APPENDIX C

HUMAN HEALTH RISK ASSESSMENT (PARK USE)

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C.1 INTRODUCTION

The Site Characterization Work Plan (Work Plan, Golder Associates, 1997) specified that a human health risk assessment be conducted in accordance with the requirements of Act 2 (25 PA Code 250, Subchapter F). This risk assessment was prepared and presented in the Site Characterization Report (SC Report, Golder Associates, 1998b) and is reproduced herein as an appendix to the Final Act 2 Report. Section 5.7 of the Work Plan specified that PADEP would be afforded the opportunity to review the summary of the constituents of potential concern (COPC), exposure pathways, and exposure factors prior to the completion of the final risk assessment. Consequently, Golder Associates prepared and submitted the Interim Risk Assessment Report (IRA) to PADEP for review and comment (Golder Associates, 1998a). The IRA presented the following items:

- An identification of COPCs for both human and ecological receptors;
- A description of the exposure pathways and receptors being evaluated;
- Proposed exposure factors based on recently collected site-specific data; and,
- The methodology for completing the toxicity assessment, risk characterization, and uncertainty analysis.

The procedures and methodologies presented in the IRA take site-specific conditions and data into account and are consistent with the procedures for conducting risk assessments as specified in the Act 2 Regulations (including Chapters 250.311, 250.402, and 250.601 through 250.606 and other pertinent sections) as well as the Pennsylvania Land Recycling Program Technical Guidance Manual (PADEP, 1997). PADEP has reviewed the IRA and has presented their comments to Golder Associates in a meeting on September 8, 1998, in a letter dated September 24, 1998, and during a telephone conversation on October 2, 1998. These comments were incorporated into the Risk Assessment and submitted to PADEP on November 25, 1998. PADEP reviewed the initial submittal of the SC Report and Risk Assessment and provided comments to the Group in writing during a meeting held on January 14, 1999. At this meeting, PADEP

comments on the Risk Assessment were discussed and it was concluded that no revision to the exposure assumptions and methods used were needed.

The ultimate goal of the site-specific risk assessment is to determine whether a cumulative excess risk to human health is in excess of the statutory threshold and, as a result, whether remediation is required. Should any remediation be required for the Site, it is currently envisioned that it will be accomplished in accordance with 25 PA Code Chapter 250.606, i.e., through the elimination of the exposure pathway(s) of concern and/or development of a risk-based, site-specific remediation standard.

Golder Associates has conducted an evaluation of the site characterization data collected between October 1997 and April 1998 in accordance with the approved Work Plan. The sample locations from which data were collected during the site characterization investigation are shown on Figure 5 of the Final Report. Additionally, the historical data collected by USEPA at the Site are also considered. The Site map showing historical sample locations is presented as Figure 4 of the Final Report. Summary of detection tables for historical and site characterization samples are presented in Appendix A of the Final Report. A more complete presentation of the Site data, including comprehensive data tables (showing all non-detected results), data validation results and narrative, were presented in Appendix F of the SC Report. A summary of the samples collected during the site characterization is provided in Tables 1 and 8 of the Final Report.

C.2 HUMAN HEALTH RISK ASSESSMENT PROCEDURES

C.2.1 Overview

The human health risk assessment evaluates potential risks to public health at the Site in the absence of site-specific controls, remediation, or mitigation measures, and includes the following:

1. Identification of constituents of potential concern;
2. Exposure Assessment;
3. Toxicity Assessment;
4. Risk Characterization; and,
5. Uncertainty Analysis.

The approach for the risk assessment is consistent with the Risk Assessment Guidance for Superfund (RAGS) Volume I, Human Health Evaluation and includes applicable sections of Parts A, B, C, and D, as appropriate (USEPA 1989a, 1989b, 1992a).

As defined by 25 PA Code Chapter 250.402, remediation of risks in excess of the statutory threshold may be accomplished through the elimination of the pathway via institutional and/or engineering controls and/or remediation using site-specific cleanup levels. As stated in the Technical Guidance Manual (PADEP, 1997), "In developing cleanup numbers for the Site, cumulative excess risk to exposed populations, including sensitive subgroups, shall not be greater than 1 in 10,000 for known or suspected carcinogens. ...For non-carcinogens...the hazard index shall not exceed one." (page E.1-14). As discussed in Section 3 of the Supplemental Characterization Report (Supplemental Report, Golder Associates, 1999a), site-specific cleanup levels were developed in accordance with 25 PA Code Chapter 250.606 and other pertinent sections of the Act 2 regulations where exceedances of MSCs occurred.

C.2.2 Identification of COPCs and Development of Conceptual Site Model

This portion of the risk assessment 1) discusses the conceptual Site model for the risk assessment; 2) compares Site data to conservative Agency screening levels designed to be protective of those exposures; and 3) identifies constituents of potential concern (COPCs) and media requiring further assessment based on conservative screening level comparisons.

An initial screening of constituents detected on-site is conducted by identifying potential exposure media and comparing maximum parameter concentrations in each medium with a conservative risk-based Agency criteria for a given exposure pathway. Where Agency screening criteria are not available for a given exposure pathway (e.g., dermal contact with surface water), more conservative criteria are used for screening purposes (i.e., ingestion of surface water). Appendix M of the SC Report discusses identification of media and constituents of potential concern. This analysis is summarized in Section 5.1 of the Final Report.

Agency screening criteria are designed to be protective of human health. Screening levels have been developed based upon a statutory risk level (i.e., PADEP target excess carcinogenic risk of $1x10^{-5}$ used in defining MSCs[1]) and a total noncarcinogenic target hazard quotient (THQ) of 1.

[1] Media-specific concentrations (MSCs) as defined by PADEP in 25 PA Code Chapter 250.

The PADEP MSCs used as screening criteria in Appendix M of the SC Report are based on the lowest value (i.e. most conservative) when more than one exposure route is possible (e.g. inhalation, ingestion, or soil-to-groundwater contaminant transfer). Therefore, media having constituent concentrations less than a conservative Agency screening criteria are not carried forward for further evaluation. Constituents with concentrations that exceed Agency criteria, or for which no criteria exist, are considered COPCs and are retained for further evaluation in the risk assessment.

Exposure media and pathways that were considered in the identification of COPCs include:

Surface water:	Ingestion Dermal Contact
Sediment:	Ingestion Dermal Contact
Fish:	Ingestion
Surface soil:	Ingestion Dermal Contact Inhalation Soil to Groundwater
Subsurface soil:	Ingestion Dermal Contact Soil to Groundwater
Groundwater:	Non-residential use Discharge to East Branch of Brandywine Creek

Appendix M of the SC Report provides a more extensive discussion of the exposure model, data evaluation, and identification of COPCs for each medium. A comparison of both the recent site characterization data and historic USEPA data with conservative Agency screening criteria is presented in this appendix. Copies of the summary of detection tables presenting the site characterization and USEPA data, along with appropriate screening criteria (for surface soil, subsurface soil, and groundwater), are presented in Appendix A of the Final Report. Site plans indicating monitoring point locations are provided as Figures 5 and 4, respectively, of the Final Report.

Based on the screening level comparison of site-specific data and conservative Agency criteria, the only medium identified to have COPCs is surface soil. The following constituents have been identified in surface soils as warranting further assessment of potential human health risks:

benzo(a)pyrene;
arsenic;
iron;
lead;
mercury; and
vanadium.

Potential exposures to surface soil containing these COPCs are evaluated in the risk assessment as discussed in the following sections.

C.2.3 Exposure Assessment

Section C.2.2 of this Appendix and Appendix M of the SC Report present the conceptual exposure model for each medium at the Site and selected COPCs based on the use of conservative screening criteria and other factors. This section refines the conceptual exposure model for surface soil, the only medium identified to have COPCs based on site-specific data collected. This section also presents the methodology for calculating exposure concentrations for the identified COPCs.

C.2.3.1 Refinement of Exposure Model for Surface Soil

The conceptual exposure model, included as part of the exposure assessment, summarizes the overall rationale and approach to evaluating human exposure to Site constituents. The following are key elements necessary for a complete exposure pathway:

- A source;
- Transport mechanisms and media;
- Exposure media;
- Exposure routes; and,
- Receptors.

All elements must be present for an exposure pathway to be complete. At Kardon Park, the potential sources considered in the identification of COPCs include impacted surface and subsurface soil, sediment, surface water, fish, and groundwater. Based on the results of the evaluation provided in Appendix M of the SC Report and summarized in Section 5.1 of the Final Report, surface soil is the only medium where constituents were identified at concentrations that exceed conservative screening criteria. Therefore, the risk assessment only focuses on relevant exposure pathways associated with surface soils.

Potential surface soil exposure routes include direct contact with soil or transport of constituents through the air pathway. Direct contact with soil is possible, though as discussed below, it is limited based on receptor characteristics for using the park. None of the COPCs are volatile so volatilization from soil into air is not considered. Soil particles with COPCs could also become airborne as fugitive dust. However, most of the Site is paved, grass, or heavily vegetated which does not allow for significant fugitive dust to be generated. Therefore, direct contact with the soil is the most likely exposure pathway.

Receptors and receptor characteristics have been defined based on information from the Borough of Downingtown. The Borough of Downingtown conducted a Park Use Survey during 1997 and 1998 to document the types and frequency of park use by typical park visitors. The Park Use Survey data sheets and Golder Associates' evaluation of the survey data are presented in Appendix N of the SC Report.

The surveys were conducted in May 1997, July 1997, August 1997, January 1998 and February 1998 by Borough of Downingtown employees. The surveys were generally conducted in the morning and afternoon for a period of two hours each. The surveys were conducted from an automobile parked in the parking lot adjacent to Pond 1. On occasion, the surveyor left the car and walked north into the park itself toward Ponds 2 and 3. The surveyor recorded the following information:

- User Demographics (Sex, Age group);
- Use (Activity, such as walking, bicycling, fishing, etc); and,
- How Long in Park (Time of arrival, Departure, and Approximate time spent).

Appendix N of the SC Report describes the methods of data reduction and presents summaries of the reduced data. The conclusions that may be drawn from this evaluation are presented in the following paragraphs.

The surveys conducted during the summer months occurred under fair weather and high use conditions. This type of survey may be considered somewhat biased, as these activities would not be expected to occur everyday, i.e., the majority of the park use occurs during fair weather. The survey was conducted at a time when most children are home (school year is over) and the weather is conducive for visits to a park. The winter survey showed far fewer visitors to Kardon Park and these were mostly transient type activities (e.g., walking, jogging, biking).

Kardon Park does not appear to be used for open-field type recreational use. There are no swings, slides, ball fields, play areas or designated picnic areas within the park with the exception of two picnic tables placed adjacent to the paved parking lot. Very little fishing occurs at the park (approximately 3% of the observed activities) and only two individuals were noted to have been playing ball. Seventy-seven percent (77%) of the activities noted were walking, running, jogging, biking, skating and skateboarding. This type of activity does not promote exposure to surface soil, as these individuals usually do not stray from the paved areas and trails in the park. In addition, these activities occur for only a limited duration of about 10 minutes or less. In essence, the park is an area that is passed through (i.e., it is a "linear" park). The surveyor has noted that there are other parks within the Borough (e.g., Kerr Park) that are designed for and promote recreational use. It should also be noted that there is a much higher percentage of adult visitors to the park (74%) than teenagers (12%) or children (14%). Again this may be due to the fact that there are only limited recreational facilities at the park and other parks nearby provide better young age group recreation.

Only about twenty percent (19.5%) of the documented activities include a potential for exposure to surface soil such as walking around the lake, walking a dog, biking to woods, and feeding the ducks. Given their limited duration, and non-intrusive nature, even these activities would result in soil exposures considerably less than those assumed for a 24-hour resident (residential exposure) or a daily 8-hour worker (non-residential exposure) exposure to soil.

Golder Associates has further refined the exposure model presented in Appendix M of the SC Report for surface soil based on the site-specific information from the Park Use Survey. According to the Park Use Survey adults, and, to a lesser extent children, are the most likely receptors. Seventy-seven percent (77%) of the documented activities do not promote exposures to surface soil. Indeed, those activities that might include exposure to surface soil (19.5% of activities) would have only limited exposures as compared to those typically assumed for a resident or daily worker. As a result, direct contact with soils at the Kardon Park Site is limited.

Much of the soils at the park are covered by vegetation (grass or wooded), or are paved and the potential for significant amounts of fugitive dust is unlikely. Inhalation of dust would be a minor component of an ingestion exposure and none of the COPCs that have been identified are known to be more toxic by the inhalation route. Dermal exposure would also be limited since most of the observed activities do not include contact with the soil (no play areas, no ball fields, etc.). As a result, inhalation and dermal exposures would be insignificant as compared to incidental ingestion and, therefore, the risk assessment only evaluates recreational park users for potential exposure through ingestion of soil.

Based on site-specific information, a second potential receptor group is the groundskeepers who mow the lawn during the growing season. These receptors are also evaluated for potential exposures through soil ingestion. Some fugitive dust exposure could occur during mowing. However, this exposure is most likely to be insignificant since the area is mowed only during the growing season, and little dust of the particle size required for inhalation is likely to be entrained into the air during mowing of grassy areas, or during rainy or damp periods.

The more conservative soil ingestion route is evaluated analogous to the exposure pathway developed for recreational use since exposure resulting from inhalation of fugitive dust during occasional mowing over the growing season is clearly much less than that from ingestion at this same location (USEPA: Risk Assessment Guidance for Superfund, Vol. I. Human Health Evaluation Manual (Interim Final, OSWER Directive 9285.7-01a, December 1989). Similarly, dermal contact may also occur. However, a substantive risk from dermal exposure is much less likely given the COPCs and the concentrations identified at the Site. Furthermore, the PA Cleanup Standards Scientific Advisory Board, with PADEP's concurrence, has not based MSCs

on the dermal route of exposure. This route of exposure is qualitatively evaluated in the risk assessment.

C.2.3.2 Exposure Factors

Given that there were previously no site-specific data to suggest otherwise, PADEP specified in their June 13, 1997 letter (page 1), that residential direct contact exposures are appropriate to evaluate surface soil at the Site. This procedure was used to identify COPC in surface soil. However, the regulations allow for the development of site-specific exposure factors when justified by supporting data (25 PA Code Chapter 250.603(b)). The Park Use Survey performed by the Borough of Downingtown provides sufficient data to justify Site-specific exposure factors to be more consistent with the documented park use.

PADEP Regulations (25 PA Code Chapter 250.306) define the default exposure assumptions to be used for the calculation of MSCs. The default assumptions are consistent with those encountered for typical residential and non-residential scenarios. Many of these factors are appropriate for use in the risk assessment for Kardon Park. However, based upon the data collected from that Park Use Survey, it is clear that some of the default exposure assumptions are inappropriate for this Site. Site-specific exposure factors for ingestion rate (and ingestion factor) and exposure frequency are more appropriate for calculating potential risks at Kardon Park.

Therefore, Golder Associates uses site-specific exposure factors for ingestion rates/factors and exposure frequency to better represent typical park user exposures to surface soils at the Site. These site-specific exposure factors were proposed in the IRA and PADEP has concurred with their use. The site-specific exposure factors were developed in a manner consistent with USEPA's Final Guidelines for Exposure Assessment (57 FR 22888-22938; USEPA, 1992b). Site-specific values used for Exposure Frequency (EF) and Ingestion Rate (IngR) and Ingestion Factor (IF) are discussed below.

Exposure Frequency - Park User

The exposure frequency (EF) cited in 25 PA Code Chapter 250.306(d) is 250 days per year (d/yr) for the residential scenario and 180 d/yr for the non-residential scenario. The residential scenario is based upon an individual residing at a specific location and essentially having daily contact with potential contaminants at that location over the entire day. The non-residential scenario is

based upon an on-site worker who returns to the same location to perform a specific job function over the course of an 8-hour work day. Neither of these scenarios is consistent with the use of Kardon Park.

Golder Associates developed an EF of 72 d/yr. This number is based on Golder Associates' best professional judgment that park visitors would use the park and conduct activities that have a potential soil exposure three times per week during the times of the year when the weather is conducive to park uses (i.e., May through October). This frequency is consistent with regular park use such as walking in the park off of the paved areas and assumes visitors would not be regularly using the park during poor weather conditions (i.e., rain), and during the colder months (November through April). Soil exposures would be minimal when the ground is frozen.

Ingestion Rate - Park User

The Ingestion Rate cited in 25 PA Code Chapter 250.306 (d) is 100 mg/day for children under the residential scenario and 50 mg/day for the adult residential and non-residential scenarios. The Park Use survey shows that for the activities that have been observed at Kardon Park, over three quarters of them (77%) do not promote exposure to surface soil and would not typically result in soil ingestion. Additionally, individuals who visit the park spend only short periods of time in the park. The majority of the visitors were noted to spend less than 10 minutes in the park. The short duration of activities is such that the amount of potential contaminated soil that could be ingested would realistically be much lower than the residential scenario (daily contact with soil over the entire day) as well as the non-residential scenario (contact with soil over an 8-hour work day 5 days per week). Consequently, based on professional judgement and Golder Associates' interpretation of the Park Use Survey, only a small portion of the daily exposure would occur at Kardon Park and more realistic ingestion rates are 25 mg/day and 12.5 mg/day for children and adults, respectively (i.e., one quarter of the standard default exposure[2]).

[2] Important observations documented by the Park Use Survey which were used by Golder Associates for developing the ingestion rate include: short duration of use, most activities (over 75%) did not include soil exposures, and the nature of the observed activities, i.e., no intrusive activities were observed. Given the above, it was judged that 25% of the default ingestion rate conservatively represents potential soil ingestion amounts at Kardon Park (i.e., for children: 25%x100mg/day = 25 mg/d; and for adults: 25%x50mg/day = 12.5 mg/day).

Ingestion Factor - Park User

The Ingestion factor cited in 25 PA Code Chapter 250.306 (d) is 57.1 mg-yr/kg-day for the residential scenario and 17.9 mg-yr/kg-day for the non-residential scenario. Incorporating the site-specific ingestion rates, the new site-specific ingestion factor is 14.3 mg-yr/kg-day.

Summary – Park User

The modified exposure factors presented above are based on professional judgment and interpretation of the Park Use Survey. Clearly, visitors to Kardon Park only rarely have an opportunity to come in contact with exposed soil surfaces as the large majority of park use activities are confined to paved areas. Additionally, the majority of the non-paved soil surface is well vegetated and, as a result, the small percentage of park use activities off of paved areas is not expected to result in significant exposures. Moreover, intrusive activities in the park soil were not observed at all. Therefore, the exposure factors discussed above are expected to still provide a conservative assessment of direct contact exposures to on-site soil. Actual soil exposures are likely to be much less than those being used and, therefore, maintain an adequate degree of conservatism for making appropriate risk management decisions. The exposure factors used in the risk assessment for the park user are provided in Table C-1.

Exposure Frequency - Park Groundskeeper

The conservative PADEP default exposure factors are used for evaluating exposures for the park groundskeepers with the exception of the exposure frequency. The proposed exposure frequency is 28 days/yr. This exposure frequency is conservatively based on the assumption that the grassy area is mowed once a week from April through October by the same individual, which is more frequent than what is typically conducted at the park. The exposure factors used in the risk assessment for the groundskeeper are provided in Table C-2.

C.2.3.3 Calculation of Exposure Concentrations

The surface soil chemical data collected during the recent site characterization will be used in the calculation of exposure concentrations[3]. The reasonable maximum exposure (RME) concentrations

[3] As discussed in the Work Plan, the sampling performed by USEPA was biased towards areas of observed potential impact and, as a result, the results represent worst-case conditions at the Site (i.e., not average conditions that receptors would be exposed to). Therefore, while the historic USEPA data are used in screening and identification of COPCs, these data are not appropriate to be used for the calculation of exposure concentrations and risk estimates. The large and randomly collected data set produced during the site characterization program will be used for the calculation of risk estimates.

are used as an estimate of worst-case exposure concentrations for the Site in accordance with USEPA (1989a; 1989c; 1992a) guidance documents. The RME concentration for a COPC is defined as either the highest detected concentration or the 95% upper confidence limit (95% UCL) on the arithmetic mean concentration. If the 95% UCL exceeds the highest concentration, then the highest detected concentration is used in the calculation in accordance with RAGS. In cases where the data set is not normally distributed, the 95% UCL of the lognormal mean is used. In accordance with RAGS (USEPA, 1992a), the 95% UCL of a mean is defined as a value that, when calculated repeatedly for randomly drawn subsets of Site data, equals or exceeds the true mean 95% of the time. The 95% UCL of the mean provides a conservative estimate of the average mean concentration.

The 95% UCL is calculated by using the following equation from USEPA (1992b), which assumes a normal distribution of analytical data:

$$UCL = \bar{x} + t\left(s/\sqrt{n}\right)$$

where:

UCL	=	95% upper confidence limit
$\bar{x}$	=	arithmetic mean untransformed data measurements
s	=	standard deviation of untransformed data measurements
t	=	student-t statistic
n	=	the number of samples

The application of the above equation to calculate 95% UCL is described by the USEPA in its guidance document (USEPA, 1992a). Unqualified (acceptable) data or data qualified by a "J" (estimated concentrations) are used in the UCL calculations. For sample results reported as not detected, one-half of the reporting limit is conservatively used in the UCL calculation. For field duplicates, the average of the two results is used.

To determine whether or not the data are normally distributed, a simple statistical evaluation of the data was performed. The coefficient of variance is calculated using the following equation:

$$CV = s/\bar{x}$$

where: s and $\bar{x}$ are as defined above.

A coefficient of variance greater than one indicates that the data are not normally distributed. RAGS (USEPA, 1992a) states that "EPA's experience shows that most large or 'complete' environmental contaminant data set from soil sampling are lognormally distributed rather than normally distributed. Consequently, to calculate the UCL of the arithmetic mean, the data should be transformed by using the natural logarithmic function (i.e., ln(x))." The 95% UCL of the arithmetic mean for a lognormally distributed data set is calculated by the following equation:

$$UCL = e^{\left(\bar{x}+0.5s^2+sH/\sqrt{n-1}\right)}$$

where: UCL = 95% upper confidence limit
e = constant (base of the natural log, equal to 2.718)
$\bar{x}$ = mean of the transformed data
s = standard deviation of the transformed data
H = H-statistic (e.g., from table published in Gilbert, 1987)
n = number of samples

The exposure concentrations for the six COPCs in surface soil were calculated three ways: arithmetic mean, 95% UCL (normal distribution) and 95% UCL (lognormal distribution). Based upon the coefficient of variance test, the data for benzo(a)pyrene, arsenic, lead, and mercury are lognormally distributed. The data for vanadium and iron are normally distributed. The 95% UCL (lognormal distribution) for these two constituents is consistent with, though slightly greater than, the 95% UCL (normal distribution). To be conservative, the 95% UCL (lognormal distribution) was used for all six constituents. These values are summarized below:

	95% UCL (lognormal distribution)
Constituent	**ppm**
Benzo(a)pyrene	1.41
Arsenic	42.1
Iron	43,392
Lead	837
Mercury	21.2
Vanadium	89.3

C.2.3.4 Quantification of Exposures

Standard intake equations are used to calculate the exposure intakes for the soil ingestion pathway, as recommended in RAGS (USEPA, 1989a). The equations are:

Soil Ingestion

For Systemic Toxicants:

$$\text{Intake} = \frac{EC \times Abs \times EF \times ED \times IngR \times CF}{BW \times AT_{DC} \times 365 \text{ days/yr}}$$

For Carinogens:

$$\text{Intake} = \frac{EC \times Abs \times EF \times IF_{adj} \times CF}{AT_{C} \times 365 \text{ days/yr}}$$

where:

EC	=	Exposure Concentration
Abs	=	Absorption Factor
EF	=	Exposure Frequency
ED	=	Exposure Duration
IngR	=	Ingestion Rate (or IR)
If_{adj}	=	Adjusted Ingestion Factor
CF	=	Conversion Factor
BW	=	Body Weight
AT_{DC}	=	Averaging time systemic toxins
AT_C	=	Averaging time carcinogens

$$\left(If_{adj} = \left(ED_c \times \frac{IR_c}{BW_c} \right) + \left(ED_a \times \frac{IR_a}{BW_a} \right) \text{where subscript c = child; where subscript a = adult} \right)$$

Tables C-1 and C-2 present the values used in the intake calculations for this risk assessment.

C.2.4 Toxicity Assessment

The purpose of the toxicity assessment is to identify the appropriate reference doses and cancer slope factors for the COPCs being evaluated in the surface soil medium. The toxicity factors are obtained from USEPA's Integrated Risk Information System (IRIS) or the Health Effects Assessment Summary Table (HEAST) as recommended in RAGS (USEPA, 1989a) and PADEP Site-Specific Human Health Risk Assessment Procedures (PADEP, 1997). For iron, Golder Associates obtained a value from the USEPA Region III Risk-Based Concentration (RBC) tables since neither IRIS nor HEAST contained a toxicity factor for this analyte. Table C-3 provides the toxicity information that is used in evaluating the COPCs for the risk assessment.

As previously discussed, the reference dose used by PADEP in developing MSCs for vanadium (5.71E-05 mg/kg-d) is based upon an acute exposure inhalation minimum risk level (MRL) value

from the Agency for Toxic Substances and Disease Registry (ATSDR). This value is inappropriate for Site-specific risk assessment purposes. The oral reference dose for vanadium used in this risk assessment (7.0E-03 mg/kg-d) was obtained from HEAST.

Lead does not have a RfD or slope factor provided as a toxicity factor. Therefore, lead will be evaluated qualitatively and discussed in relation to the MSC for direct contact (derived from the uptake-biokinetic model).

C.2.5 Risk Characterization

Risk characterization integrates the exposure assessment and toxicity assessment to estimate potential risks to human health from COPCs in surface soil. The risk characterization presents quantitative and qualitative descriptions of risk. As stated in RAGS (USEPA, 1989a). "A risk characterization cannot be considered complete unless the numerical expression of risk are accompanied by explanatory text interpreting and qualifying the results." Thus, the risk characterization serves as a bridge between the risk assessment and risk management and is a key step in the ultimate decision making process.

Potential human health hazards associated with exposure to noncarcinogenic substances, or carcinogenic substances with systemic toxicities other than cancer, are evaluated differently than carcinogenic risks. The daily intake over a specific exposure duration is compared to a reference dose (RfD) based on a similar time period to determine a ratio called a hazard quotient. The formula for estimation of the hazard quotient is:

$$\text{Hazard Quotient} = \frac{\text{Intake}}{\text{RfD}}$$

The hazard quotients for individual chemicals that effect the same organ may be added to estimate the occurrence and severity of toxic effects resulting from exposure to multiple constituents. The sum of the hazard quotients for individual chemicals for a single exposure/effect is referred to as the Hazard Index (HI).

For carcinogens, risk is estimated as the likelihood of an individual developing cancer over a lifetime as a result of exposure to a potential cancer-causing substance. The slope factor

converts daily intakes averaged over a lifetime of exposure, as derived in the exposure assessment, to the estimated incremental lifetime cancer risk. The equation for risk estimation is:

Risk = (Chronic Daily Intake)*(Slope Factor)

The sum of the estimated cancer risk for each constituent is added to represent the total estimated cancer risk for exposure to surface soil.

Tables C-4 and C-5 present the calculated risk for the park user and park groundskeeper, respectively, for all of the COPCs except for lead. The potential risk from lead is qualitatively discussed below.

Park User

As shown by Table C-4, benzo(a)pyrene and arsenic are the only COPCs which contribute to carcinogenic risk for a park user. The cumulative carcinogenic risk is calculated as 2.96E-06 which is less than the 1E-05 target risk used by PADEP in developing the MSCs. To evaluate systemic risk, individual hazard quotients are calculated for arsenic, iron, mercury, and vanadium yielding a cumulative hazard index value of 1.68E-01 and assumes that each of the chemicals affect the same organ. The hazard index is less than the target hazard index of 1 and as a result, park users would not be adversely affected via direct contact with Site surface soil.

The 95% UCL for lead is 837 ppm which is greater than the PADEP residential MSC of 500 ppm, but less than the non-residential MSC of 1,000 ppm. However, as previously discussed in Section C.2.3, surface soil exposures at the Site are considerably less than both the PADEP residential and non-resident exposure scenarios. The Site-specific exposure factors developed for this Site would yield over thirteen times less exposure than those for a typical residential scenario. Consequently, based on the PADEP MSCs and the reduced exposures at this Site, park user exposure to lead in surface soil would not result in a cumulative risk in excess of the statutory threshold.

Based on the conservative Site-specific exposure factors described in Section C.2.3.2 and the risk characterization described herein, the surface soil at Kardon Park does not pose a cumulative risk to park users in excess of the statutory threshold. Furthermore, the estimated carcinogenic

Based on assumptions above: namely, majority stay on paved trail and exposure to non paved areas are limited

risks are well over an order of magnitude less than the maximum carcinogenic risk level specified by PADEP for developing cleanup numbers at a Site[4].

Groundskeeper

As shown by Table C-5, benzo(a)pyrene and arsenic are the only COPCs which contribute to carcinogenic risk for a groundskeeper. The cumulative carcinogenic risk is calculated as 1.44E-06 which is less than the 1E-05 target risk used by PADEP in developing the MSCs. To evaluate systemic risk, individual hazard quotients are calculated for arsenic, iron, mercury, and vanadium, yielding a cumulative hazard index value of 2.79E-02 and assumes that each of the chemicals affect the same organ. The hazard index is less than the target hazard index of 1.

The 95% UCL calculated for lead (837 ppm) is less than the PADEP non-residential MSC of 1,000 ppm. Additionally, the Site-specific exposure factors previously discussed in Section C.2.3 show that the groundskeeper would have less exposure than those for a typical non-residential (Site worker) scenario. Consequently, groundskeeper exposures to lead in surface soil would not result in unacceptable levels of health risks.

Based on the conservative Site-specific exposure factors described in Section C.2.3.2 and the risk characterization described herein, the surface soil at Kardon Park does not pose a cumulative risk to park groundskeepers in excess of the statutory threshold.

C.2.6 Uncertainty Analysis

This section qualitatively analyzes the results of the risk assessment for uncertainty. In particular, the uncertainties and limitations associated with the toxicity factors, exposure factors, exposure concentration, and risk estimation is discussed.

Some of the uncertainties and limitations of the quantitative risk assessment, as related to toxicity and exposure assessments, have been previously identified and discussed in Sections C.2.4 and

[4] The following is taken from the Cleanup Standard Scientific Advisory Board (CSSAB) qualified endorsement of the Act 2 Proposed Regulations, dated June 12, 1996. *"The CSSAB has developed statewide health-based standards for direct contact to soil and groundwater that are generally based on the EPA default exposure assumptions with appropriate modification for conditions in the Commonwealth of Pennsylvania. In developing these standards, the CSSAB has applied an excess cancer risk level of 1 x 10-5, based on the unanimous decision of the CSSAB that this level of risk is protective of human health. This decision was based on all of the known public health-protecting assumptions included in toxicological and human exposure evaluations. Furthermore, it is consistent with numerous USEPA and state programs and the highly conservative nature of the MSC calculation procedure."*

C.2.3, respectively. However, a more detailed discussion of pathway-specific uncertainties associated with the assessment of potential current and future risks at Kardon Park is presented below.

Health risk estimation quantitatively defines the general magnitude of human health risks, the precision of which is limited by the size and quality of the database and other input parameters. Consequently, the results of the analyses in this report are only as accurate as the available information, especially with respect to constituent toxicity and exposure concentration and parameters. Uncertainties may arise because of the general need to make a relatively large number of assumptions and inferences to complete each of the involved steps. Some of these assumptions and inferences are needed to compensate for lack of toxicological data on the chemical of interest, or for gaps in the information available to estimate potential exposures.

Toward this end, the approach taken in this assessment to offset uncertainties is biased toward health-protective assumptions that are likely to exaggerate potential risks. For example, the exposure scenarios and calculations of exposure concentrations are based on assumptions that are likely to overestimate rather than underestimate exposures.

A conservative approach has been taken to estimate the exposure levels and their duration, and to characterize the hazards associated with the COPCs found in surface soil at the Site. Consequently, the health risk estimates derived in this risk assessment are magnified, with each step building on the previous one. This approach is designed to compensate for inherent uncertainties, and also provides a margin of safety in the use of risk assessment results for making risk management decisions.

Toxicity factors (RfD_o and CSF_o) are developed by USEPA and other regulatory agencies using conservative assumptions regarding the potential systemic and carcinogenic effects that exposure to specific chemical may have on the human body. In developing these factors, each assumptions made is conservative in order to overestimate rather than underestimate potential toxic effects.

However, in most risk assessments, chemicals are present that cannot be included in the quantitative risk assessment because little or no information on the toxicity of the chemicals is available. In the current assessment, the only COPC for which there is no available carcinogenic and/or

noncarcinogenic toxicity value is lead. However, as discussed in Section C.2.5, lead is not expected to pose significant health risks at the Site due to the Site-specific exposure scenario.

The exposure factors used by PADEP to develop direct contact soil MSCs (25 PA Code Chapter 250.306) are also conservative. Indeed, using a residential scenario to identify and screen Site data for a park user is also conservative. Although Site-specific exposure factors have been developed to more accurately reflect the park use, they have been based upon the conservative exposure factors presented in Act 2.

Additionally, the use of the 95% UCL calculated for the lognormal distribution of Site data is a conservative way to estimate the exposure concentration of the COPCs. As stated in RAGS supplemental guidance (USEPA, 1992b), "Because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable *[the exposure concentration]*. The 95 percent UCL provides reasonable confidence that the true site average will not be underestimated."

The estimation of systemic and carcinogenic risk brings together all of the conservative assumptions used in developing toxicity factors, exposure factors, and exposure concentrations. The procedures used in the quantitative risk assessment are based on those used to calculate statewide Health Standards under Act 2. In its Qualified Endorsement of the Act 2 Proposed Regulations (June 12, 1996), the Cleanup Standards Scientific Advisory Board discussed the procedures used to develop these standards and stated that the procedures are "highly conservative." These same procedures are used to characterize risk for Kardon Park and as shown in Tables C-4 and C-5, no unacceptable human health risks have been identified for exposure to surface soil.

In summary, the risk estimates developed herein conservatively compensate for inherent uncertainties and also provide an appropriate margin of safety in the use of the risk assessment results for making risk management decisions. It is very likely that the estimates calculated in this risk assessment overestimate the potential risks associated with the COPCs in surface soil at Kardon Park.

C.3 REFERENCES

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TABLE C-1
EXPOSURE PARAMETERS FOR PARK USERS
KARDON PARK
DOWNINGTOWN, PENNSYLVANIA

Term		Systemic	Carcinogens
EC	Exposure Concentration (mg)	95% UCL (lognormal distribution)	95% UCL (lognormal distribution)
RfD_o	Oral Reference Dose (mg/kg-day)	Chemical-specific	N/A
CSF_o	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	N/A	Chemical-Specific
BW	Body Weight (kg) Soil	15	70
Abs	Absorption (unitless)	1	1
EF	Exposure Frequency (d/yr) Soil	72	72
ED	Exposure Duration (yr) Soil	6	24
IngR	Ingestion Rate - Soil (mg/day) Child Adult	25 N/A	25 12.5
IF_{adj}	Ingestion Factor Soil (mg-yr/kg-day)	N/A	14.3
CF	Conversion Factor Soil (kg/mg)	$1x10^{-6}$	$1x10^{-6}$
AT_{DC}	Averaging Time for systemic toxicants (yr) Soil	6	N/A
AT_c	Averaging Time for carcinogens (yr)	N/A	70

TABLE C-2

EXPOSURE PARAMETERS FOR PARK GROUNDSKEEPERS
KARDON PARK
DOWNINGTOWN, PENNSYLVANIA

Term		Systemic	Carcinogens
EC	Exposure Concentration (mg)	95% UCL (lognormal distribution)	95% UCL (lognormal distribution)
RfD_o	Oral Reference Dose (mg/kg-day)	Chemical-specific	N/A
CSF_o	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	N/A	Chemical-Specific
BW	Body Weight (kg) Soil	70	70
Abs	Absorption (unitless)	1	1
EF	Exposure Frequency (d/yr) Soil	28	28
ED	Exposure Duration (yr) Soil	25	25
IngR	Ingestion Rate Soil (mg/day)	50	50
IF_{adj}	Ingestion Factor Soil (mg/yr/kg-d)	N/A	17.9
CF	Conversion Factor Soil (kg/mg)	$1x10^{-6}$	$1x10^{-6}$
AT_{DC}	Averaging Time for systemic toxicants (yr) Soil	25	N/A
AT_c	Averaging Time for carcinogens (yr)	N/A	70

TABLE C-3

TOXICITY FACTORS
KARDON PARK
DOWNINGTOWN, PENNSYLVANIA

Chemical of Potential Concern in Surface Soil	Toxicity Factor	Source
Benzo(a)pyrene	7.3E+0 per (mg/kg)/day (CSFo)	IRIS, 1998
Arsenic	3E-4 mg/kg-day (RfDo)	IRIS, 1998
Arsenic	1.5E+00 per (mg/kg)/day (CSFo)	IRIS, 1998
Iron	3E-01 mg/kg-day (RfDo)	NCEA, Region 3 RBC Table, April 1998
Lead	500 mg/kg ((MSC direct contact for inorganic regulated substance in soil)	Appendix A, Table 4; PA Bulletin, Volume 27, No. 33. August 16, 1997
Mercury	1E-4 mg/kg-d (RFDo)	IRIS, 1998 (methyl mercury)
Vanadium	7E-3 mg/kg-day (RfDo)	HEAST, 1998

RfDo = Reference Dose, oral
CSFo = Cancer Slope Factor, oral

TABLE C-4
CALCULATION OF POTENTIAL RISK TO PARK USER
Kardon Park Site, Downingtown, Pennsylvania

For systemic toxicants the hazard quotient is determined by:

$$HQ = \frac{EC*Abs*EF*ED*IR*CF}{RfD_o*Bw*AT_{DC}*365}$$

For carcinogens, the risk is calculated by:

$$Risk = \frac{EC*Abs*EF*IF_{adj}*CSF_o*CF}{AT_C*365}$$

Parameter	CSF_o [kg-d/mg]	RfD_o [mg/kg-d]	Hazard Quotient	Risk
benzo(a)pyrene	*7.30E+00*	-	-	4.14E-07
arsenic	*1.50E+00*	*3.00E-04*	4.62E-02	2.55E-06
iron	-	*3.00E-01*	4.76E-02	-
lead	-	-	-	-
mercury	-	*1.00E-04*	6.98E-02	-
vanadium	-	*7.00E-03*	4.20E-03	-
Cumulative			**1.68E-01**	**2.96E-06**

There is no CSF_o or RfD_o established for Lead. The exposure concentration was compared to PADEP direct contact MSCs, and considering the reduced exposures of the park user, it was concluded that no unacceptable health effects would result from park user exposure to lead in surface soil (see Section C.2.5).

TABLE C-5
CALCULATION OF POTENTIAL RISK TO PARK GROUNDSKEEPER
Kardon Park Site, Downingtown, Pennsylvania

For systemic toxicants the hazard quotient is determined by:

$$HQ = \frac{EC*Abs*EF*ED*IR*CF}{RfD_o*Bw*AT_{DC}*365}$$

For carcinogens, the risk is calculated by:

$$Risk = \frac{EC*Abs*EF*IF_{adj}*CSF_o*CF}{AT_C*365}$$

Parameter	CSFo [kg-d/mg]	RfDo [mg/kg-d]	Hazard Quotient	Risk
benzo(a)pyrene	*7.30E+00*	-	-	2.02E-07
arsenic	*1.50E+00*	*3.00E-04*	7.69E-03	1.24E-06
iron	-	*3.00E-01*	7.93E-03	-
lead	-	-	-	-
mercury	-	*1.00E-04*	1.16E-02	-
vanadium	-	*7.00E-03*	6.99E-04	-
Cumulative			**2.79E-02**	**1.44E-06**

There is no CSF_o or RfD_o established for Lead. The exposure concentration was compared to PADEP direct contact MSCs, and considering the reduced exposures of the park user, it was concluded that no unacceptable health effects would result from park user exposure to lead in surface soil (See Section C.2.5).