue concentration of COC (mg/kg, from Table B.7-1)
AT = averaging time (days, from Table C-1).
Y = conversion factor (kg/10^3 g),
$IR_{i(f)}$ = daily ingestion rate of freshwater fish in age period i (g/day, Table C-1),
$EF_{i(f)}$ = frequency of ingestion exposure to fish in age period i (days/yr, Table C-1),
ED_i = exposure duration in age period i (yrs),
Bio = relative oral bioavailability factor (1.0, unitless),
Prep = reductions in COC concentrations due to fish preparation (0.0 unitless),
BW_i = average body weight over period i (kg, Table C-1).

Estimates of the concentrations of COCs in fish tissues were developed as shown in Appendix B.7. For the fish pathway, no reductions in COC concentrations due to preparation (filleting or cooking) were assumed to occur (i.e., Prep = 0.0). This assumption probably will overestimate fish ingestion doses of COCs. In addition, since the chemicals were present in a food matrix (fish tissue), the relative oral bioavailability factor was assumed to be 1.0 for all COCs.

Hazard quotients for the fish ingestion pathway are calculated the same was as for soil and sediment shown in equation C-7. The results of the ADD and hazard quotient calculations for the fish ingestion pathway are summarized in Table C-7 and C-8. Results for children are shown in Table C-7, and results for adults are shown in Table C-8.

TABLE C–7

Risk Calculations for Ingestion of Fish from the Mississippi River by a Child

Dose Estimation Equation:

ADDpot = (Cf x IR x EF x ED x Bio x Conv)/(AT x BW) x Prep

ADDpot = potential average daily dose (mg/kg–day)
Cf = chemical concentration in fish estimated as (Table C.7–1) (mg/kg)
IR = daily fish ingestion rate for child (10 g/day)
EF = frequency of fish ingestion events for child (365 days/yr)
ED = exposure duration for child (6 years)
Conv = conversion factor (1 kg/1,000 g)
BW = average body weight for child (15 kg)
AT = averaging time (365 days/year x 6 years)
Prep = reductions in concentration due to fish preparation (unitless), assumed to be 1.0
Bio = relative oral bioavailability (unitless), assumed to be 1.0

Risk Characterization Equation:

HQ = ADDpot / RfD

HQ = Hazard Quotient
RfD = USEPA Reference Dose (Table 8–2)

Constituents hibiting Potential Noncarcinogenic Effects	Fish Tissue Concentration mg/kg) (a)	Potential Average Daily Dose (ADD) (mg/kg–day)	Reference Dose RfD (mg/kg–day) (a) [Uncertainty Factor] (b)	Target Organ (c)	Hazard Quotient (d)
CADMIUM	0.036	$2x10^{-5}$	0.001 [10]	Kidney	2E–02
ZINC	0.013	$9x10^{-6}$	0.3 [3]	Blood Chemistry	3E–05

SCREENING HAZARD INDEX (e)					2E–02

(a) Calculation as described in Appendix B.7, shown in Table B.9.
(b) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.
(c) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.
(d) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001.
(e) Calculated by summing hazard quotients for all COCs, irrespective of target organs affected. A value less than one is interpreted to indicate little potential for the occurrence of adverse effects.

TABLE C–8

Risk Calculations for Ingestion of Fish from the Mississippi River by an Adult Subsistence Fisher

Dose Estimation Equation:

ADDpot = (Cf x IR x EF x ED x Bio x Conv)/(AT x BW) x Prep

ADDpot = potential average daily dose (mg/kg–day)
Cf = chemical concentration in fish estimated as (Table B.7–1) (mg/kg)
IR = daily fish ingestion rate for adult (30 g/day)
EF = frequency of fish ingestion events for adult (365 days/yr)
ED = exposure duration for adult (24 years)
Conv = conversion factor (1 kg/1,000 g)
BW = average body weight for adult (70 kg)
AT = averaging time (365 days/year x 24 years)
Prep = reductions in concentration due to fish preparation (unitless), assumed to be 1.0
Bio = relative oral bioavailability (unitless), assumed to be 1.0

Risk Characterization Equation:

HQ = ADDpot / RfD

HQ = Hazard Quotient
RfD = USEPA Reference Dose (Table 8–2)

1. Noncancer Risk Characterization

Constituents Exhibiting Potential Noncarcinogenic Effects	Fish Tissue Concentration (mg/kg) (a)	Potential Average Daily Dose (ADDpot) (mg/kg–day)	Reference Dose RfD (mg/kg–day) [Uncertainty Factor] (b)	Target Organ (c)	Hazard Quotient(d)
CADMIUM	0.036	$2x10^{-5}$	0.001 [10]	Kidney	2E–02
ZINC	0.013	$6x10^{-6}$	0.3 [3]	Blood Chemistry	2E–05

SCREENING HAZARD INDEX (e)					2E–02

(a) Calculated as described in Appendix B.7, see Table B.9.
(b) Uncertainty factors represent the multiplicative factors used in extrapolation of the RfC from the available toxicological data. Uncertainty factors do not necessarily indicate the degree of uncertainty associated with an RfC value.
(c) A target organ or critical effect is the organ/effect most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the particular constituent of concern.
(d) The symbol "E–" refers to scientific notation; 1E–5, for example, indicates a value of 0.00001.
(e) Calculated by summing hazard quotients for all COCs, irrespective of target organs affected. A value less thanone is interpreted to indicate little potential for the occurrence of adverse effects.

REFERENCES FOR APPENDIX C

U.S. ENVIRONMENTAL PROTECTION AGENCY (USEPA). 1992a. Guidelines for Exposure Assessment. May 29, 1992. Fed. Reg. 57:22888-22938.