COMPARISON OF A POINT ESTIMATE AND PROBABILISTIC RISK

ASSESSMENT OF A MILITARY GOLF COURSE SLATED FOR BASE CLOSURE

by

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(Under Direction of Mary A. Smith)

ABSTRACT

The current guidelines for human health risk assessments uses conservative point estimates to characterize the hazards associated with exposure to chemicals in the environment. The probabilistic methods currently proposed by the USEPA focus on Monte Carlo analysis which can be applied to the same exposure scenarios presented in the point estimate approach. The major objective of this study was to compare the results of the point estimate and probabilistic methods (one-dimensional Monte Carlo analysis considering uncertainty in the concentration term), when applied to various exposure scenarios and receptors. The site was a golf course on a Naval Air Station slated for closure. Cancer risks and noncancer health hazards from human exposure to a golf course potentially contaminated with pesticides, metals and organic compounds were evaluated. The values obtained in the point estimate appear overly conservative and are approximately 1 to 30-fold greater than the probabilistic method results.

INDEX WORDS: Risk Assessment, Monte Carlo Analysis, Probabilistic, Point Estimate, Golf course

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DEDICATION

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CHAPTER 1

INTRODUCTION

Purpose of the Study

The current USEPA guidelines for human health risk assessment uses a conservative "point estimate (PE)" (i.e., single values) to characterize the hazards associated with exposure to chemicals in the environment (Smith 1994). The probabilistic methods proposed to replace the point estimate by the USEPA use Monte Carlo analysis (MCA) as a tool for quantifying variability and uncertainty in risk (USEPA 1999). The probabilistic risk assessment uses a distribution of data rather than a single point estimate to represent key exposure variables (chemical concentrations, frequency duration of contact, body weight, etc.) (Finley 1994). The MCA method can be applied to the same exposure scenarios as in the point estimate approach. It has been suggested that probabilistic analyses offer a more accurate estimate of the plausible risk, especially at the "upper-bound" exposures (between 95^{th} and 99^{th} percentile) (Burmaster 1991). In this study, probabilistic methods currently proposed by the EPA (USEPA 1999) were and applied to several complex exposure scenarios. The results were contrasted with those obtained using the point estimate approach currently recommended by the USEPA (USEPA 1989). The specific objectives for this study were to illustrate the advantages and disadvantages of point estimates vs. probabilistic analyses, and to examine the magnitude of the differences between the risk estimates obtained using these two methods.

This study will also examine if agricultural chemicals applied to a golf course are a source of potential risk to humans who may come in frequent or infrequent contact with the soil on the golf course. It is widely known that some agricultural chemicals applied to lawns and golf course turf pose a risk to human health and the environment. A human health risk assessment was performed that examined the route and pathways of exposure to humans, and evaluated current and future cancer risks and noncancer health hazards. Performing two different risk assessment methods (point estimate vs. probabilistic) using the same site data allowed a thorough comparison of estimates of risk from the two methods. The findings of this study will provide regulators, scientists and concerned citizens the critical scientific information needed to make "risk" decisions concerning the golf course industry. Information derived from this study will also help identify those constituents that may be of most concern following exposure.

This study focuses on the reasonable maximum exposure (RME) versus probabilistic methods to an on-unit worker (maintenance worker), a future excavation worker, a recreational golfer, and resident adult/child possibly exposed to contaminated soil from a golf course on a military installation slated for closure. The RMEs represent the highest exposure that is reasonably expected to occur in a small, but definable "high-end" segment of the potentially exposed population. For all carcinogenic exposures to residents, a weighted-average adult/child is evaluated. This assumes that a portion of the overall lifetime exposure to carcinogens occurs at a higher level of intensity during the first six years of a child's life (i.e., accounts for increased soil ingestion during child years). Probabilistic risk assessment (PRA) as defined by EPA "is the general term for risk assessments that use probability models to represent likelihood of different risk levels in a population (i.e., variability) or to characterize uncertainty in risk estimates" (USEPA 1999).

A Monte Carlo analysis (MCA) and separate sensitivity/uncertainty analysis was performed to evaluate variability and uncertainty in exposure parameters for soil including ingestion, dermal absorption and inhalation routes of exposure. Using the probabilistic approach rather than the single point estimate approach (current practice) provided "multiple descriptors" of risk and more complete information on which to make decisions.

Studying the potential for health risks to on-unit workers, recreational golfers, and residents is warranted because several of the pesticides (i.e., chlordane, DDT, dieldrin, toxaphene) previously used on golf course turf and home lawns are currently banned by the EPA. However, these compounds are hydrophobic, highly immobile in soil, and persistent in nature. They build up in the tissue of organisms, and may potentially leach to the groundwater and contaminate residential drinking water supplies. Due to the growing popularity of the sport, the increased number of people playing golf including young children, and the number of golf course communities built near or on residential properties, this topic warrants further evaluation.

The majority of US military bases have golf courses, and several military installations slated for closure are to be returned to municipalities. The public who will utilize these former military installations for industrial, recreational and residential purposes may be concerned about potential risks. This document addresses issues surrounding “risks” from golf courses treated with pesticides.

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CHAPTER 2

LITERATURE REVIEW

Background

Probabilistic risk assessment (PRA) as defined by EPA "is the general term for risk assessments that use probability models to represent likelihood of different risk levels in a population (i.e., variability) or to characterize uncertainty in risk estimates" (USEPA 1999a). For human health risk assessments, the probability distributions for risk reflect variability or uncertainty in exposure (USEPA 1999a).

The Monte Carlo (MC) simulation is the most common method for PRA. The MCA or Monte Carlo simulation is "a technique for repeatedly sampling from probability distributions to derive a distribution of outcomes (e.g., risks)" (USEPA 1999a). The US EPA's *Guiding Principles for Monte Carlo Analysis* (USEPA 1997a) and *Risk Assessment Guidance for Superfund: Volume 3 - (Part A, Process for Conducting Probabilistic Risk Assessment)* DRAFT (USEPA 1999a), were used as the primary guidance documents for the probabilistic assessment.

The golf course industry has come under intense scrutiny because of its application of agricultural chemicals used to maintain quality playing surfaces, and the potential effect these chemicals may have on human health and the environment. The pesticides (including insecticides, fungicides and herbicides) used to maintain golf courses have the potential to contaminate drinking water supplies, and adversely affect human health and harm the environment (Balogh and Walker 1992, Noah 1994, Zaneski 1994). The chemicals may contaminate the environment through runoff and leaching, and may produce adverse effects in nontarget organisms (Kendal et al. 1992, Kendal et al. 1993). Some anti-development groups have focused on such potentially negative effects of golf courses in an effort to stop housing or commercial real estate development (Kenna and Snow 2000). The popular press has reported that some golf course developments faced strong opposition from various organizations concerned with the effects of golf courses on the environment, and as a result, developers have helped clients with environmental permitting issues (Golf Course News 1998).

Pesticide movement on golf courses

An 18-hole golf course facility in the United States is typically comprised of (a) 0.8 to 1.2 ha (1.9 to 2.9 acres) of putting greens, (b) 10 to 20 ha (24.7 to 49.4 acres) of fairways and (c) 0.6 to 1.2 ha (1.5 to 2.9 acres) of tees. Only 20 to 30 % of the area on a typical golf course is used and maintained to specific criteria as part of the playing requirements of the game (Beard 2000). Putting greens are a focal point for environmental concerns because they receive more pesticides per unit area than any other turfgrass sites (Smith and Tillotson 1993). The greens are typically 80% by volume coarse sand, to give a high percolation and water removal rate (Shuman et al. 2000). The majority of insecticide products are applied to fairways, tees, and greens with proportionately less applied to roughs. The porous medium of golf course greens coupled with high inputs of fertilizer and irrigation water promotes leaching - not only of soluble nitrogen sources, but even of less soluble fertilizer (Shuman et al. 2000). The fairway areas present different problems that lead to detrimental environmental effects through fertilizer losses.

Researchers examined the potential movement of nutrients and pesticides following application to a golf course (Sharpley et al. 1987). They found that if nitrogen and phosphorus are added to turfgrass and subsequently are lost in runoff and subsurface flow, they can eventually find their way to potable water supplies. The added nutrients, especially phosphorus, can cause eutrophication of surface water, leading to problems for fisheries, recreation, industry, or drinking water due to increases in the growth of undesirable algae and aquatic weeds (Sharpley and Menzel 1987).

Between 1.4 and 3.2 million herbicide acre-treatments per year were made between 1992 and 1996 (Kline and Company 2000). The greatest herbicide use by volume during this period were applications to fairways and roughs. Fungicides are more heavily relied upon in the golf course industry than for other turf market industries. Approximately 160,000 and 189,000 acres of turf were treated with fungicides during 1994 and 1996, respectively, with a higher percentage of greens being treated (73-93%) than other golf course areas (Kline and Company 2000). As far as quantity of active ingredients applied, herbicides still predominate due to the large overall acreage and also use of older products with relatively higher application rates.

Researchers have examined the potential for movement of pesticides in surface runoff from golf courses as well as movements below the root zone. Watschke et al. (2000) applied an herbicide, an insecticide, and a fungicide at label rates to two turfgrasses maintained as golf course fairway turf. Their results suggested that certain pesticides applied to sloped plots of turfgrass could be transported in surface runoff when irrigation is applied more heavily than the normal within 24 hr of the pesticide application. The concentrations of all compounds were very low, even in the first two liters of runoff (Watschke et al. 2000). This suggests that most pesticide exposures from golf courses would be from contact with soil or soil particles, rather than contaminated runoff.

The behavior of pesticides on golf courses has been widely studied (Smith et al. 1993; Miles et al. 1992; Odanka et al. 1994). Results from these studies suggests that well-managed turfgrass should not result in significant groundwater contamination from pesticides, nitrogen or phosphorus; however, both phosphorous and pesticides can reach groundwater when applied to turf. The key to reducing or eliminating movement is the use of integrated pest management (IPM), soil testing, and experience when applying the chemicals (Branham et al 2000). Odanka et al. (1994) modeled leaching and runoff of pesticides in golf courses, and concluded that only pesticides with relatively high water solubility can be washed away from the turf greens. In 1989, the United States Golf Association (USGA) sponsored a research program at 12 universities focusing on the environmental issues related to the golf course industry. The main focus of the study was to determine if fertilizers and pesticides affected the surface and groundwater surrounding golf courses (Kenna and Snow 2000). The studies were conducted on the major pathways of chemical fate in the environment, including leaching, runoff, plant uptake and utilization, volatilization, microbial degradation, and other gaseous losses. The research showed that the majority of pesticides used on golf courses have a negligible effect on the environment (Kenna and Snow 2000). The results from the USGA-sponsored research is described in greater detail in Chapter 1 (Kenna and Snow

2000). In most cases, the small amount of leachate or runoff collected from research plots, were found at levels well below the health and safety standards established by the United States Environmental Protection Agency (USEPA) (Kenna and Snow 2000). The studies demonstrated that the turfgrass canopy, thatch, and root system were an effective filter or sponge (Kenna and Snow 2000). The results documented that heavy textured soils adsorbed pesticides and fertilizers better than the light textured or sandy soils (Kenna and Snow 2000).

<u>Human health risks to golfers and pesticide applicators</u>

In contrast to industry-sponsored research that reported low risks from pesticides used on golf courses, Theo Colborn, Dianne Dumanoski, and John Peterson Myers published a book entitled *Our Stolen Future*. It addressed issues concerning widespread hormone disrupting chemicals, and the adverse effects at low levels, which result in potentially serious risks to the environment and public health. In response to the book, EPA stated that “The Agency is working with the golf industry as well as many other pesticide user groups to reduce the risks from the use of pesticides through the Pesticide Environmental Stewardship Program (PESP). PESP is a broad effort by EPA, USDA, and FDA to work with pesticide users and others to reduce pesticide use and risk in both agricultural and nonagricultural settings by developing use/risk reduction strategies that include reliance on biological pesticides and increasing adoption of Integrated Pest Management (IPM) programs”. The Golf Course Superintendents Association of America and the Professional Lawn Care Association are both partners in PESP through the New York Audubon Society's Cooperative Sanctuary Program. The Sanctuary Program encourages property owners, both corporate and private; to improve wildlife habitat on their property and to adopt IPM programs to control problems that may occur. The aim of the partnership is to reduce the risk and use of pesticides. EPA recommends that "golfers who seek to reduce their exposure to pesticides may wish to ask if the golf course follows IPM practices and what pesticides are used". Some golf courses may have a list of pesticides they use and when they are applied. Golfers may also want to schedule their play to avoid recent pesticide applications (USEPA 1997a).

The potential for human health risk on the golf course or nearby warrants further evaluation. The pesticide applicators, either professional contractors or golf course workers, may be exposed to these poisons during mixing, storage and application. Some golfers play shortly after pesticides have been applied and can be exposed directly to the pesticides on the turf, as well as to pesticide vapors and mists. Also, individuals living near golf courses can be potentially exposed in their homes from the vapors and mists. In addition to the long-term health effects of pesticides, like cancer, there have recently been various reports of people suffering immediate health problems after exposure to pesticides. In one extremely unusual case in 1982, a Navy lieutenant died two weeks after he spent three consecutive days playing golf at the Army Navy Country Club in Arlington, Virginia. His doctor reported that the lieutenant suffered a severe reaction to chloroalonil, a pesticide used weekly on the golf course (Spitzer 1995).

Volatilization can be a major route of pesticide loss following application to turfgrass. Consequently, a significant proportion of applied pesticides may be available for human exposure via volatile and dislodgeable foliar residues. Volatilization studies report that organophosphate insecticides possessing high toxicity and volatility might result in exposure situations that cannot be deemed completely safe as judged by the

USEPA Hazard Quotient determination (Cooper et al. 1995, Murphy et al. 1996a, Murphy et al. 1996b, Clark 1997). Also, the level of hazard increases for insecticides with high vapor pressures and low reference dose (RfD) values, which may help predict the hazards associated with other pesticides with similar chemical characteristics.

During the golfing season, most golf courses are open every day during the week, leaving little time between pesticide application and reentry into the treated area. The inhalation of volatile pesticides may be of toxicological concern given the high susceptibility of humans to airborne toxins; particularly those associated with aerosols. In addition, it has been shown that dermal exposure of agricultural workers is related to the amount of pesticide present as dislodgeable foliar residues (Zweig et al. 1985). The legs, hands and arms of golfers are often unprotected during play. The hands are most likely the main route of dermal exposure since they are usually unprotected and are involved in a number of repetitive tasks that result in direct exposure to turf (e.g., picking up golf balls, repairing ball marks on greens, replacing divots in the fairway, cleaning club heads, etc.) (Kross et al. 1996). Thus, the potential for significant exposure to pesticides applied to golf courses certainly exists. Golf course workers are known to be exposed to a variety of chemicals including pesticides, herbicides, fertilizers, and motor fuels (Kross et al. 1996). A national study of mortality among 686 golf course superintendents from 1970-1992 (Kross et al. 1996) demonstrated an increased percentage of death from non-Hodgkin's lymphoma and leukemia (proportionate mortality ratios 237 and 162, respectively) (Shokeir et al. 1997).

Clark et al. (2000) examined potential routes for golfer exposure to pesticides applied to turfgrass. They examined airborne pesticide concentrations and estimated the inhalation and dermal exposure for golfers using the USEPA Hazard Quotient. Their research showed that exposure situations exist following application of pesticides to turfgrass that cannot be deemed completely safe. Their assessment, however, must be viewed in terms of the assumptions that were used in making these estimations. In all instances, the maximum pesticide concentrations were used for the entire 4-hour exposure period, and dermal transfer coefficients and dermal penetration factors were taken from non-turfgrass situations that are likely to exceed those that would take place on a golf course. They viewed such estimates as worst-case scenarios, and suggested that in order to accurately predict the health implications of pesticide exposure on golfers, a relevant dosimetry/biomonitoring evaluation of golfers, playing golf on a golf course, needs to be carried out. With more accurate exposure estimates, they suggest that the exposure levels they reported will be found to be in excess of the true exposure to pesticides on a golf course.

In addition to potential applicator exposure of pesticides on turfgrass, there are potential exposure scenarios from dermal uptake and inhalation. Studies of the fate of total and dislodgeable (i.e., removed via contact and abrasion) residues of pesticides on turfgrass foliage have demonstrated that a very low percentage (5-10% at most) of the total residue present immediately after application is in dislodgeable form and concentrations decrease rapidly with time (Sears et al. 1987, Hurto and Prinster 1993). Biomonitoring studies of the uptake and excretion of pesticide residues in individuals reentering treated turf areas and demonstrate ample safety margins (according to Solomon et al. 1993, Vaccaro et al. 1996). Additional research on both application and reentry exposure in turfgrass is being completed by the Occupational and Residential

Exposure Task Force, an industry association currently working cooperatively to meet an EPA data call-in (USEPA 1994). Regarding potential inhalation exposure, air monitoring during and following application to turfgrass confirms very low levels may be present, indicating this is at most a secondary route of potential exposure (Yeary and Leonard 1993).

Human health risk assessment and the Law

Federal law requires detailed evaluation of pesticides to protect human health and the environment. In 1996, Congress made significant changes to strengthen pesticide laws through the Food Quality Protection Act (FQPA) (USEPA 1999). The EPA requires extensive test data from pesticide producers that demonstrate pesticide products can be used without posing harm to human health and the environment. To implement provisions of the Food Quality Protection Act of 1996, EPA considers the special sensitivity of infants and children to pesticides, as well as aggregate exposure of the public to pesticide residues from all sources, and the cumulative effects of pesticides and other compounds with common mechanisms of toxicity (USEPA 1999). The Agency develops any mitigation measures or regulatory controls needed to effectively reduce each pesticide's risks (USEPA 1999). EPA then reregisters pesticides that meet the safety standard of the FQPA and can be used without posing unreasonable risks to human health or the environment. All pesticides sold or distributed in the United States must be registered by EPA, based on scientific studies showing that they can be used without posing unreasonable risks to people or the environment. Because of advances in scientific knowledge, the law requires that pesticides, which were first registered before November 1, 1984, be reregistered to ensure that they meet today's standards that are more stringent.

EPA uses a risk assessment for evaluating health impacts of a pesticide. Based on the conclusions of a risk assessment, EPA can then make a more informed decision regarding whether to approve a pesticide chemical for use, as proposed, or whether additional protective measures are necessary to limit occupational or non-occupational exposure to a pesticide (USEPA 1999).

The following section describes EPAs Reregistration Eligibility Decision (RED) risk assessment results for the herbicide diclofop-methyl. They estimated that golfers who regularly play on treated courses may face an excess cancer lifetime risk of 2.2×10^{-6}. These risk estimates, however, are believed to overstate the actual risk to golfers who play on treated courses. The Agency suggests that the cancer risks associated with golfers on diclofop-methyl treated turf is an upper-bound estimate since the post-application risk assessment is based on protective assumptions related to golfer behavior and diclofop-methyl use practices. Therefore, the Agency finds that mitigation is unnecessary for post-application exposure to golfers. The cancer risk for a "handler" due to dermal and inhalation exposure range from $1.4x10^{-2}$ to $5.1x10^{-6}$ at the baseline level, $8.4x10^{-5}$ to $6.0x10^{-7}$ with personal protective equipment (PPE), and $5.8x10^{-5}$ to $1.4x10^{-6}$ at the engineering controls level. Cancer risk for post-application exposure to workers mowing/maintaining golf course turf is $6.1x10^{-6}$ on the day of application. However, the Agency assumed that an individual might come into contact with diclofop-methyl residues for four hours per day, two days per year. The golfer would need to be on the course during both of those treatment days to obtain that level of risk. Also, the analysis assumes that an individual is exposed to the highest residues for four hours per episode (USEPA 2000).

There are some minor differences between the EPA's OPP risk assessments and EPA's CERCLA Superfund risk assessments. The OPP risk assessment for resident adult/child are applicable for pesticides approved for residential use only. There are certain pesticides that have "residential-use only" which may be used by professional applicators. These pesticides are not available for purchase by the homeowner, however the professional applicator could apply to residential area and the resident could be exposed.

The OPP agency evaluates noncancer hazards as margin of exposure (MOE) values based on dose to represent risks, or how close a chemical exposure is to being a concern, associated with a chemical exposure (unitless). The dose estimates generated using this method are based on central tendency estimates of the unit exposure, area treated, and body weight, and a central to upper-percentile assumption for the application rate and are considered to be representative of central tendency exposures (USEPA 1997b). A risk evaluation for the resident via the EPA RAGS method should be compared to those values derived via the OPP method to ensure that risks are not underestimated.

Current study

Currently, no probabilistic risk assessment for soil exposures at golf courses exists. The EPA currently recommends that MC simulation be used to analyze uncertainty and variability surrounding single-point risk estimates for the multiple descriptors of risk. The uncertainty analysis was performed using the software package Crystal Ball, Version 2000.2 (Decisioneering Inc 2000), in conjunction with Excel. The Crystal Ball software performed Monte Carlo simulations for the probabilistic distributions of the uncertain exposure parameters, using the Latin Hypercube Sampling (LHS) technique to predict the multiplicative exposure factors. Each simulation was run with 10,000 iterations and the results were used to estimate various percentiles of risk using the standard EPA RME risk equations (USEPA 1991). The pathway specific PDFs used in the 1-D MCA for variability and for each exposure pathway were derived from several well-referenced sources and published scientific journal articles. After the exposure models were defined, the next step was to (1) identify point estimates for all of the model inputs, (2) find the distributions/probability distributions for each input parameter, and (3) input the data into the simulation program.

The focus of this thesis is to perform a risk assessment to evaluate current and future cancer risks and noncancer health hazards from human exposure to a former United States military golf course potentially contaminated with pesticides, herbicides, insecticides, metals and volatile organic compounds (VOCs). The reasonable maximum exposure (RME) to an on-unit worker (maintenance worker), a future excavation worker, a recreational golfer, and resident adult/child possibly exposed to the contaminated soil, will be evaluated. The specific aims are 1) determine if the Naval Air Station Cecil Field golf course poses a risk to these receptors; 2) conduct and present results of the uncertainty and sensitivity analyses, and 3) examine the magnitude of differences between the risk estimates obtained using the point estimate vs. probabilistic methods. The thesis is presented in two separate manuscripts. The first manuscript (Chapter 3), "A Risk Assessment of a Military Golf Course Slated for Base Closure" is a risk assessment which examines the potential risks and hazards associated from human exposure to a former United States military golf course potentially contaminated with pesticides, herbicides, insecticides, metals and volatile organic compounds. The point estimate risk assessment was performed using USEPA standard methods and exposure assumptions based on the latest EPA guidance. The information derived from this risk assessment will help identify those constituents that may be of most concern following exposure. The second manuscript (Chapter 4), “Comparison of a Point Estimate and Probabilistic Risk Assessment of a Military Golf Course Slated for Base Closure” examines the probabilistic methods currently proposed by the USEPA and apply it to the same exposure scenarios presented in the point estimate approach. The specific objectives for this study are to illustrate the advantages and disadvantages of the point estimate vs. probabilistic analysis, and to examine the magnitude of the differences between the risk estimates obtained using these two methods.

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CHAPTER 3

A RISK ASSESSMENT OF A MILITARY GOLF COURSE SLATED FOR BASE CLOSURE[1]

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ABSTRACT

Using current EPA guidelines, a risk assessment was conducted for a golf course on a Naval Air Station slated for closure. Future reuse plans include industrial, public, recreational and residential use. Cancer risks and noncancer health hazards from human exposure to a golf course potentially contaminated with pesticides, metals and organic compounds were evaluated. The EPA's "reasonably maximally exposed (RME)" individual scenarios include a maintenance worker, future excavation worker and recreational golfer. The RMEs represent the highest exposure that is reasonably expected to occur in a small, but definable "high-end" segment of the potentially exposed population. Future residential exposures to an adult/child potentially exposed to contaminated soil due to recreational and residential activities were also evaluated. The lifetime cancer risks for all receptors exceeded the RME cancer risk (>1E-6) via the ingestion and dermal pathway, but not the inhalation pathway. For non-cancer health effects, the hazard index (HI) for all RME scenarios was below EPA's action level of 1.0, except for the resident child (HI=4.61). Ideally, closed military bases would be returned to public use. However, a major concern is whether there would be risks to the public. These results demonstrate that there are potential risks associated with residential use of the golf course and probably reflects the use of pesticides common at any golf course, not specifically military golf courses.

Key Words: risk assessment, golf, concentration, soil, pesticides, military base

INTRODUCTION

The golf course industry has come under intense scrutiny because of its use of agricultural chemicals to maintain quality playing surfaces and the potential effect these chemicals may have on human health and the environment. Some articles in the popular press suggest that pesticides (including insecticides, fungicides and herbicides) used to maintain golf courses could potentially contaminate drinking water supplies, and adversely affect human health and harm the environment (Balogh and Walker 1992, Noah 1994, Zaneski 1994). The chemicals may contaminate the environment through runoff and leaching, and may bring about adverse effects to nontarget organisms (Kendal et al. 1992, Kendal et al. 1993). According to industry group, some anti-development groups have publicized potential negative effects of golf courses in an effort to halt housing or commercial real estate development (Kenna and Snow 2000). Golf course magazines have reported that some golf course developments may or have faced strong opposition from various organizations concerned with the effects of golf courses on the environment (Golf Course News 1998). Currently, there are more than 16,000 golf courses in the USA, and 932 more are under construction (Snyder and Cisar 2000). Most golf courses are built in suburban areas with surrounding residential properties. Despite the increase in golf course construction and the sport of golfing, there are few data available on the human health impacts to golf course workers, golfers and residents who live near golf courses. Clark et al. (2000) found that there are volatile and dislodgeable residues available that for golfer exposure following pesticide application to turfgrass, and that many of these exposures may be unsafe using the USEPA Hazard Quotient assessment.

Anyone on the golf course or nearby is potentially at risk of pesticide exposure. Pesticide applicators, either professional contractors or golf course workers, may be exposed to poisons during mixing, storage and application of pesticides. Golfers, who may play shortly after pesticides have been applied, can be exposed directly to the pesticides on the turf, as well as to pesticide vapors and mists. The pesticides residues on the turf surfaces could rub off onto the individuals or their equipment during a round of golf. Hands are the most likely route of dermal exposure since they are usually unprotected and are involved in a number of repetitive tasks that result in direct exposure to turf (e.g., picking up golf balls, repairing ball marks on greens, replacing divots in the fairway, cleaning club heads, etc.) (Kross et al. 1996).

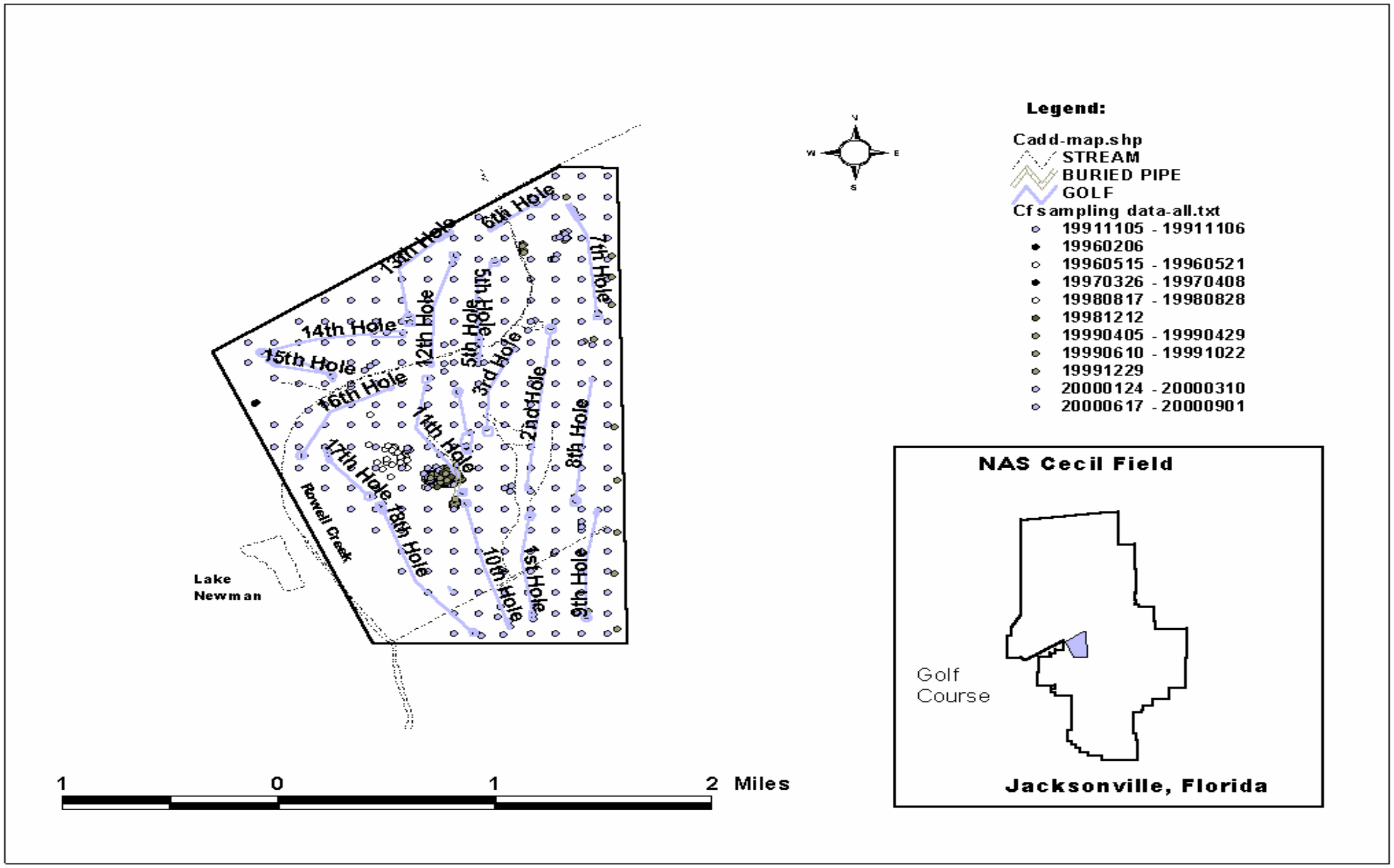
Performing a risk assessment to evaluate current and future cancer risks and noncancer health hazards from a golf course may lead to measures that are more protective for golf course workers and provide regulatory agencies with critical scientific information to make "risk" decisions concerning the golf course industry. The NAS golf course that is slated for base closure provides an interesting example of past and present golf course practices, and their potential effects on the environment and human health. Also, the facility will be transferred to the Jacksonville Port Authority and will have multiple uses (USEPA 1994). The risk assessment process provides an opportunity for stakeholders (state, city, businesses, homeowners, local environmental groups, and low-income and minority populations) to participate in the cleanup process and offer input to decision-makers.

The purpose of this study was to perform a risk assessment to evaluate current and future cancer risks and noncancer health hazards from human exposure to a former golf course on a U.S. military base contaminated with pesticides, herbicides, insecticides, metals and volatile organic compounds (VOCs). The reasonable maximum exposure (RME) to an on-unit worker (maintenance worker), a future excavation worker, a recreational golfer and a resident adult/child possibly exposed to contaminated soil was also evaluated.

Site Description and History

The Naval Air Station (NAS) Cecil Field, a final National Priority List (NPL) Site, is located 14 miles southwest of Jacksonville in the northeastern part of Florida (Figure 3.1) and covers approximately 22,000 acres. Small communities and individual dwellings are near NAS Cecil Field, and commercial properties and low-density residential areas characterize the land use (ABB-ES 1992). The NAS Cecil Field was established in 1941 and provides facilities, services, and material support for the operation and maintenance of naval weapons, aircraft, and other units of the operating forces as designated by the Chief of Naval Operations. The NAS Cecil Field was slated for closure by the Base Realignment and Closure Commission (BRAC) in 1999 and much of the facility will be transferred to the Jacksonville Port Authority. Reuse plans have been developed to assist in the property transfer and other closure activities. Anticipated future uses include public buildings and facilities, residential land use, a new runway and industrial use. Naval operations at NAS Cecil Field ceased September 30, 1999.

The 18-hole golf course (approximately 244 acres) is located in a wooded area within the Cecil Field NAS property (Figure 3.1). The area is covered with dense



(Figure 3.1 NAS Cecil Field Golf Course Sampling Map adapted from TTNUS 1999) undercover. An access road and several small trails that traverse the area appear to be well maintained and free of vegetation, and the greens and fairways are flat and grassy.

Surface runoff in the southwest vicinity of the golf course flows into the golf course drainage system, which eventually drains to Rowell Creek. There is little to no surface runoff at the golf course due to dense vegetation.

Previous studies indicated that golf course maintenance personnel may have disposed empty, partially full, and full pesticide containers in a pit approximately 40 feet wide by 40 feet long, located between fairways 11 and 17. A new pesticide facility was completed in 1978, and the disposal practices were discontinued. The final remedial action for this waste includes excavation and removal of the contaminated soil and pesticide containers.

Previous remedial investigation (RI) of the NAS Cecil Field land uses and contaminants have been reported (TTNUS 1999). This study focuses on the NAS Cecil Field golf course, and the receptors (industrial, recreational and residential) who may contact the golf course soil. The exposure pathways evaluated for the current and future scenarios include incidental ingestion and dermal contact of soil, and inhalation of air-borne particulates and vapors.

MATERIALS AND METHODS

Sampling sites and sample collection

Approximately 732 soil samples were collected from 527 locations on the fairways, greens and tees throughout the entire golf course, during the sampling activities (TTNUS 1999, ABBES 1992) (Figure 3.1). The soil samples were collected from 0 to 0.3 m (0 to 1 foot) depths. The soil samples were analyzed for: target compound list

(TCL) volatile organic compounds (VOCs), TCL semi-volatile organic compounds (SVOCs), target analyte list (TAL) inorganics, and Pesticides/poly chlorinated biphenyls (PCBs) by an off-site approved EPA laboratory.

Soil samples collected during a focused RI (1993), and additional soil samples collected from 1996 to 2000, were used to define the volume, location, and characteristics of the buried pesticide containers and to confirm the presence or absence of hazardous substances throughout the golf course. The results of the soil sampling indicated the presence of pesticides, metals, organics and herbicides.

Results of the analysis reported that the area behind the 11th tee of the golf course indicated significant levels of arsenic, toxaphene and chlordane, which exceeded the Region IX Preliminary Remediation Goals (PRGs) Table (USEPA 2001) and the Florida Department of Environmental Protection (FDEP 2001) residential soil screening levels.

Risk Assessment Methods

A human health risk assessment was conducted to characterize the risks associated with potential exposure to site-related contaminants at the NAS Cecil Field golf course. The risk assessment calculations are based on the RME concentrations for each principal complete pathway. The RMEs represent the highest exposure that is reasonably expected to occur in a small, but definable “high-end” segment of the potentially exposed population. The risk assessment was performed using standard methods and exposure assumptions based on the latest USEPA guidance (USEPA 1989, 1991 and 1995).

Exposure Point Concentrations

The summary statistics were calculated on the data (e.g., the mean and 95 percent upper confidence limit on the mean [95% UCL]) for each constituent/exposure group combination (see Table 3.1). The method for calculating the 95% UCL in the soil was based on the recommended EPA (USEPA 1997b) method for calculating lognormal distributions. The method involved four major steps: 1) probability plots were constructed for the contaminants and appropriate statistical tests were used to determine lognormal or normal distributions; 2) if the data were normally distributed the Student-t equation (Equation 1) was used to calculate the UCL of the population mean; 3) if the data were lognormally distributed the UCL was calculated by the H-statistic (Equation 2), standard bootstrap (Equation 3) and bootstrap-t (Equation 4) (Efron and Tibshirani 1993) methods. The values of the 95% UCL obtained by the three methods were compared, and the method that yielded a value closest to the respective 95th percentiles for the lognormal distributions was selected as the UCL; 4) if the data distribution was neither normal or lognormal, the bootstrap method was used to calculate the UCL.

For some of the constituents in Table 3.2, the 95% UCL was calculated via the standard bootstrap method because the highly skewed nature of the distribution made the Bootstrap-t process unstable, and the standard bootstrap was more robust than the Bootstrap-t method. The following formulas were used to calculate the upper confidence limit:

$$UCL_n = \text{x-bar} + t\ (s_x \ /\ \text{square root}\ (n)) \qquad (1)$$

Table 3.1 Exposure Point Concentrations based on the 95% UCL

Chemical	Distribution	Exposure Point Concentration Point Estimate (Dermal & Ingestion) mg/kg	Exposure Point Concentration Point Estimate (Inhalation)[b] m^3/kg
4,4-DDD	LN	119.65[a]	9.1E-08[a]
4,4-DDT	LN	6.53	4.9E-09
Alpha-Chlordane	LN	9.54	7.2E-09
Arsenic	LN	14.62[a]	1.1E-08[a]
Chlordane (technical)	N	26.87[a]	2.0E-08[a]
Chlordane (nonstereospecific)	LN	38.44	2.9E-08
Dieldrin	LN	1.03	7.8E-10
Gamma-Chlordane	LN	11.87	9.0E-09
Heptachlor Epoxide	N	0.210	1.6E-10
Total Chlordane	LN	2.99[a]	2.3E-09[a]
Toxaphene	N	1460.8[a]	1.1E-06[a]

[a]Exposure Point Concentration values derived via standard bootstrap method.
[b]Exposure Point Concentration values for inhalation (mg/m^3) = EPC_{soil} (mg/kg) / PEF (m^3/kg).

$$UCL_L = \exp(\text{y-bar} + 0.5s_y^2 + s_y H_{1-a} \text{ square root } (n\text{-}1)) \quad (2)$$

$$UCL = \text{x-bar}_B + Z_a\, \sigma_B \quad (3)$$

$$UCL = \text{x-bar}_{a,\, n-1}\, \sigma_x \text{ / square root } (n) \quad (4)$$

Where UCL_n is the 95% upper confidence limit of the mean for a normal distribution, x-bar is the arithmetic average for normal distribution, t is the 1-tailed 95% t value or Student's t-statistic (depending on the number of observations), s_x is the standard deviation of x, n is the number of observations of x, UCL_L is the 95% upper confidence limit of the mean for a normal distribution, UCL_L is the 95% upper confidence limit of the mean for a log-normal distribution, y-bar and s_y^2 are the arithmetic mean and variance of the transformed data, H is the value (H-statistic) used to calculate the log-normal UCL selected from Table A12 in Land (1975), x-bar_B is the bootstrap estimate of the population mean (arithmetic mean), Z_a is the z-statistic, σ_B is the bootstrap estimate of the standard error, σ_x is the estimated standard error of the untransformed data.

A screening was performed against the most current USEPA Region IX PRGs (USEPA 2001) and the FDEP Soil Target Levels (STL) (FDEP 2001). For constituents that exceeded the PRG screening level and FDEP STLs, the maximum concentration was compared to 2X unit-background average concentration (USEPA 1995) for inorganics. Constituents that exceed the PRG, FDEP STL, and the 2 X-background screens, were retained as human health constituents of potential concern. The entire golf course was assumed the exposure unit (EU) and the exposure point concentration (EPC) was developed by calculating the upper 95% UCL from the entire surface soil data set and

Table 3.2 Derivation of Exposure Point Concentrations

Chemical	**95% UCL** *(normal)* mg/kg	**95% UCL** *(lognormal)* mg/kg	**Bootstrap (Standard)** mg/kg	**Bootstrap-t** (mg/kg)
4,4-DDD	122.65	478.02	119.64	135.62
4,4-DDT	8.61	6.53	6.53	8.12
Alpha-Chlordane	1.92	9.54	-	2.12
Arsenic	14.83	12.88	14.61*	14.88
Chlordane (technical)	28.48	300.72	26.87	26.77
Chlordane (nonstereospecific)	13.89	38.45	-	14.61
Dieldrin	0.42	1.03	-	0.45
Gamma-Chlordane	2.90	11.87	11.87	3.26
Heptachlor Epoxide	0.210	4154.06	-	0.226
Total Chlordane	3.23	382.50	2.99	3.331
Toxaphene	1522.00	20555.73	1460.8	1639.31

then applied to each receptor.

RME Assumptions

The RME values are conservative (overestimate) exposure estimates and represent the highest exposure that is reasonable expected to occur at a site and can be estimated by combining upper bound (90^{th} or 95^{th} percentile) values for some but not all exposure parameters (USEPA 1995). Table 3.3 presents the RME parameters evaluated for the following NAS Cecil Field golf course receptors: 1) Current on-unit maintenance worker: Includes golf course maintenance personnel, pesticide applicators and grounds caretaker; 2) Current recreational golfer: pesticide residues may rub off onto people or their equipment during a round of golf; 3) Future excavation worker: This receptor was based on cleanup (excavation and removal) of hazardous waste at the military installation; 4) Future resident adult and child: This receptor was based on cleanup (excavation and removal) of hazardous waste at military bases slated for residential reuse. The risk assessment examined three exposure scenarios based on the following assumptions: Scenario (1) assumed that all of the receptors were exposed to the entire golf course; Scenario (2) assumed that the residential adult/child was exposed to the most contaminated ½ acre of the golf course; Scenario (3) assumed a "typical" recreational golfer by deleting data associated with the buried containers and pesticide buildings.

Choice of Exposure Units - Scenario 1

Current On-Unit Maintenance Worker

The on-unit maintenance worker was assumed to be exposed at random and with equal coverage to the entire golf course. Hence, the entire golf course was assumed to be the

Table 3.3 RME Default Exposure Assumptions

Parameter	Definition	Units	Default Value	Source
ABS	Absorption factor soil	unitless	0.01 (organics)	USEPA 1995
		unitless	0.001 (inorganics)	USEPA 1995
ATc	Averaging time; carcinogens	days	70 years x 365 days/year	USEPA 1989, 1991
ATnc	Averaging time; noncarcinogens	days	ED x 365 days/year	USEPA 1989
AF	Adherence factor-main worker	mg/cm^2	1	USEPA 1995
	Adherence factor-excav worker	mg/cm^2	0.3	USEPA 2001
	Adherence factor-golfer	mg/cm^2	0.07	TtNUS 1999
	Adherence factor-res adult	mg/cm^2	1	USEPA 1995
	Adherence factor-res child	mg/cm^2	1	USEPA 1995
BW	Body weight-main worker	kg	70	USEPA 1991
	Body weight-excav worker	kg	70	USEPA 1991
	Body weight-golfer	kg	70	USEPA 1991
	Body weight-res adult	kg	70	USEPA 1995
	Body weight-res child	kg	15	USEPA 1995
CAIR	Air exposure point concentration	mg/m^3	chemical specific	site data
CF	Conversion factor units	mg/kg	0.000001	-
Cs	Chemical concentration in soil	mg/kg	chemical specific	site data
ED	Exposure duration-main worker	years	25	USEPA 1991
	Exposure duration-excav worker	years	1	USEPA 2001
	Exposure duration-golfer	years	20	TtNUS 1999
	Exposure duration-res adult	years	24	USEPA 1995
	Exposure duration-res child	years	6	USEPA 1995
EF	Exposure frequency-main worker	days/year	250	USEPA 1991
	Exposure frequency-excav worker	days/year	250	USEPA 2001
	Exposure frequency-golfer	days/year	100	TtNUS 1999
	Exposure frequency-res adult	days/year	350	USEPA 1995
	Exposure frequency-res child	days/year	350	USEPA 1995
ET	Exposure time -main worker	hours/day	8	USEPA 1995
	Exposure time -excav worker	hours/day	8	USEPA 1995
	Exposure time -golfer	hours/day	3.65	USEPA 1997
	Exposure time -res adult	hours/day	15	USEPA 1995
	Exposure time -res child	hours/day	18	USEPA 1995
FI	Fraction ingested-main worker	unitless	1	USEPA 1995
	Fraction ingested-excav worker	unitless	1	USEPA 1995
	Fraction ingested-golfer	unitless	1	USEPA 1995
	Fraction ingested-res adult	unitless	1	USEPA 1995
	Fraction ingested-res child	unitless	1	USEPA 1995

Table 3.3 RME Default Exposure Assumptions - continued

Parameter	Definition	Units	Default Value	Source
IR	Ingestion rate-main worker	mg/day	50	USEPA 1991
	Ingestion rate-excav worker	mg/day	330	USEPA 2001
	Ingestion rate-golfer	mg/day	50	USEPA 1991
	Ingestion rate-res adult	mg/day	100	USEPA 1995
	Ingestion rate-res child	mg/day	200	USEPA 1995
INHR	Inhalation rate-main worker	m^3/hour	2.5	USEPA 1995
	Inhalation rate- excav worker	m^3/hour	2.5	USEPA 1995
	Inhalation rate-golfer	m^3/hour	2.5	USEPA 1995
	Inhalation rate-res adult	m^3/hour	0.83	USEPA 1995
	Inhalation rate-res child	m^3/hour	0.625	USEPA 1995
PEF	Particulate emission factor	m^3/kg	1.32E x 10^9	USEPA 1995
RfD	Reference Dose	mg/kg-day	chemical & pathway specific	IRIS 2001
SA	Available surface area-main worker	cm^2/day	3200	USEPA 1992
	Available surface area-excav worker	cm^2/day	3300	USEPA 2001
	Available surface area-golfer	cm^2/day	3000	TtNUS 1999
	Available surface area-res adult	cm^2/day	5000	USEPA 1992
	Available surface area-res child	cm^2/day	1800	USEPA 1992
SF	Slope Factor	mg/kg-day	chemical & pathway specific	IRIS 2001

EU, and the EPC was developed from the entire surface soil data set.

Current Recreational Golfer

The recreational golfer was assumed to be exposed at random and with equal coverage to the entire golf course. Hence, the entire golf course was assumed to the EU and the EPC was developed from the entire surface soil data set.

Future Excavation Worker

The future excavation worker was assumed to be exposed to surface soil. The entire sample consisting of both surface soil measurements and subsurface soil measurements was assumed to be representative of any location on the golf course at which excavation might occur in the future. Therefore, although the entire data set was used to develop an EPC for this receptor, the actual exposure unit would be much smaller than the entire golf course.

Future Resident (Adult and Child)

The future resident would be exposed in the area of a residential lot – about ½ an acre. Because a future residential lot could be located anywhere on the golf course, ideally, the most contaminated half acre would be used to represent the future residential EU. However, using a point estimate risk assessment, the 95% UCL from the entire golf course was used to estimate the concentration for residential exposure.

Choice of Exposure Units - Scenario 2

Future Resident (Adult and Child)

The most contaminated half acre of the golf course (2^{nd} green) was used to represent the future residential EU. The majority of pesticide use is on the greens and tees. Measurements from the greens and tees were assumed to be representative of the most contaminated area (½ an acre) on the golf course and the green-and-tee data set (Table 3.4) was used to develop an EPC for the future residential adult/child.

Choice of Exposure Units - Scenario 3

Current Recreational Golfer

There are two major areas of this golf course observed to have very high concentrations of pesticide-contaminated soil. First, the area between fairways 11 and 17, were used as the disposal pit for empty, partially full, and full pesticide containers. Second, a cluster of buildings behind the 11th tee, were used as the pesticide mixing and storage facilities. To assume that the NAS Cecil Field golf course is representative of "all golf courses", the data from these two areas was extracted from the "entire" golf course data set and the EPC was developed from the remaining data set (Table 3.5). This assumption is based on the fact that most golf courses do not have buried pits of pesticide containers potentially leaching into the soil.

Exposure Calculations

The exposure was assumed to occur via the dermal, ingestion and inhalation of soil pathways. Risks were calculated by the following exposure equations based on EPA (USEPA 1989, 1991 and 1995) guidance:

$$\text{Risk}_{(\textit{ingestion})} = \frac{(\text{Cs} * \text{IR} * \text{FI} * \text{EF} * \text{ED} * \text{CF})}{\text{AT} * \text{BW}} \times \mathit{SF} \quad (5)$$

$$\text{Risk}_{(\textit{dermal})} = \frac{(\text{Cs} * \text{CF} * \text{AF} * \text{ABS} * \text{EF} * \text{ED})}{\text{AT} * \text{BW}} \times \mathit{SF} \quad (6)$$

$$\text{Risk}_{(\textit{inhalation})} = \frac{(\text{Ca} * \text{INHR} * \text{ET} * \text{EF} * \text{ED})}{\text{AT} * \text{BW}} \times \mathit{SF} \quad (7)$$

$$\text{HI}_{(\textit{ingestion})} = \frac{(\text{Cs} * \text{IR} * \text{FI} * \text{EF} * \text{ED} * \text{CF})}{\text{AT} * \text{BW}} \times (1/\mathit{RfD}) \quad (8)$$

Table 3.4 Exposure Point Concentrations based on the 95% UCL of the Green-and Tee Data Set

Chemical	**Exposure Point Concentration Point Estimate (Dermal & Ingestion)** mg/kg	**Exposure Point Concentration Point Estimate (Inhalation)**[b] m^3/kg
4,4-DDT	0.563	8.14E-09
Alpha-Chlordane	10.745	1.31E-08
Arsenic	17.28[a]	4.27E-10
Chlordane (nonstereospecific)	100.25	7.59E-08
Dieldrin	0.271[a]	2.05E-10
Gamma-Chlordane	12.74[a]	9.65E-09
Heptachlor Epoxide	0.449	3.4E-10

[a]Exposure Point Concentration values derived via standard bootstrap method.
[b]Exposure Point Concentration values for inhalation (mg/m^3) = EPC_{soil} (mg/kg)/PEF (m^3/kg)

$$HI_{(dermal)} = \frac{\underline{Cs * CF * AF * ABS * EF * ED * SA)}}{AT * BW} \times (1/\ RfD) \quad (9)$$

$$HI_{(inhalation)} = \frac{(Ca * INHR * ET * EF * ED)}{AT * BW} \times (1/\ RfD) \quad (10)$$

$$\text{Combined Total Risk}^{\ddagger} = Risk_{(ingestion)} + Risk_{(dermal)} + Risk_{(inhalation)} \quad (11)$$

$$\text{Combined Total HI} = HI_{(ingestion)} + HI_{(dermal)} + HI_{(inhalation)} \quad (12)$$

where:

ABS	=	Absorption factor soil (unitless)
AF	=	Adherence factor soil to skin (mg/cm^2)
AT	=	Averaging time; carcinogens or noncarcinogens (days)
BW	=	Body weight (kg)
Ca	=	Air exposure point concentration (mg/m^3)
CF	=	Conversion factor (kg/mg)
Cs	=	Concentration in soil (mg/kg)
ED	=	Exposure duration (years)
EF	=	Exposure frequency (days/years)
ET	=	Exposure time (hour/day)
FI	=	Fraction ingested (unitless)
INHR	=	Inhalation rate (m^3/hour)
IR	=	Ingestion rate (mg/day)
PEF	=	Particulate emission factor (m^3/kg)
RfD	=	Reference dose oral, dermal or inhalation $(mg/kg\text{-}day)^{-1}$
SA	=	Available surface area (cm^2)
SF	=	Slope factor-cancer oral, dermal or inhalation $(mg/kg\text{-}day)^{-1}$

‡For carcinogens, the resident adult is assessed as an age-apportioned adult/child.

The RME exposure parameters (Table 3.2) used for each receptor in this risk assessment and the reference dose/cancer potency slope factors derived from the IRIS database are listed in Table 3.6. Equations 5 through 7 represent the standard equations used to estimate risks, and equations 8 – 10 represent hazard indexes for each individual pathway (ingestion, dermal contact and inhalation). Equations 11 and 12 represent combined risks or HIs for a receptor. The total risk and HIs are utilized to identify chemicals of concern.

Table 3.5 Exposure Point Concentrations based on the 95% UCL of the Golf Course Data Set Minus the Extracted Contaminated Areas

Chemical	**Distribution**	**Exposure Point Concentration Point Estimate (Dermal & Ingestion)** mg/kg	**Exposure Point Concentration Point Estimate (Inhalation)**[b] m^3/kg
4,4-DDD	N	0.269[a]	2.04E-10
4,4-DDT	LN	0.263[a]	2.00E-10
Alpha-Chlordane	LN	1.544[a]	1.17E-09
Arsenic	LN	7.872[a]	5.96E-09
Chlordane (technical)	N	23.500[a]	1.78E-08
Chlordane (nonstereospecific)	LN	15.193[a]	1.15E-08
Dieldrin	LN	0.409[a]	3.10E-10
Gamma-Chlordane	LN	1.606[a]	1.22E-09
Heptachlor Epoxide	LN	0.266[a]	2.01E-10
Toxaphene	LN	6.291[a]	4.77E-09

[a]Exposure Point Concentration values derived via standard bootstrap method.
[b]Exposure Point Concentration values for inhalation (mg/m^3) = EPC_{soil} (mg/kg) / PEF (m^3/kg).

RESULTS AND DISCUSSION

Scenario 1

Under the current land use scenario, individual carcinogenic risks and nocarcinogenic hazards from the golf course soil to the on-unit maintenance worker and recreational golfer are summarized in Table 3. 7. The total carcinogenic risks (excess cancer lifetime risk) associated with exposure to soil for the on-unit maintenance worker and recreational golfer are 7×10^{-4} and 1×10^{-4}, respectively, via the ingestion and dermal pathways.

Under the future land use scenario, carcinogenic risks and noncarcinogenic hazards for the excavation worker and residential adult/child are also summarized in Table 3.7. The total carcinogenic risks associated with exposure to soil for the excavation worker and residential adult/child are 8×10^{-5} and 4×10^{-3}, respectively, via the ingestion and dermal pathways.

The combined pathway exposure route HI for the resident adult was 1.24 and the child 4.6 (via the ingestion pathway). For noncarcinogens, the single-point RME hazard index for the on-unit maintenance worker, excavation worker and golfer were all below EPA's action level of 1.0. None of the receptors exceeded the risks and hazards via the inhalation pathway (Table 3.7). For every receptor and pathway of this assessment, toxaphene represented greater than 90% of the risk.

Scenario 2

Table 3.8 summarizes the risks to the future resident adult and child based on a residential lot – about ½ an acre. The most contaminated ½ an acre data (Table 3.4) calculated a carcinogenic risk of 2×10^{-4} (ingestion and dermal) for the resident

Table 3.6 Reference Dose and Slope Factor Values

Chemical	Oral RfD[a] (mg/kg-day)	Surrogate RfD (mg/kg-day)	Oral SF[a] (mg/kg-day)$^{-1}$	Surrogate SF (mg/kg-day)$^{-1}$	Oral-to-Dermal Adjustment Factor[b]	Surrogate Oral-to-Dermal Adjustment Factor[b]
4,4-DDD	-	5×10^{-4}[c]	2.4×10^{-1}	-	0.700	-
4,4-DDT	5×10^{-4}	-	3.4×10^{-1}	-	0.700	-
Alpha-Chlordane	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Arsenic	3×10^{-4}	-	1.5	-	-	0.800[e]
Chlordane	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Chlordane (technical)	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Dieldrin	5×10^{-5}	-	1.6×10^{1}	-	0.500	-
Gamma-Chlordane	5×10^{-4}	-	3.5×10^{-1}	-	0.500	-
Heptachlor Epoxide	1.3×10^{-5}	-	9.1	-	0.720	-
Total Chlordane	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Toxaphene	No Data	-	1.1	-	0.500	-

[a]Values derived from IRIS 2002.

[b]Values derived from USEPA Region IX PRG table (USEPA 2001).

[c]The Oral RfD for 4,4-DDT (5×10^{-4}) was used as a surrogate for 4,4-DDD.

[d]The Oral SF (3×10^{-5}) and Oral RfD (5×10^{-4}) for gamma-chlordane was used as a surrogate for alpha-chlordane, chlordane, chlordane (technical), and total chlordane.

[e]Default value per EPA Region IV guidance (USEPA 1995).

Dermal Slope Factor = (Oral SF) /(Oral-to-Dermal Adjustment Factor).

Dermal Reference Dose = (Oral RfD) x (Oral-to-Dermal Adjustment Factor).

Table 3.7 Summary of Human Health Associated Risks/Hazards NAS Cecil Field Golf Course

MEDIA	RECEPTOR	COCs	EXPOSURE ROUTE			EXPOSURE ROUTE TOTAL (Estimated Lifetime Cancer Risk)	HAZARD INDEX			EXPOSURE ROUTE TOTAL (Estimated Hazard Index)	PRIMARY TARGET ORGAN
			Ingestion	Dermal	Inhalation		Ingestion	Dermal	Inhalation		
Surface Soil (0-1 ft)	**On-Unit Worker**	Arsenic	4.E-06	3.E-07	1.E-08	4.E-06	0.024	0.002	-	0.026	Skin
		4,4'-DDD	5.E-06	5.E-06	1.E-08	1.E-05	0.117	0.107	0.00003	0.224	Multiple
		Chlordane (NS)	2.E-06	3.E-06	7.E-10	5.E-06	0.038	0.048	0.00002	0.086	Liver
		Chlordane (T)	2.E-06	2.E-06	5.E-10	4.E-06	0.026	0.034	0.000003	0.060	Liver
		Dieldrin	3.E-06	4.E-06	9.E-10	6.E-06	0.010	0.013	-	0.023	Liver
		Toxaphene	3.E-04	4.E-04	9.E-08	6.E-04	-	-	-	**-**	
		Total On-Unit Worker	*3.E-04*	*4.E-04*	*1.E-07*	***7E-04***	*0.215*	*0.204*	*0.0001*	***0.418***	
	Excavation Worker	Arsenic	1.E-06	4.E-09	5.E-10	1.E-06	0.157	0.001	-	0.158	Skin
		4,4'-DDD	1.E-06	6.E-08	9.E-11	1.E-06	0.773	0.033	-	0.806	Multiple
		Toxaphene	7.E-05	4.E-06	3.E-09	8.E-05	-	-	-	-	Liver
		Total Excavation Worker	*7.E-05*	*4.E-06*	*3.E-09*	***8.E-05***	*0.930*	*0.034*	-	***0.964***	
	Recreational Golfer	Arsenic	1.E-06	6.E-09	2.E-09	1.E-06	0.010	0.0001	-	0.0096	Skin
		4,4'-DDD	2.E-06	1.E-07	3.E-10	2.E-06	0.047	0.003	-	0.050	Liver
		Toxaphene	9.E-05	8.E-06	1.E-08	1.E-04	-	-	-	-	
		Total Recreational Golfer	*9.E-05*	*8.E-06*	*1.E-08*	***1.E-04***	*0.056*	*0.003*	-	***0.059***	
	Resident Adult* **(*Lifetime Receptor*)**	Arsenic	3.E-05	9.E-07	2.E-08	4.E-05	0.067	0.004	-	0.071	Skin
		4,4'-DDD	4.E-05	1.E-05	4.E-09	6.E-05	0.328	0.234	-	0.562	Liver
		4,4'-DDT	3.E-06	1.E-06	2.E-10	5.E-06	0.018	0.013	0.000002	0.031	Liver
		Alpha-Chlordane	5.E-06	2.E-06	3.E-10	7.E-06	0.026	0.026	0.00001	0.052	Multiple
		Chlordane (NS)	2.E-05	9.E-06	1.E-09	3.E-05	0.105	0.105	0.00002	0.211	Liver
		Chlordane (T)	1.E-05	6.E-06	9.E-10	2.E-05	0.074	0.074	0.00002	0.147	Liver
		Dieldrin	3.E-05	1.E-05	2.E-10	4.E-05	0.028	0.028	0.00000	0.056	Liver
		Gamma-Chlordane	7.E-06	3.E-06	4.E-10	9.E-06	0.033	0.033	0.00001	0.065	Liver
		Heptachlor Epoxide	3.E-06	9.E-07	2.E-10	4.E-06	0.022	0.015	0.000002	0.038	Liver
		Total Chlordane	2.E-06	7.E-07	1.E-10	2.E-06	0.008	0.008	0.000002	0.016	Liver
		Toxaphene	3.E-03	1.E-03	1.E-07	4.E-03	-	-	-	-	
		Total Resident Adult	*3.E-03*	*1.E-03*	*2.E-07*	***4.E-03***	*0.709*	*0.540*	*0.0001*	***1.24***	

No EPA-verified toxicity (RfD) values available for this constituent.
*For carcinogens, the resident adult is assessed as an age-apportioned adult/child.
NS = nonstereospecific T = technical

Table 3.7 Summary of Human Health Associated Risks/Hazards NAS Cecil Field Golf Course – continued

MEDIA	RECEPTOR	COCs	EXPOSURE ROUTE			EXPOSURE ROUTE TOTAL (Estimated Lifetime Cancer Risk)	HAZARD INDEX			EXPOSURE ROUTE TOTAL (Estimated Hazard Index)	PRIMARY TARGET ORGAN
			Ingestion	Dermal	Inhalation		Ingestion	Dermal	Inhalation		
Surface Soil (0-1 ft)	**Resident Child**	4,4'-DDD	*	*	*	*	3.06	0.393	-	3.45	Liver
		Aroclor-1254	*	*	*	*	0.98	0.177	0.0001	1.16	Multiple
		Total Resident Child					*4.04*	*0.570*	*0.0001*	***4.61***	

-No EPA-verified toxicity (RfD) values available for this constituent.
*For carcinogens, the resident adult is assessed as an age-apportioned adult/child.

adult/child. Comparatively, the combined risk calculated using the entire golf course data was 4 x 10^{-3}. In this case, the cancer risk from the entire golf course exceeds the risks by the most contaminated ½ acre by 20-fold. For noncarcinogenic hazards the HI, for the resident child was 5.07 (ingestion), and the resident adult was below the EPA's action level of 1.0. Comparatively, the combined hazard using the entire golf course data was 4.61. In this case, the hazard index from the entire golf course exceeds the hazard by the most contaminated ½ acre by 1-fold. The inhalation risk was negligible for this scenario.

Scenario 3

For the recreational golfer, a combined carcinogenic risk of 3 x 10^{-6}, represents the risk from the NAS Cecil Field golf course if the data from the pits and the buildings were extracted from the data set. The ingestion pathway (2 x 10^{-6}) is the only pathway which exceeds EPA's 1 x 10^{-6} action level (Table 3.9). Comparatively, the combined risk calculated using the entire golf course data was 1 x 10^{-4}. In this case, the cancer risk from the entire golf course exceeds the risks by the extracted pits/buildings data by 200-fold.

For noncarcinogenic hazards, all pathways were below the EPA's action level of 1.0, and the inhalation risk/hazard was negligible.

The NAS Cecil Field golf course soil had pesticide (chlordane) concentrations on the golf greens 4 times greater than the concentration on the fairways, and 2 times greater than the golf tees (Figure 3.2). This confirms studies by Smith et. al (1993) that "golf putting greens are a focal point of environmental concerns because they receive more pesticides per unit area than any other turfgrass sites".

Table 3.8 Summary of Human Health Associated Risks/Hazards NAS Cecil Field Golf Course Green-and Tee Data Set

MEDIA	RECEPTOR	COCs	EXPOSURE ROUTE			EXPOSURE ROUTE TOTAL (Estimated Lifetime Cancer Risk)	HAZARD INDEX			EXPOSURE ROUTE TOTAL (Estimated Hazard Index)	PRIMARY TARGET ORGAN
			Ingestion	Dermal	Inhalation		Ingestion	Dermal	Inhalation		
Surface Soil (0-1 ft)	**Resident Adult*** **(*Lifetime Receptor*)**	Arsenic	4.E-05	1.E-06	8.E-10	4.E-05	0.079	0.005	-	0.084	Skin
		4,4'-DDT	3.E-07	9.E-08	3.E-10	4.E-07	0.002	0.001	0.000003	0.003	Liver
		Alpha-Chlordane	6.E-06	3.E-06	6.E-10	8.E-06	0.029	0.029	0.000011	0.059	Multiple
		Chlordane (NS)	5.E-05	2.E-05	3.E-09	8.E-05	0.275	0.275	0.000065	0.549	Liver
		Dieldrin	7.E-06	3.E-06	4.E-11	1.E-05	0.007	0.007	0.000001	0.015	Liver
		Gamma-Chlordane	7.E-06	3.E-06	4.E-10	1.E-05	0.035	0.035	0.000008	0.070	Liver
		Heptachlor Epoxide	6.E-06	2.E-06	4.E-10	8.E-06	0.047	0.033	0.000004	0.080	Liver
		Total Resident Adult	*1.E-04*	*3.E-05*	*6.E-09*	***2.E-04***	*0.474*	*0.385*	*0.0001*	***0.860***	
	Resident Child	Arsenic	*	*	*	*	0.736	0.008	-	0.745	Skin
		4,4'-DDT	*	*	*	*	0.014	0.002	0.00001	0.016	Liver
		Alpha-Chlordane	*	*	*	*	0.275	0.049	0.00005	0.324	Multiple
		Chlordane (NS)	*	*	*	*	2.563	0.461	0.0003	3.025	Liver
		Dieldrin	*	*	*	*	0.069	0.012	0.000003	0.082	Liver
		Gamma-Chlordane	*	*	*	*	0.326	0.059	0.00003	0.384	Liver
		Heptachlor Epoxide	*	*	*	*	0.442	0.055	0.00002	0.497	Liver
		Total Resident Child					*4.426*	*0.647*	*0.0004*	***5.073***	

-No EPA-verified toxicity (RfD) values available for this constituent.
*For carcinogens, the resident adult is assessed as an age-apportioned adult/child.

CONCLUSIONS

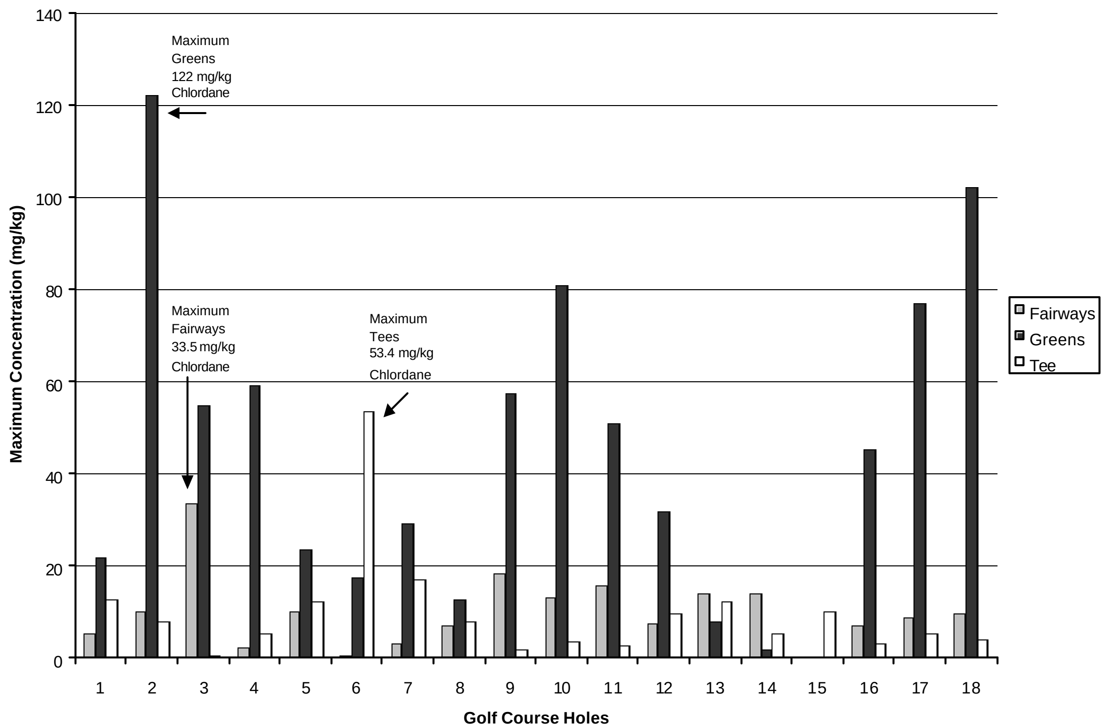
Golf course construction has grown at an ever-increasing rate, and the sport of golfing is growing among the young. Most golf courses are usually built in suburban areas with surrounding residential properties. Despite the increase in golf course construction and the sport of golfing, there are few data available on the human health impacts to golf course workers, golfers and residents. The results of the risk assessment for the NAS golf course are similar to those obtained by Clark et al. (2000), who found that there are volatile and dislodgeable residues available for golfer exposure following pesticide application to turfgrass and that not all of these exposures can be deemed completely safe using the USEPA Hazard Quotient assessment. The majority of TCL VOCs, TCL SVOCs, TAL inorganics, and Pesticide/PCBs initially examined in this risk assessment were deemed safe by the USEPA HI and National Oil and Hazardous Substance Pollution Contingency Plan (NCP) criteria. According to these guidelines and EPA RAGs (USEPA 1989), the compounds were excluded from the risk assessment because their individual constituents have risk levels less than 1×10^{-6} and hazard indexes less than 1.0. However, the pesticides that exceeded the established criteria are those currently banned for use by the EPA.

Many of the exposure parameters used in this risk assessment are default values recommended by the EPA. These default parameters are usually conservative and do not necessarily reflect the actual behavior of receptors, but are used in the absence of site-specific information. Also, the assumptions regarding future land use are speculative.

By extracting data from the contaminated pits/buildings data set, the risks to the golfer exceeded the EPA's action level of 1×10^{-6} for ingestion. This risk assessment

Table 3.9 Summary of Human Health Associated Risks/Hazards NAS Cecil Field Golf Course Extracted Data Set

MEDIA	RECEPTOR	COCs	EXPOSURE ROUTE			EXPOSURE ROUTE TOTAL (Estimated Lifetime Cancer Risk)	HAZARD INDEX			EXPOSURE ROUTE TOTAL (Estimated Hazard Index)	PRIMARY TARGET ORGAN
			Ingestion	Dermal	Inhalation		Ingestion	Dermal	Inhalation		
Surface Soil (0-1 ft)	**Recreational Golfer**	Arsenic	7.E-07	3.E-09	9.E-10	7.E-07	0.0051	0.00003	-	0.0052	Skin
		4,4'-DDD	4.E-09	2.E-10	7.E-13	4.E-09	0.0001	0.00001	0.00000001	0.0001	Liver
		4,4'-DDT	5.E-09	3.E-10	7.E-13	5.E-09	0.0001	0.00001	0.0000002	0.0001	Multiple
		Alpha-Chlordane	3.E-08	3.E-09	4.E-12	3.E-08	0.0006	0.0001	0.0000021	0.0007	Liver
		Chlordane (NS)	3.E-07	2.E-08	4.E-11	3.E-07	0.0059	0.0005	0.0000032	0.0064	Liver
		Chlordane (T)	5.E-07	4.E-08	6.E-11	5.E-07	0.0092	0.0008	0.0000000	0.0100	Liver
		Dieldrin	4.E-07	3.E-08	5.E-12	4.E-07	0.0016	0.0001	0.0000002	0.0017	Liver
		Gamma-Chlordane	3.E-08	3.E-09	4.E-12	3.E-08	0.0006	0.0001	0.0000006	0.0007	Liver
		Heptachlor Epoxide	1.E-07	8.E-09	2.E-11	1.E-07	0.0040	0.0002	-	0.0042	Liver
		Toxaphene	4.E-07	3.E-08	5.E-11	4.E-07	-	-		-	
		Total Recreational Golfer	*2.E-06*	*1.E-07*	*1.E-09*	***3.E-06***	*0.0273*	*0.0018*	*0.0000063*	***0.0291***	



(Figure 3.2 Maximum Concentration Tee/Green/Fairway Surface Soil NAS Cecil Field) scenario is probably more representative of a “typical” golf course. The results show that golfers should try to minimize incidental soil ingestion.

Based on the results of this risk assessment, we recommend that pesticides for lawn and golf course maintenance should not contain known or probable carcinogens without appropriate use of personal protective equipment, by workers during application. Attention should be given to the leachability and toxicity of pesticides used. Golfers can reduce their exposure to pesticides by scheduling their play to avoid recent pesticide applications. Workers can reduce their exposure with personal protective equipment (PPE) and engineering controls levels.

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CHAPTER 4

COMPARISON OF A POINT ESTIMATE AND PROBABILISTIC RISK ASSESSMENT OF A MILITARY GOLF COURSE SLATED FOR BASE CLOSURE[1]

[1]Hodoh, O.B., T.W. Simon and M.A. Smith. To be submitted to *Risk Analysis*.

ABSTRACT

Using current EPA guidelines, a point estimate (PE) risk assessment was compared to a probabilistic risk assessment using a one-dimensional Monte Carlo analysis (MCA) considering uncertainty in the concentration term. The site was a golf course on a Naval Air Station slated for closure. Future reuse plans include industrial, public, recreational and residential use. Cancer risks and noncancer health hazards from human exposure to a golf course potentially contaminated with pesticides, metals and organic compounds were evaluated. The major objective of this study was to compare the results of the PE and probabilistic methods when applied to various exposure scenarios. The EPAs "reasonably maximally exposed" individual scenarios include a maintenance worker, excavation worker and recreational golfer. The RMEs represent the highest exposure that is reasonably expected to occur in a small, but definable "high-end" segment of the potentially exposed population. Future residential exposures to an adult or child potentially exposed to contaminated soil due to recreational and residential activities were also evaluated. The point estimate risk assessment predicted a risk range of 8×10^{-5} to 4×10^{-3} carcinogenic, and a hazard index of 0.059 to 4.6 (noncarcinogenic) for the receptors in this study. The values obtained in this study are approximately 1 to 30-fold greater than the 95th percentile risk predicted in the probabilistic risk assessment and some exceeded even the 97.5th percentile risk estimate. The extent of conservatism built into the point estimate risk assessment may result in significant cleanup cost compared to the probabilistic approach.

Key Words: risk assessment, golf, Monte Carlo, variability, uncertainty

1. INTRODUCTION

The current guidelines for human health risk assessments uses conservative "generally 95% UCL (upper confidence limits)" point estimates (PE) (i.e., single values) to characterize the health hazards associated with exposure to chemicals in the environment (Smith 1994). The probabilistic methods currently proposed by the USEPA focus on Monte Carlo analysis (MCA) as a tool for quantifying variability and uncertainty in risk (USEPA 1999a). The probabilistic risk assessment uses a distribution of data rather than a single point estimate to represent key exposure variables (chemical concentrations, frequency duration of contact, body weight, etc.) (Finley 1994b). The MCA method can be applied to the same exposure scenarios presented in the point estimate approach. It has been suggested that probabilistic analyses offer a more accurate estimate of the plausible risk, especially at the "upper-bound" exposures (between 95th and 99th percentile) (Burmaster 1991). In this study, probabilistic methods currently proposed by the EPA (USEPA 1999a) were applied to several complex chemical exposure scenarios. The results were contrasted with those obtained using the point estimate approach currently recommended (USEPA 1989). The specific objectives for this study were to illustrate the advantages and disadvantages of the point estimate vs. probabilistic analysis, and to examine the magnitude of the differences between the risk estimates obtained using these two methods. A sensitivity analysis was also performed to identify the exposure parameters that contributed the greatest uncertainty in the risk estimates.

Using current EPA guidelines (USEPA 1989) the point estimate approach and RME scenarios for the Naval Air Station Cecil Field golf course have been described in Hodoh et al. (2002).

2. METHODS

Probabilistic risk assessment (PRA) as defined by EPA "is the general term for risk assessments that use probability models to represent likelihood of different risk levels in a population (i.e., variability) or to characterize uncertainty in risk estimates" (USEPA 1999a). For human health risk assessments, the probability distributions for risk reflect variability or uncertainty in exposure (USEPA 1999a).

The Monte Carlo (MC) simulation is the most common method for PRA. The term "Monte Carlo" was derived from Monte Carlo, Monaco, based on casino gambling and games of chance, which exhibit random behavior (Decisioneering 2000). With today's powerful desktop computers, Monte Carlo simulations can be performed by most with "reasonably close approximations of a risk distribution using numerical techniques" (USEPA 1999a). The MCA or Monte Carlo simulation is "a technique for repeatedly sampling from probability distributions to derive a distribution of outcomes (e.g., risks)" (USEPA 1999a). The US EPA's *Guiding Principles for Monte Carlo Analysis* (USEPA 1997a) and *Risk Assessment Guidance for Superfund: Volume 3 - (Part A, Process for Conducting Probabilistic Risk Assessment)* DRAFT (USEPA 1999a), were used as the primary guidance documents for the probabilistic assessment. After the exposure models were defined, the next step was to (1) identify point estimates for all of the model inputs, (2) find the distributions/probability distributions (Table 4.1) for each input, and (3) input data into the simulation program. The LHS was performed for 10,000 iterations and the

Table 4.1 Summary of Point Estimates and Probability Distributions - Exposure Factors NAS Cecil Field Golf Course

Parameter	**Point Estimate**	**Units**	**Source**	**Distribution**	**Mean**	**SD**	**Min**	**Likeliest**	**Max**	**Source**
Adherence factor-main worker	1	mg/cm^2	USEPA 1995	Lognormal	0.52	0.9	-	-	-	Finley et al. 1994c
Adherence factor-exc worker	0.3	mg/cm^2	USEPA 2001	Lognormal	0.52	0.9	-	-	-	Finley et al. 1994c
Adherence factor-golfer	0.07	mg/cm^2	TtNUS, 1999	Lognormal	0.06176	3.71	-	-	-	TtNUS 1999
Adherence factor-res adult	1	mg/cm^2	USEPA 1995	Lognormal	0.52	0.9	-	-	-	Finley et al. 1994c
Adherence factor-res child	1	mg/cm^2	USEPA 1995	Lognormal	0.52	0.9	-	-	-	Finley et al. 1994c
Available surface area-main worker	3200	cm^2/day	USEPA 1992	Lognormal	4550	550	-	-	-	Burmaster & Crouch 1997
Available surface area-exc worker	3300	cm^2/day	USEPA 2001	Lognormal	4550	550	-	-	-	Burmaster & Crouch 1997
Available surface area-golfer	3000	cm^2/day	TtNUS, 1999	Lognormal	18942	1.16	-	-	-	TtNUS 1999
Available surface area-res adult	5000	cm^2/day	USEPA 1992	Lognormal	4550	550	-	-	-	Burmaster & Crouch 1997
Available surface area-res child	1800	cm^2/day	USEPA 1992	Lognormal	1550	225	-	-	-	Burmaster & Crouch 1997
Body weight-main worker	70	kg	USEPA 1991	Lognormal	77.1	13.5	-	-	-	Smith 1994
Body weight-exc worker	70	kg	USEPA 1991	Lognormal	77.1	13.5	-	-	-	Smith 1994
Body weight-golfer	70	kg	USEPA 1991	Lognormal	77.1	13.5	-	-	-	Smith 1994
Body weight-res adult	70	kg	USEPA 1995	Lognormal	77.1	13.5	-	-	-	Smith 1994
Body weight-res child	15	kg	USEPA 1991	Lognormal	14.2	3.02	-	-	-	Burmaster & Crouch 1997
Exposure duration-main worker	25	years	USEPA 1991	Lognormal	7.3	8.7	-	-	-	Department of Labor 1992
Exposure duration-exc worker	1	years	USEPA 1991	Constant	-	-	-	-	-	
Exposure duration-golfer	20	years	TtNUS, 1999	Lognormal	10.61	2.02	-	-	-	TtNUS 1999
Exposure duration-res adult	24	years	USEPA 1995	Lognormal	11.36	13.72	-	-	-	Israeli & Nelson 1992
Exposure duration-res child	6	years	USEPA 1995	Lognormal	11.36	13.72	-	-	-	Israeli & Nelson 1992

Table 4.1 Summary of Point Estimates and Probability Distributions - Exposure Factors NAS Cecil Field Golf Course - continued

Parameter	**Point Estimate**	**Units**	**Source**	**Distribution**	**Mean**	**SD**	**Min**	**Likeliest**	**Max**	**Source**
Exposure frequency-main worker	250	days/year	USEPA 1991	Triangular	-	-	156	245	307	USEPA 1991
Exposure frequency-exc worker	250	days/year	USEPA 2001	Triangular	-	-	156	245	307	USEPA 1991
Exposure frequency-golfer	100	days/year	TtNUS 1999	Lognormal	97.45	1.93	-	-	-	TtNUS 1999
Exposure frequency-res adult	350	days/year	USEPA 1995	Triangular	-	-	180	345	365	Smith 1994
Exposure frequency-res child	350	days/year	USEPA 1995	Triangular	-	-	180	345	365	Smith 1994
Exposure time -main worker	8	hours/day	USEPA 1995	Lognormal	7.9	4.14	-	-	-	EFH, Table 15-107, 1997a
Exposure time -exc worker	8	hours/day	USEPA 1995	Lognormal	7.9	4.14	-	-	-	EFH, Table 15-107, 1997a
Exposure time -golfer	3.65	hours/day	USEPA 1997	Normal	3.65	3.52	-	-	-	EFH, Table 15-109, 1997a
Exposure time-res adult	15	hours/day	USEPA 1995	Uniform	-	-	8	-	20	Finley & Paustenbach 1994a
Exposure time -res child	18	hours/day	USEPA 1995	Uniform	-	-	8	-	20	Finley & Paustenbach 1994a
Fraction ingested-main worker	1	unitless	USEPA 1995	Uniform	-	-	0.1	-	0.5	Finley & Paustenbach 1994a
Fraction ingested-exc worker	1	unitless	USEPA 1995	Uniform	-	-	0.1	-	0.5	Finley & Paustenbach 1994a
Fraction ingested-golfer	1	unitless	USEPA 1995	Uniform	-	-	0.1	-	0.5	Finley & Paustenbach 1994a
Fraction ingested-res adult	1	unitless	USEPA 1995	Uniform	-	-	0.1	-	0.5	Finley & Paustenbach 1994a
Fraction ingested-res child	1	unitless	USEPA 1995	Uniform	-	-	0.1	-	1	Finley & Paustenbach 1994a
Ingestion rate-main worker	50	mg/day	USEPA 1991	Triangular	-	-	0.1	25	50	Lagoy 1987
Ingestion rate-exc worker	330	mg/day	USEPA 2001	Lognormal	1.8*	30.51*	-	-	-	USEPA 2001
Ingestion rate-golfer	50	mg/day	USEPA 1991	Triangular	-	-	0.1	25	50	Lagoy 1987

Table 4.1 Summary of Point Estimates and Probability Distributions - Exposure Factors NAS Cecil Field Golf Course - continued

Parameter	Point Estimate	Units	Source	Distribution	Mean	SD	Min	Likeliest	Max	Source
Ingestion rate-res adult	100	mg/day	USEPA 1995	Triangular	-	-	0.1	25	50	Lagoy 1987
Ingestion rate-res child	200	mg/day	USEPA 1995	Triangular	-	-	5	100	500	Finley et al. 1994b
Inhalation rate-main worker	2.5	m^3/hour	USEPA 1995	Triangular	-	-	0.75	2.36	4.00	USEPA 1991
Inhalation rate- exc worker	2.5	m^3/hour	USEPA 1995	Triangular	-	-	0.75	2.36	4.00	USEPA 1991
Inhalation rate-golfer	2.5	m^3/hour	USEPA 1995	Lognormal	1.90	0.650	-	-	-	Cal EPA 1996
Inhalation rate-res adult	0.83	m^3/hour	USEPA 1995	Lognormal	1.90	0.650	-	-	-	Cal EPA 1996
Inhalation rate-res child	0.625	m^3/hour	USEPA 1995	Lognormal	0.85	0.213	-	-	-	Cal EPA 1996

*Geometric mean, Geometric standard deviation results were used to estimate various percentiles of risk using the standard risk equations and cancer slope factors for each chemical of concern.

2.1 Variability and Uncertainty in the PE and PRA

The EPA currently recommends that MC simulation be used to analyze uncertainty and variability surrounding single-point risk estimates for the multiple descriptors of risk. The uncertainty analysis was performed using the software package Crystal Ball, Version 2000.2 (Decisioneering Inc 2000), in conjunction with Excel. The Crystal Ball software performed Monte Carlo simulations for the probabilistic distributions of the uncertain exposure parameters, using Latin Hypercube Sampling (LHS) technique to predict the multiplicative exposure factors. Each simulation was run with 10,000 iterations and the results were used to estimate various percentiles of risk using the standard EPA RME risk equations (USEPA 1991).

2.2 Exposure Factor Probability Distribution Functions (PDF) for the 1-D MCA

Table 4.1 provides a summary of the point estimate and the PDFs for every exposure parameter value used in the point estimate and MCA analysis. The values represent variability for all of the pathway-specific probability distribution functions for each exposure pathway. Also included in the table are their individual distributions and descriptive statistics. EPA (USEPA 1999) currently recommends that the PDFs used in the PRA may be developed from site-specific data, EPAs Exposure Factor Handbook and current literature PDFs. The major sources used to obtain parameter values were the Exposure Factors Handbook (EPA 1997c), as well as published scientific journal articles (Table 4.1).

2.3 Toxicity Values

The cancer potency slope factors and noncarcinogenic reference doses (Table 4.2) were obtained from EPA's IRIS (IRIS 2002) database and EPA Region IX PRG Table (USEPA 2001). Since the slope factors are characterized by a point estimate (toxicity values), rather than a probability distribution, this parameter was entered as a fixed value of 1.0, for running the uncertainty/sensitivity analysis model.

2.4 Variability and Uncertainty in the Soil Concentration Term

In PRA, the exposure point concentration (EPC) is usually entered as the 95% upper confidence limit (UCL) of the mean to account for uncertainty in the site characterization (USEPA 1992a). Due to surface water runoff and erosion by the wind, the concentration in the surface soil may change, which may affect the spatial variability of the contaminants in the golf course soil. Uncertainties in the estimate of the true mean may result from sample data and variation, location of the exposure unit, and physical and chemical processes.

The methods used to calculate the UCLs and confidence intervals (CI) are described in Hodoh et al. (2002). In the conventional risk assessment, the EPC (95% for the arithmetic mean) characterizes the uncertainty in the concentration term. Per USEPA 1999a, the 95% UCL and 95% lower confidence limit (LCL) represent the 95th percentile and the 5th percentile of the distribution of uncertainty around the mean. The statistical procedure used to calculate the 95% UCL of the means for the NAS Cecil Field golf course data set were derived from USEPA (1997b, 1999) methods for lognormal

Table 4.2 Reference Dose and Slope Factor Values

Chemical	Oral RfD[a] (mg/kg-day)	Surrogate RfD[a] (mg/kg-day)	Oral SF[a] (mg/ kg-day)$^{-1}$	Surrogate SF[a] (mg/ kg-day)$^{-1}$	Oral-to-Dermal Adjustment Factor[b*]	Surrogate Oral-to-Dermal Adjustment Factor[b*]
4,4-DDD	-	5×10^{-4}[c]	2.4×10^{-1}	-	0.700	-
4,4-DDT	5×10^{-4}	-	3.4×10^{-1}	-	0.700	-
Alpha-Chlordane	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Arsenic	3×10^{-4}	-	1.5	-	-	0.800[e]
Chlordane (NS)	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Chlordane (T)	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Dieldrin	5×10^{-5}	-	1.6×10^{1}	-	0.500	-
Gamma-Chlordane	5×10^{-4}	-	3.5×10^{-1}	-	0.500	-
Heptachlor Epoxide	1.3×10^{-5}	-	9.1	-	0.720	-
Total Chlordane	-	5×10^{-4}[d]	-	3.5×10^{-1}[d]	-	0.500[d]
Toxaphene	No Data	-	1.1	-	0.500	-

[a]Values derived from IRIS 2002.

[b]Values derived from USEPA Region IX PRG table (USEPA 2001).

[c]The Oral RfD for 4,4-DDT (5×10^{-4}) was used as a surrogate for 4,4-DDD.

[d]The Oral SF (3×10^{-5}) and Oral RfD (5×10^{-4}) for gamma-chlordane was used as a surrogate for alpha-chlordane, chlordane, chlordane (technical), and total chlordane.

[e]Default value per EPA Region IV guidance (USEPA 1995).

Dermal Slope Factor = (Oral SF) /(Oral-to-Dermal Adjustment Factor*).

Dermal Reference Dose = (Oral RfD) x (Oral-to-Dermal Adjustment Factor*).

* The adjustment factor used to convert the oral RfD values to dermal RfD values.

NS – nonsteroespecific

T - Technical

distributions and the bootstrap analysis. For some of the constituents, the 95% UCL of the mean was calculated via the standard bootstrap method because of the highly skewed nature of the distribution made the Bootstrap-t process unstable, and the standard bootstrap was more robust than the Bootstrap-t method (USEPA 1997b, Hodoh et al. 2002).

Table 4.3 summarizes the 90% CI for the arithmetic mean of the data using the two bootstrap methods and the H-statistic (USEPA 1992a) to compute the UCL of the mean of a lognormal distribution. The methods yield three multiple point estimates (95% LCL, sample mean and 95% UCL), which represent three PDF estimates for variability in risk, or the 90% CI for each percentile of the risk distribution.

To characterize uncertainty in the concentration term, multiple one-dimensional Monte Carlo (1-D MCA) simulations were run by selecting one of the three input parameters. The resulting risk distributions represent the 5th and 95th percentiles for uncertainty in the concentration term, and the mean represents the most likely risk estimate of the 90% upper and lower confidence limits of the distribution (USEPA 1999a).

The probabilistic simulations were performed on a personal computer with Crystal Ball® 2000 version 5.2 (Decisioneering Inc., 2000) and Microsoft® Excel 97. The simulation software sampled all distribution variables 10,00 times using the LHS strategy.

Table 4.3 Distribution Parameters - Uncertainty in the Soil Concentration

Chemical	Distribution	Exposure Point Concentration (***Dermal & Ingestion***) (mg/kg)	**5% LCL** (mg/kg)	**Arithmetic Mean** (mg/kg)	**95% UCL** (mg/kg)
4,4-DDD	LN	119.65[a]	0.101	46.06	135.6
4,4-DDT	LN	6.53	0.234	4.14	8.12
Alpha-Chlordane	LN	9.54	1.11	1.49	2.12
Arsenic	LN	14.62[a]	9.30	11.94	14.88
Chlordane (T)	N	26.87[a]	10.69	18.628[b]	26.77
Chlordane (NS)	LN	38.44	7.37	10.41	14.61
Dieldrin	LN	1.03	0.239	0.32	0.451
Gamma-Chlordane	LN	11.87	1.53	2.14	3.26
Heptachlor Epoxide	N	0.210	0.103	0.153[b]	0.226
Total Chlordane	LN	2.99[a]	0.125	1.26	3.33
Toxaphene	N	1460.8[a]	4.42	571.18[b]	1639.3

[a]Exposure Point Concentration values derived via standard bootstrap method.
[b]Sample mean due to normal distribution.
T - technical
NS - nonstereospecific

Chemical	Distribution	Exposure Point Concentration (***Inhalation***) (mg/m^3)	**5% LCL** (mg/m^3)	**Arithmetic Mean** (mg/m^3)	**95% UCL** (mg/m^3)
4,4-DDD	LN	9.1E-08[a]	7.7E-11	3.5E-08	1.0E-07
4,4-DDT	LN	4.9E-09	1.8E-10	3.1E-09	6.2E-09
Alpha-Chlordane	LN	7.2E-09	8.4E-10	1.1E-09	1.6E-09
Arsenic	LN	1.1E-08[a]	7.0E-09	9.0E-09	1.1E-08
Chlordane (T)	N	2.0E-08[a]	8.1E-09	1.41E-08[b]	2.0E-08
Chlordane (NS)	LN	2.9E-08	5.6E-09	7.9E-09	1.1E-08
Dieldrin	LN	7.8E-10	1.8E-10	2.4E-10	3.4E-10
Gamma-Chlordane	LN	9.0E-09	1.2E-09	1.6E-09	2.5E-09
Heptachlor Epoxide	N	1.6E-10	7.8E-11	1.16E-10[b]	1.7E-10
Total Chlordane	LN	2.3E-09[a]	9.5E-11	9.5E-10	2.5E-09
Toxaphene	N	1.1E-06[a]	3.3E-09	4.33E-07[b]	1.2E-06

[a]Exposure Point Concentration values derived via standard bootstrap method.
[b]Sample mean due to normal distribution.
T - technical
NS - nonstereospecific

2.5 Uncertainty Analysis

Uncertainties in the exposure parameters for the individual exposure pathways were evaluated for the current and future risk scenarios in this study. The uncertainty analysis was performed on the standard risk equations using the statistical information for the uncertain exposure parameters. The soil exposure equations and the parameters that were assessed include ingestion rate, inhalation rate, and exposure frequency exposure duration, averaging time, body weight, surface area, adherence of soil-on-skin factor, and fraction ingested. Specific uncertain parameters were applied for adults and children. The results from the uncertainty analysis were used to quantify the degree to which the standard default values overestimate the predicted percentiles of exposure (90 - 95th) that they are intended to estimate and determine which parameters are responsible for the majority of the variation (Dawoud and Purucker 1996).

2.6 Sensitivity Analysis

Sensitivity analyses were performed to evaluate the influence of each exposure variable on the risk estimates. The initial sensitivity analysis was performed in the point estimate risk assessment to determine which exposure pathways and variables have the greatest influence on risk. The risks and hazard indexes were calculated for each receptor and exposure pathway using RME risk equations and the input parameters are shown in Table 4.1. A sensitivity analysis was also performed with a 1-D MCA to determine which variables have the largest contribution to the variance in risk estimates. The risks and hazard indexes were calculated for each receptor and exposure pathway and the probability distribution input parameters found in Table 4.1. The sensitivity analysis values were measured by the Pearson Correlation Coefficient (r^2), and reported as percentages of contribution to the variance or uncertainty of the risks/hazard index.

3.0 RESULTS AND DISCUSSION

Further insight into the point estimate risk results were achieved by comparison with the probabilistic results. Copeland et al. (1993) stated that "the probabilistic approach to the characterization of health risk provides the risk manager with a more complete perspective on the potential variability in the risk estimate and can also identify factors contributing most significantly to variance in risk results". When the risks are expressed as probability distributions (e.g., based on mathematical probability), then the risk for the most highly exposed as well as the typical individual are presented (Copeland et. al 1993). The distributions described in Table 4.3 were used in the Monte Carlo simulations.

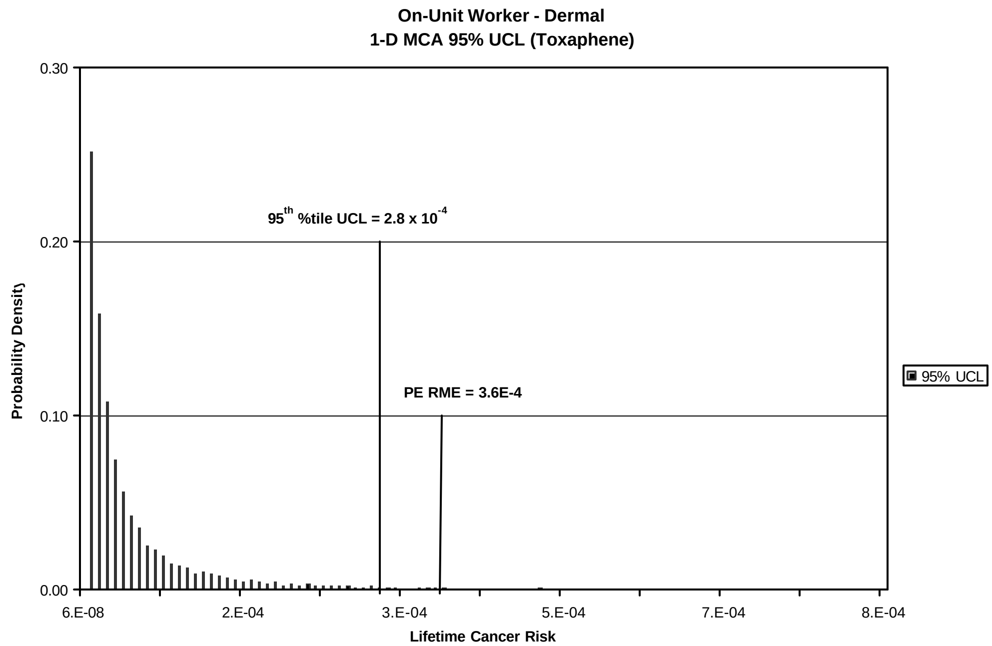
3.1 Current Land-Use Scenario 1-D MCA Results

3.1.1 On-Unit Maintenance Worker

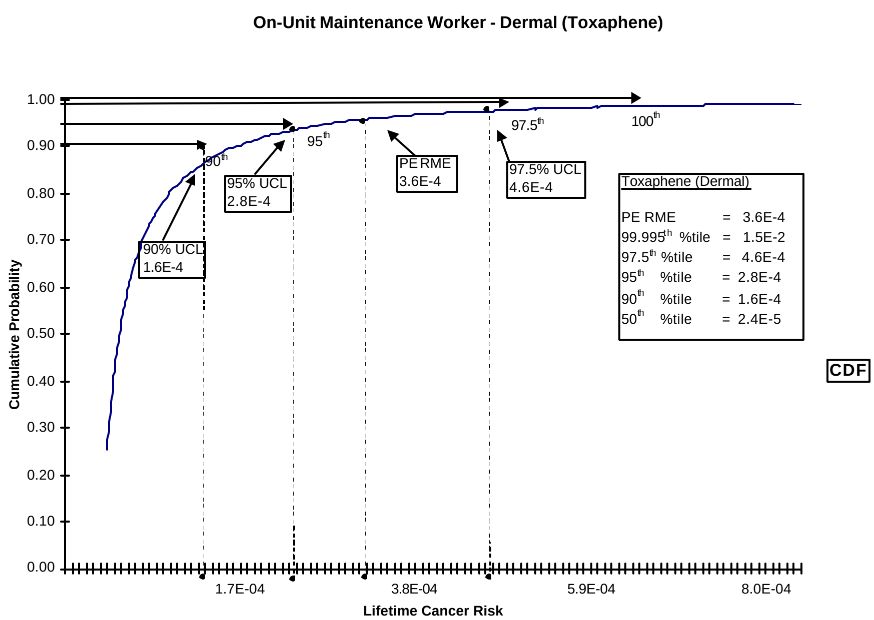
The results of the PRA predicted a 95th percentile excess lifetime cancer risk of 3 x 10^{-4}, and the 50th percentile (most likely exposure) was 3 x 10^{-5} (Table 4.4). The 1-D MCA for uncertainty (represents the sum of all constituents) in concentration at the 95th percentile of variability in risk ranged from 3 x 10^{-6} at the 5th percentile to 3 x 10^{-4} at the 95th percentile (represents the 90% confidence limits) (Table 4.4). Comparatively, the PE risk was 7 x 10^{-4} (Table 4.4). The predicted RME cancer risk exceeds the 95th percentile value predicted by the PRA by 4-fold. Figure 4.1A presents the ELCR vs. the relative probability for the final range of risks associated with exposure to toxaphene via the dermal pathway. The cumulative probability graph (Figure 4.1B) presents the

Table 4.4 PE and 1-D MCA Results for the On-Unit Maintenance Worker

Pathway	Chemical	Point Estimate Risk	50th %tile Risk	90th %tile Risk	95% LCL	95% Mean	95% UCL	97.5th %tile Risk	99.99th %tile Risk
Ingestion	4,4'-DDD	5.0E-06	2.5E-10	1.0E-09	1.2E-12	5.4E-10	1.6E-09	2.3E-09	1.4E-08
	Arsenic	3.8E-06	8.1E-08	3.5E-07	3.3E-07	4.1E-07	5.3E-07	7.5E-07	4.7E-06
	Chlordane (NS)	2.4E-06	1.8E-08	7.8E-08	5.9E-08	8.3E-08	1.2E-07	1.6E-07	7.5E-07
	Chlordane (T)	1.8E-06	3.4E-08	1.5E-07	8.8E-08	1.5E-07	2.2E-07	3.2E-07	2.0E-06
	Dieldrin	2.8E-06	2.6E-08	1.1E-07	8.7E-08	1.2E-07	1.6E-07	2.3E-07	1.1E-06
	Toxaphene	2.8E-04	6.5E-06	2.8E-05	1.1E-07	1.5E-05	4.3E-05	6.1E-05	3.8E-04
	Total Ingestion Risk	*3.0E-04*	*6.7E-06*	*2.9E-05*	*6.8E-07*	*1.6E-05*	*4.4E-05*	*6.2E-05*	*3.9E-04*
Inhalation	4,4'-DDD	1.3E-08	1.8E-09	6.8E-09	6.9E-12	3.2E-09	9.3E-09	1.2E-08	1.6E-08
	Arsenic	1.2E-08	1.5E-09	5.6E-09	4.8E-09	6.2E-09	7.7E-09	9.7E-09	1.3E-08
	Chlordane (NS)	7.1E-10	3.3E-11	1.3E-10	8.8E-11	1.2E-10	1.8E-10	2.2E-10	3.0E-10
	Chlordane (T)	5.0E-10	6.1E-11	2.4E-10	1.3E-10	2.2E-10	3.2E-10	4.1E-10	5.6E-10
	Dieldrin	8.7E-10	4.7E-11	1.8E-10	1.3E-10	1.8E-10	2.5E-10	3.1E-10	4.3E-10
	Toxaphene	8.7E-08	1.2E-08	4.6E-08	1.7E-10	2.2E-08	6.3E-08	7.9E-08	1.1E-07
	Total Inhalation Risk	*1.1E-07*	*1.5E-08*	*5.9E-08*	*5.3E-09*	*3.2E-08*	*8.1E-08*	*1.0E-07*	*1.4E-07*
Dermal	4,4'-DDD	4.6E-06	3.13E-07	2.11E-06	2.7E-09	1.2E-06	3.6E-06	5.89E-06	1.97E-04
	Arsenic	3.1E-07	1.88E-08	1.27E-07	1.4E-07	1.8E-07	2.2E-07	3.54E-07	1.18E-05
	Chlordane (NS)	3.0E-06	6.90E-08	4.74E-07	4.0E-07	6.5E-07	8.0E-07	1.37E-06	2.86E-05
	Chlordane (T)	2.1E-06	1.26E-07	8.49E-07	5.9E-07	1.0E-06	1.5E-06	2.37E-06	7.93E-05
	Dieldrin	3.7E-06	2.12E-09	6.54E-07	6.1E-07	8.0E-07	1.1E-06	1.88E-06	5.01E-05
	Toxaphene	3.6E-04	2.42E-05	1.63E-04	7.6E-07	9.8E-05	2.8E-04	4.57E-04	1.53E-02
	Total Dermal Risk	*3.7E-04*	*2.5E-05*	*1.7E-04*	*2.5E-06*	*1.0E-04*	*2.9E-04*	*4.7E-04*	*1.6E-02*
	Combined Pathway Risk	*6.7E-04*	*3.1E-05*	*2.0E-04*	*3.2E-06*	*1.2E-04*	*3.3E-04*	*5.3E-04*	*1.6E-02*



(Figure 4.1A Probability Distribution Function Graph)



(Figure 4.1B Cumulative Distribution Function Graph)

(1-D MCA On-Unit Worker - Dermal 95 %tile UCL - Toxaphene) specific percentile risk due to toxaphene via the dermal pathway. For the ingestion and dermal contact exposure pathways to carcinogens in soil, the risks from toxaphene (4×10^{-5} and 3×10^{-4}, respectively) are larger than the other COCs, and thus were presented graphically. At the 95th percentile, toxaphene represented greater than 90 % of the risk for the ingestion and dermal pathway of the PRA and PE assessment. The sensitivity analyses results (section 3.4) for the on-unit worker demonstrated that exposure duration and the adherence of soil-on-skin factor are the most sensitive parameters (input parameter that demonstrated the most influence on the outcome of the risk prediction) for this receptor.

3.1.2 Recreational Golfer

The probabilistic risk assessment predicted a 95th percentile excess lifetime cancer risk of 7×10^{-5}, and the 50th percentile (most likely exposure) was 7×10^{-6} (Table 4.5). The 1-D MCA for uncertainty in concentration at the 95th percentile of variability in risk ranged from 3×10^{-7} at the 5th percentile to 7×10^{-5} at the 95th percentile (Table 4.5). Comparatively, the PE risk was 1×10^{-4} (Table 4.5). The predicted RME cancer risk exceeds the 95th percentile value predicted by the PRA by 30-fold. At the 95th percentile, toxaphene represented greater than 90 % of the risk for the ingestion and dermal pathway of the PRA and PE assessment. The sensitivity analyses results (section 3.4) for the golfer demonstrated that exposure duration and the adherence of soil-on-skin factor are the most sensitive parameters for this receptor.

Table 4.5 PE and 1-D MCA Results for the Recreational Golfer

Pathway	Chemical	Point Estimate Risk	50th %tile Risk	90th %tile Risk	95% LCL	95% Mean	95% UCL	97.5th %tile Risk	99.99th %tile Risk
Ingestion	Arsenic	1.2E-06	7.7E-08	1.7E-07	1.3E-07	1.6E-07	2.0E-07	2.4E-07	5.9E-07
	4,4'-DDD	1.6E-06	1.1E-07	2.5E-07	2.2E-10	1.0E-07	3.0E-07	3.4E-07	8.6E-07
	Toxaphene	9.0E-05	6.2E-06	1.4E-05	4.4E-08	5.7E-06	1.6E-05	1.9E-05	4.8E-05
	Total Ingestion Risk	*9.3E-05*	*6.4E-06*	*1.4E-05*	*1.7E-07*	*6.0E-06*	*1.7E-05*	*2.0E-05*	*4.9E-05*
Inhalation	Arsenic	1.7E-09	5.3E-11	1.5E-10	1.2E-10	1.5E-10	1.9E-10	2.3E-10	7.6E-10
	4,4'-DDD	3.1E-10	1.1E-10	3.2E-10	3.0E-13	1.4E-10	4.0E-10	5.0E-10	1.6E-09
	Toxaphene	1.3E-08	4.3E-09	1.2E-08	4.1E-11	5.3E-09	1.5E-08	1.9E-08	6.2E-08
	Total Inhalation Risk	*1.5E-08*	*4.5E-09*	*1.3E-08*	*1.6E-10*	*5.6E-09*	*1.6E-08*	*2.0E-08*	*6.4E-08*
Dermal	Arsenic	6.4E-09	3.7E-10	1.4E-08	2.3E-08	3.0E-08	3.7E-08	9.3E-08	2.3E-05
	4,4'-DDD	9.6E-08	6.1E-09	2.3E-07	4.6E-10	2.1E-07	6.2E-07	1.5E-06	3.9E-04
	Toxaphene	7.5E-06	4.7E-07	1.7E-05	1.3E-07	1.7E-05	4.8E-05	1.2E-04	3.0E-02
	Total Dermal Risk	*7.6E-06*	*4.8E-07*	*1.8E-05*	*1.5E-07*	*1.7E-05*	*4.9E-05*	*1.2E-04*	*3.0E-02*
	Combined Pathway Risk	*1.0E-04*	*6.9E-06*	*3.2E-05*	*3.3E-07*	*2.3E-05*	*6.6E-05*	*1.4E-04*	*3.0E-02*

Table 4.6. PE and 1-D MCA Results for the Excavation Worker

Pathway	Chemical	Point Estimate Risk	50^{th} %tile Risk	90^{th} %tile Risk	95% LCL	95% Mean	95% UCL	97.5^{th} %tile Risk	99.99^{th} %tile Risk
Ingestion	4,4-DDD	1.3E-06	1.9E-09	1.5E-07	4.4E-10	1.8E-07	5.2E-07	1.5E-06	8.3E-04
	Arsenic	1.0E-06	1.3E-09	1.0E-07	2.3E-07	3.0E-07	3.6E-07	1.1E-06	5.7E-04
	Toxaphene	7.4E-05	1.1E-07	8.3E-06	8.0E-08	1.0E-05	3.0E-05	8.8E-05	4.8E-02
	Total Ingestion Risk	*7.6E-05*	*1.1E-07*	*8.5E-06*	*3.1E-07*	*1.1E-05*	*3.1E-05*	*9.0E-05*	*5.0E-02*
Inhalation	4,4-DDD	8.6E-11	6.7E-11	1.5E-10	1.4E-13	6.2E-11	1.8E-10	2.2E-10	5.6E-10
	Arsenic	4.7E-10	3.6E-08	8.0E-08	2.6E-10	3.4E-08	9.7E-08	1.2E-07	3.0E-07
	Toxaphene	3.5E-09	2.7E-09	5.9E-09	2.0E-11	2.5E-09	7.2E-09	8.6E-09	2.2E-08
	Total Inhalation Risk	*4.0E-09*	*3.9E-08*	*8.6E-08*	*2.8E-10*	*3.6E-08*	*1.0E-07*	*1.3E-07*	*3.3E-07*
Dermal	4,4-DDD	5.7E-08	4.2E-07	2.0E-06	2.2E-09	1.0E-06	3.0E-06	4.4E-06	3.9E-05
	Arsenic	3.8E-09	4.6E-09	2.1E-08	2.0E-08	2.6E-08	3.3E-08	4.8E-08	4.3E-07
	Toxaphene	4.4E-06	5.1E-06	2.4E-05	9.7E-08	1.2E-05	3.6E-05	5.3E-05	4.7E-04
	Total Dermal Risk	*4.5E-06*	*5.5E-06*	*2.6E-05*	*1.2E-07*	*1.4E-05*	*3.9E-05*	*5.7E-05*	*5.1E-04*
	Combined Pathway Risk	*8.1E-05*	*5.6E-06*	*3.4E-05*	*4.3E-07*	*2.4E-05*	*7.0E-05*	*1.5E-04*	*5.0E-02*

3.2 Future Land-Use Scenario 1-D MCA Results

3.2.1 Excavation Worker

The results of the probabilistic risk assessment predicted a 95th percentile probability of excess lifetime cancer risk of 7 x 10^{-5}, and the 50th percentile (most likely exposure) was 6 x 10^{-6} (Table 4.6). The 1-D MCA showed that the 95th percentile of variability in risk ranged from 4 x 10^{-7} at the 5th percentile to 7 x 10^{-5} at the 95th percentile (Table 4.6). Comparatively, the PE risk was 8 x 10^{-5} (Table 4.6). The predicted RME cancer risk exceeded the 95th percentile value predicted by the PRA by 1-fold. Toxaphene represented greater than 90 % of the risk for both the ingestion and dermal pathway, in both the PRA and PE assessment. The sensitivity analyses results (section 3.4) for the excavation worker demonstrated that ingestion rate and exposure time are the parameters that most influence risk estimates for this receptor.

3.2.2 Future Resident Adult

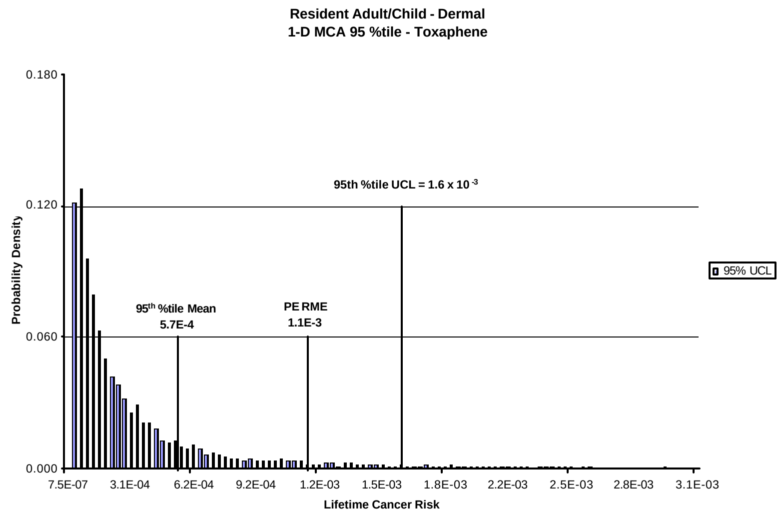
The probabilistic results predicted a 95th percentile excess lifetime cancer risk of 9 x 10^{-3}, and the 50th percentile (most likely exposure) was 1 x 10^{-3} (Table 4.7). The 1-D MCA showed that the 95th percentile of variability in risk ranged from 1 x 10^{-4} at the 5th percentile to 9 x 10^{-3} at the 95th percentile (Table 4.7). Comparatively, the PE risk was 4 x 10^{-3} (Table 4.7). The predicted RME cancer risk is less than the 95th percentile value predicted by the PRA by 5-fold. Figure 4.2A presents the ELCR vs. the relative probability for the final range of risks associated with exposure to toxaphene via the dermal pathway. The cumulative probability graph (Figure 4.2B) presents the specific percentile risk to toxaphene via the dermal pathway. For the ingestion and dermal

Table 4.7 PE and 1-D MCA Results for the Resident Adult/Child

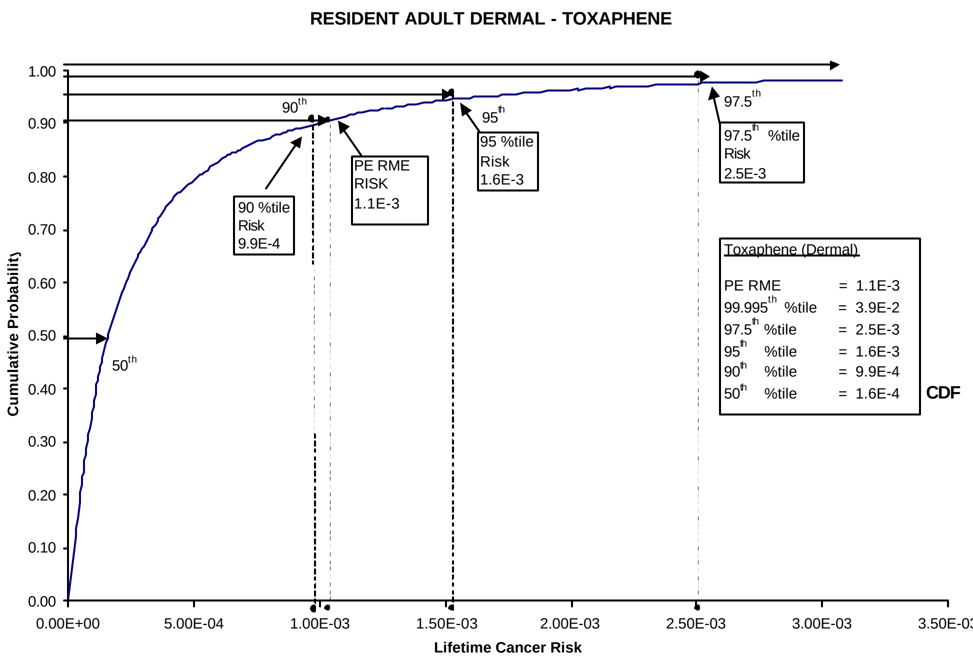
Pathway	Chemical	Point Estimate Risk	50th %tile Risk	90th %tile Risk	95% LCL	95% Mean	95% UCL	97.5th %tile Risk	99.99th %tile Risk
Ingestion	Arsenic	3.4E-05	1.1E-05	5.8E-05	5.6E-05	7.2E-05	8.9E-05	1.3E-04	8.8E-04
	4,4'-DDD	4.5E-05	1.7E-05	8.4E-05	9.7E-08	4.4E-05	1.3E-04	1.9E-04	1.3E-03
	4,4'-DDT	3.5E-06	1.4E-06	7.1E-06	3.2E-07	5.6E-06	1.1E-05	1.6E-05	1.1E-04
	Alpha-Chlordane	5.2E-06	3.8E-07	1.9E-06	1.6E-06	2.1E-06	3.0E-06	4.2E-06	2.9E-05
	Chlordane (NS)	2.1E-05	2.6E-06	1.3E-05	1.0E-05	1.5E-05	2.1E-05	2.9E-05	2.0E-04
	Chlordane (T)	1.5E-05	4.8E-06	2.4E-05	1.5E-05	2.6E-05	3.8E-05	5.3E-05	3.7E-04
	Dieldrin	2.6E-05	3.7E-06	1.9E-05	1.5E-05	2.1E-05	2.9E-05	4.1E-05	2.8E-04
	Gamma-Chlordane	6.5E-06	5.9E-07	2.9E-06	2.1E-06	3.0E-06	4.6E-06	6.5E-06	4.5E-05
	Heptachlor Epoxide	3.0E-06	1.1E-06	5.3E-06	3.8E-06	5.6E-06	8.2E-06	1.2E-05	8.1E-05
	Total Chlordane	1.6E-06	6.0E-07	3.0E-06	1.8E-07	1.8E-06	4.7E-06	6.6E-06	4.6E-05
	Toxaphene	2.5E-03	9.3E-04	4.7E-03	1.9E-05	2.5E-03	7.2E-03	1.0E-02	7.1E-02
	Total Ingestion Risk	*2.7E-03*	*9.7E-04*	*4.9E-03*	*1.2E-04*	*2.7E-03*	*7.6E-03*	*1.1E-02*	*7.5E-02*
Inhalation	Arsenic	2.0E-08	1.9E-08	5.6E-08	4.9E-08	6.2E-08	7.8E-08	1.1E-07	4.9E-07
	4,4'-DDD	3.7E-09	3.9E-09	1.2E-08	1.2E-11	5.4E-09	1.6E-08	2.2E-08	1.0E-07
	4,4'-DDT	2.0E-10	2.3E-10	6.9E-10	2.8E-11	4.9E-10	9.6E-10	1.3E-09	6.0E-09
	Alpha-Chlordane	3.0E-10	6.3E-11	1.9E-10	1.4E-10	1.8E-10	2.6E-10	3.5E-10	1.6E-09
	Chlordane (NS)	1.2E-09	4.4E-10	1.3E-09	9.0E-10	1.3E-09	1.8E-09	2.4E-09	1.1E-08
	Chlordane (T)	8.6E-10	8.0E-10	2.4E-09	1.3E-09	2.3E-09	3.3E-09	4.4E-09	2.0E-08
	Dieldrin	1.5E-10	6.2E-11	1.8E-10	1.3E-10	1.8E-10	2.5E-10	3.4E-10	1.6E-09
	Gamma-Chlordane	3.8E-10	9.7E-11	2.9E-10	1.9E-10	2.6E-10	4.0E-10	5.4E-10	2.5E-09
	Heptachlor Epoxide	1.7E-10	1.7E-10	5.1E-10	3.3E-10	4.8E-10	7.1E-10	9.7E-10	4.5E-09
	Total Chlordane	9.5E-11	9.9E-11	2.9E-10	1.5E-11	1.5E-10	4.0E-10	5.5E-10	2.5E-09
	Toxaphene	1.5E-07	1.6E-07	4.6E-07	1.7E-09	2.2E-07	6.4E-07	8.7E-07	4.0E-06
	Total Inhalation Risk	*1.8E-07*	*1.8E-07*	*5.3E-07*	*5.3E-08*	*3.0E-07*	*7.4E-07*	*1.0E-06*	*4.7E-06*

Table 4.7 PE and 1-D MCA Results for the Resident Adult/Child - continued

Pathway	Chemical	Point Estimate Risk	50^{th} %tile Risk	90^{th} %tile Risk	95% LCL	95% Mean	95% UCL	97.5^{th} %tile Risk	99.99^{th} %tile Risk
Dermal	Arsenic	9.2E-07	1.25E-07	7.70E-07	7.9E-07	1.0E-06	1.3E-06	1.93E-06	3.09E-05
	4,4'-DDD	1.4E-05	2.08E-06	1.28E-05	1.6E-08	7.1E-06	2.1E-05	3.21E-05	5.13E-04
	4,4'-DDT	1.1E-06	1.76E-07	1.76E-07	5.1E-08	9.1E-07	1.8E-06	2.72E-06	4.35E-05
	Alpha-Chlordane	2.2E-06	6.64E-08	4.10E-07	3.5E-07	4.7E-07	6.7E-07	1.03E-06	1.64E-05
	Chlordane (NS)	9.0E-06	4.57E-07	2.82E-06	2.3E-06	3.3E-06	4.6E-06	7.07E-06	1.13E-04
	Chlordane (T)	6.3E-06	8.37E-07	5.16E-06	3.4E-06	5.9E-06	8.5E-06	1.29E-05	2.07E-04
	Dieldrin	1.1E-05	6.45E-07	3.98E-06	3.5E-06	4.6E-06	6.5E-06	9.97E-06	1.59E-04
	Gamma-Chlordane	2.8E-06	1.02E-07	5.89E-07	4.8E-07	6.8E-07	1.0E-06	1.58E-06	2.52E-05
	Heptachlor Epoxide	8.9E-07	1.27E-07	7.83E-07	5.9E-07	8.7E-07	1.3E-06	1.96E-06	3.14E-05
	Total Chlordane	7.0E-07	1.04E-07	6.42E-07	4.0E-08	4.0E-07	1.1E-06	1.61E-06	2.57E-05
	Toxaphene	1.1E-03	1.61E-04	9.93E-04	4.4E-06	5.7E-04	1.6E-03	2.49E-03	3.98E-02
	Total Dermal Risk	*1.1E-03*	*1.7E-04*	*1.0E-03*	*1.6E-05*	*5.9E-04*	*1.7E-03*	*2.6E-03*	*4.1E-02*
	Combined Pathway Risk	***3.8E-03***	***1.1E-03***	***5.9E-03***	***1.4E-04***	***3.3E-03***	***9.2E-03***	***1.3E-02***	***1.2E-01***



(Figure 4.2A   Probability Distribution Function Graph)



(Figure 4.2B.   Cumulative Distribution Function Graph)

(1-D MCA Resident Adult/Child - Dermal 95 %tile UCL – Toxaphene)

Table 4.8 PE and 1-D MCA Results for the Resident Child

Pathway	Chemical	Point Estimate Hazard Index	50th %tile HI	90th %tile HI	95% LCL	95% Mean	95% UCL	97.5th %tile HI	99.99th %tile HI
Ingestion	4,4'-DDD	3.1	1.6	8.2	0.01	4.3	12.5	18.3	116.9
	Chlordane (NS)	1.0	0.17	0.88	0.68	1.0	1.4	2.0	12.6
	Total Ingestion Hazard Index	*4.0*	*1.7*	*9.0*	*0.7*	*5.2*	*13.9*	*20.2*	*129.5*
Inhalation	4,4'-DDD	-	-	-	-	-	-	-	-
	Chlordane (NS	0.0001	0.00004	0.0002	0.0001	0.0002	0.0002	0.0003	0.0020
	Total Inhalation Hazard Index	*0.0001*	*0.00004*	*0.0002*	*0.0001*	*0.0002*	*0.0002*	*0.0003*	*0.0020*
Dermal	4,4'-DDD	0.39	0.11	0.77	0.00	0.48	**1.42**	2.24	48.13
	Chlordane (NS)	0.18	0.02	0.12	0.11	0.15	0.21	0.34	7.26
	Total Dermal Hazard Index	*0.57*	*0.13*	*0.88*	*0.11*	*0.63*	*1.63*	*2.58*	*55.39*
	Combined Pathway Hazard Index	*4.6*	*1.9*	*9.9*	*0.8*	*5.9*	*15.5*	*22.8*	*184.9*

contact exposure pathways to carcinogens in soil, the risks from toxaphene (7×10^{-3} and 2×10^{-3}, respectively) are larger than the other COCs, and thus were presented graphically. At the 95th percentile, toxaphene represented the largest risk (greater than 90 %) for both the ingestion and dermal pathway of the PRA and PE assessment. The sensitivity analyses results (section 3.4) for the residential adult/child demonstrated that ingestion rate; exposure time and adherence of soil-to-skin are the most sensitive parameters for this receptor.

3.2.3 Future Resident Child

The probabilistic results predicted a 95th percentile Hazard Index (HI) of 16.0, and the 50th percentile (most likely exposure) was 1.9 (Table 4.8). The 1-D MCA showed that the 95th percentile of variability in HI ranged from 0.80 at the 5th percentile to 16.0 at the 95th percentile (Table 4.8). Comparatively, the PE HI was 4.6. The predicted RME HI is less than the 95th percentile value predicted by the PRA by 11-fold. At the 95th percentile, 4,4-DDD represented greater than 70 % of the hazard for the ingestion and dermal pathway in both the PRA and PE assessment. The sensitivity analyses results (section 3.4) for the resident child demonstrated that ingestion rate and exposure time are the most sensitive parameters for this receptor.

The area of the golf course with the greatest source of risk for all receptors (mainly the on-unit worker) was the buried pesticide container pit located between fairways 11 and 17, and the pesticide mixing-storage building.

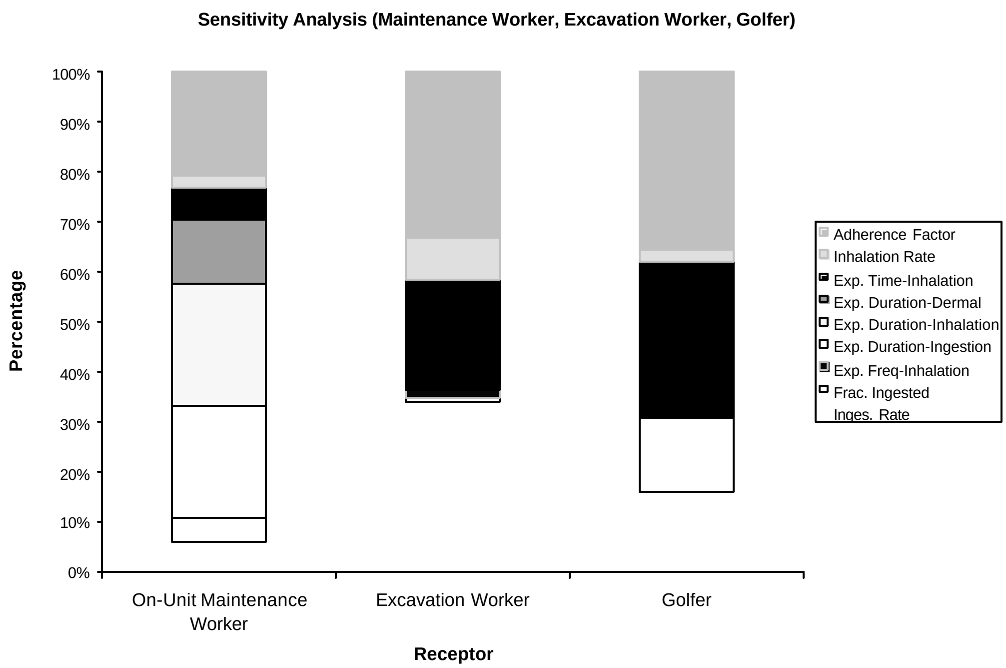
3.3 Uncertainty Analysis

Uncertainties in the risk predictions from exposure to contaminated soil have been evaluated for the current and future risk scenarios in this study. The soil exposure equations and the parameters that were assessed include ingestion rate, inhalation rate, exposure frequency, exposure duration, averaging time, body weight, surface area, adherence of soil-on-skin factor, and fraction ingested.

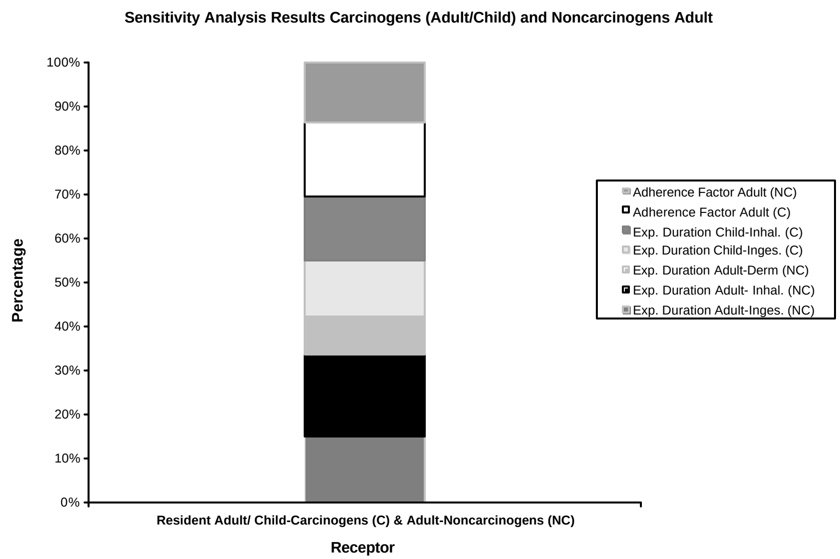
The results of the uncertainty analysis demonstrated that for all receptors, the ingestion, inhalation, and dermal contact pathways to contaminants in the soil, the coefficient of variation were greater than 1.0. A coefficient greater than 1.0 reflected the several orders of magnitude of variation between the minimum and maximum predictions of the soil model.

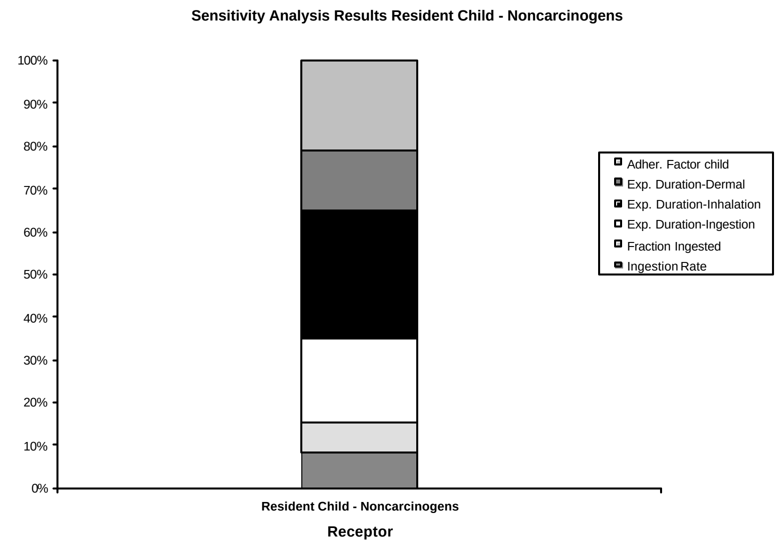
3.4 Sensitivity Analysis

The results of the sensitivity analysis (Figures 4.3 and 4.4) demonstrated that the ingestion rate and exposure time are the main parameters that influence quantitations of risk by the ingestion and inhalation pathways, respectively, for the excavation worker, golfer and resident adult/child. The adherence of soil-on-skin factor is the most sensitive parameter for the dermal contact pathway model, for the excavation worker, golfer and resident adult/child. For the on-unit worker, the sensitivity analysis (Figure 4.3) demonstrated that the exposure duration is the main parameter influencing risk for the ingestion and inhalation pathways. The adherence of soil-on-skin factor is the most sensitive parameter for the dermal contact pathway model. The majority of the PDF parameters were derived from the Exposure Factors Handbook (USEPA 1997c) and the studies were based on high-quality data, which indicates a high confidence in the probabilistic risk estimates. There may be a potential for risk reduction (for all receptors) at this golf course by limiting exposure time and duration that would decrease the chances of incidental soil ingestion and the adherence of soil-on skin factor.



(Figure 4.3 Sensitivity Analysis Chart for On-Unit Maintenance Worker, Excavation Worker and Golfer)





(Figure 4.4 Sensitivity Analysis Chart for Resident Adult and Child)

The resulting sensitivity analysis implies that the values chosen for the PE risk assessment exposure parameters are sufficiently conservative: they lead to risk levels associated with the probability of exceeding a HI (>1.0) or cancer risk (>1 x 10^{-6}). The 1-D MCA sensitivity analysis results were approximately the same as those achieved in the PE analysis.

4. CONCLUSIONS

The results documented in this study show that point estimates could be as high as 30 times the maximum range of the probabilistic analysis for some pathways. Burmaster and Harris (1993) stated that "it is widely known recognized that the values used to generate point estimate risk assessment results are conservatively biased and often yield an exposure estimate that is greater than the 99th percentile".

The PE predicted risk of 4 x 10^{-3} for the resident adult/child and hazard index of 4.6 for the resident child were approximately 5 to 11-fold less than the 95th percentile risk predicted in the PRA and fell between the 50th and 90th percentile of the risk estimate. The exceedance of the PRA risks/hazards over the PE results by the residential adult and child may be attributed to the longer exposure frequency (350 days/year) and exposure time (18 and 15 hours per day) of the residential receptors. The increased exposure over time leads to increased opportunities to be exposed to the contaminants in the soil.

At least 95% of the receptors (on-unit maintenance workers, excavation workers, golfers and residential adult/child) potentially exposed to contaminants at the golf course do not have a lifetime cancer risk greater than 3 x $10^{-4,}$ 7 x 10^{-5}, 7 x 10^{-5} and 9 x 10^{-3}, respectively with a HI (resident child) of 16.0. The most likely risk estimate (on-unit maintenance workers, excavation workers, golfers and residential adult/child), represented by the 50th percentile risk, should be no greater than (3 x 10^{-5} , 6 x 10^{-6}, 7 x 10^{-6} and 1 x 10^{-3}, respectively) and a HI (resident child) of 1.9. Toxaphene contributed most (greater than 90%) to the excess cancer lifetime risk for the maintenance worker, excavation worker, golfer and resident adult child, and 4,4-DDD contributed most to the hazard index (greater than 70%) for the resident child.

Sensitivity analysis revealed that for greater accuracy of the PE risk assessments, attention should be given to the development of the probability distribution for exposure duration, exposure time and adherence of soil-to skin factor. All of the probability distributions used were derived from scientific literature and may increase or decrease the accuracy of the results for a specific site.

Many of the exposure parameters used in this risk assessment are default values recommended by the EPA. These default parameters are usually conservative and do not necessarily reflect the actual behavior of receptors, but are used in the absence of site-specific information. Also, the assumptions regarding future land use are speculative.

Based on this study, the results of the point estimate were higher than the probabilistic analysis. The PRA results were 1 to 40-fold less than those obtained by the RME assessment. There is still a degree of uncertainty associated with the PRA due to the lack of PDFs for the toxicity values. The PRA results were useful in providing the full range of risk estimates especially at the upperbound or greater than 95th percentile. The performance of a sensitivity analysis for this study identified which exposure parameters affected the potential risk for the golf course. The MCA simulations were very labor intensive and may provide useful information (full range of possible risks) when decisions concerning costly remediation projects are involved.

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CHAPTER 5

CONCLUSIONS

Golf course construction has grown at an ever-increasing rate, and the sport of golfing is growing among the young. Most golf courses are usually built in suburban areas with surrounding residential properties. Despite the increase in golf course construction and the sport of golfing, there are few data available on the human health impacts to golf course workers, golfers and residents.

Based on the results of this risk assessment, we recommend that pesticides for lawn and golf course maintenance should not contain known or probable carcinogens without appropriate use of personal protective equipment, by workers during application. Attention should be given to the leachability and toxicity of pesticides used. Golfers can reduce their exposure to pesticides by scheduling their play to avoid recent pesticide applications. Workers can reduce their exposure with personal protective equipment (PPE) and engineering controls levels.

At least 95% of the receptors (on-unit maintenance workers, excavation workers, golfers and residential adult/child) potentially exposed to contaminants at the golf course do not have a lifetime cancer risk greater than $3 \times 10^{-4,}$ 7×10^{-5}, 7×10^{-5} and 9×10^{-3}, respectively with a HI (resident child) of 16.0. The most likely risk estimate (on-unit maintenance workers, excavation workers, golfers and residential adult/child), represented by the 50^{th} percentile risk, should be no greater than (3×10^{-5} , 6×10^{-6},

7×10^{-6} and 1×10^{-3}, respectively) and a HI (resident child) of 1.9. Toxaphene contributed most (greater than 90%) to the excess cancer lifetime risk for the maintenance worker, excavation worker, golfer and resident adult/child, and 4,4-DDD contributed most to the hazard index (greater than 70%) for the resident child.

Based on this study, the results of the point estimate were higher than the probabilistic analysis. The PRA results were 1 to 40-fold less than those obtained by the RME assessment. There is still a degree of uncertainty associated with the PRA due to the lack of PDFs for the toxicity values. The PRA results were useful in providing the full range of risk estimates especially at the upperbound or greater than 95th percentile. The MCA simulations were very labor intensive and may provide useful information (full range of possible risks) when decisions concerning costly remediation projects are involved.

APPENDICES

APPENDIX A. Final Summary Statistics – Golf Course Data

CAS #	Analyte	Proportion Detected	Proportion J" Detected	Average MDL	Min MDL	Max MDL	Min Detect	Arithmetic Mean	Std. Dev.	95% UCL of Mean	Max Detect	Reasonable Maximum Exposure	Rationale for Dist.
75-34-3	1,1-DICHLOROETHANE	2/2	1/2	0.007	0.001	0.130	0.001	0.390	-	0.390	0.001	0.001	D
96-12-8	1,2-DIBROMO-3-CHLOROPROPANE*	2/2	0/2	0.018	0.0002	0.290	0.001	0.002	0.002	0.011	0.003	0.003	D
95-50-1	1,2-DICHLOROBENZENE	1/1	0/1	0.319	0.001	2.10	0.004	0.004	-	0.004	0.004	0.004	D
541-73-1	1,3-DICHLOROBENZENE	1/1	0/1	3.519	0.001	2.10	0.006	0.006	-	0.006	0.006	0.006	D
106-46-7	1,4-DICHLOROBENZENE*	2/2	0/2	0.340	0.001	21.0	0.004	0.005	0.001	0.010	0.006	0.006	D
93-72-1	2,4,5-TP SILVEX {2-(2,4,5-TRICHLORO PHENOXY) PROPIONIC ACID}	1/1	0/1	0.015	0.002	0.027	0.080	0.080	-	0.080	0.080	0.080	D
94-75-7	2,4-D (2,4-DICHLOROPHENOXY ACETIC ACID)-Herb	1/1	0/1	0.062	0.011	0.140	0.047	0.047	-	0.047	0.047	0.047	D
53-19-0	2,4'-DDD	1/6	1/6	-	-	-	0.00	0.048	0.118	0.146	0.290	0.146	D
95-48-7	2-METHYLPHENOL	1/1	1/1	7.662	0.170	370.0	0.110	0.110	-	0.110	0.110	0.110	D
NO CAS#	3,5-DCBA	1/1	0/1	0.022	0.012	0.027	0.038	0.038	-	0.038	0.038	0.038	D
72-54-8	4,4'-DDD*	31/31	20/31	0.187	0.003	9.10	0.0001	46.1	251.3	478.02	1400.0	478.02	LN
72-55-9	4,4'-DDE*	133/133	103/133	1.160	0.003	370.0	0.0002	0.122	0.213	0.501	0.858	0.501	LN
50-29-3	4,4'-DDT*	76/76	48/76	0.242	0.004	9.10	0.0002	4.136	23.5	6.53	152.0	6.53	LN
100-02-7	4-NITROPHENOL	2/2	0/2	1.024	0.022	10.0	0.390	0.390	-	0.390	0.390	0.390	D
67-64-1	ACETONE	7/7	2/2	0.023	0.010	0.110	0.015	0.050	0.067	0.166	0.199	0.166	LN
309-00-2	ALDRIN*	8/8	7/8	0.820	0.002	370.0	0.0001	0.002	0.002	0.047	0.006	0.006	LN
319-84-6	ALPHA-BHC [HCH (alpha)]*	3/3	2/3	0.813	0.002	370.0	0.0002	0.003	0.005	0.012	0.009	0.009	D
5103-71-9	ALPHA-CHLORDANE*	216/216	87/216	1.265	0.002	370.0	0.0001	1.490	3.900	9.53	54.00	9.53	LN
7429-90-5	ALUMINUM	51/51	0/51	-	-	-	178.0	3155.4	3927.2	4952.5	14500.0	4952.5	LN
7440-36-0	ANTIMONY	3/3	3/3	0.911	0.340	3.0	0.530	0.590	0.056	0.684	0.640	0.640	D
11097-69-1	AROCLOR 1254*	2/2	2/2	7.562	0.034	370.0	0.776	1.068	0.413	1.36	1.36	1.36	D[1]
11096-82-5	AROCLOR 1260*	1/1	0/1	7.458	0.034	370.0	0.064	0.064	-	0.064	0.064	0.064	D
7440-38-2	ARSENIC*	301/301	57/301	0.835	0.290	5.4	0.360	11.942	30.5	12.9	449.00	12.9	LN
7440-39-3	BARIUM	40/40	35/40	2.095	4.370	27.0	1.400	8.455	9.823	10.6	64.00	10.6	LN
71-43-2	BENZENE*	1/1	0/1	0.007	0.001	0.130	0.003	0.003	-	0.003	0.003	0.003	D
56-55-3	BENZO(A)ANTHRACENE*	1/1	1/1	1.258	0.170	37.0	0.071	0.071	-	0.071	0.071	0.071	D
50-32-8	BENZO(A)PYRENE*	3/3	3/3	1.292	0.086	37.0	0.067	0.079	0.010	0.087	0.087	0.087	D[1]
205-99-2	BENZO(B)FLUORANTHENE*	7/7	6/7	1.385	0.170	37.0	0.056	0.153	0.126	0.357	0.420	0.357	N
207-08-9	BENZO(K)FLUORANTHENE*	5/5	4/5	1.343	0.170	37.0	0.087	0.178	0.136	0.594	0.410	0.410	N[1]
65-85-0	BENZOIC ACID	8/8	5/8	2.180	2.000	2.3	0.800	8.663	12.6	117.5	34.0	34.0	LN
319-85-7	BETA-BHC [HCH (beta)]*	1/1	0/1	0.810	0.002	370.0	0.120	0.120	-	0.120	0.120	0.120	D
117-81-7	BIS(2-ETHYLHEXYL) PHTHALATE	19/19	19/19	1.717	0.170	37.0	0.035	0.100	0.048	0.128	0.210	0.128	LN
7440-43-9	CADMIUM	7/7	2/7	0.640	0.230	1.1	0.480	2.079	1.353	6.06	4.50	6.06	LN
7440-70-2	CALCIUM	48/48	27/48	1.056	27.000	308.2	53.7	7804.9	21382.0	33067.9	110000.0	33067.9	LN
57-74-9	CHLORDANE (57-74-9)-Insec	132/132	38/132	1.442	0.017	370.0	0.004	10.410	24.360	38.40	9.70	38.4	LN
12789-03-6	CHLORDANE (12789-03-6)-Insec	9/9	1/9	-	-	-	0.856	18.628	15.9	28.5	48.3	28.5	N
67-66-3	CHLOROFORM	2/2	2/2	0.007	0.001	0.130	0.001	0.002	0.001	0.005	0.002	0.002	D
7440-47-3	CHROMIUM	50/50	12/50	1.00	1.00	1.00	0.480	6.789	6.35	11.2	30.0	11.2	LN
218-01-9	CHRYSENE	3/3	3/3	1.290	0.170	37.0	0.081	0.086	0.009	0.101	0.096	0.101	N
7440-48-4	COBALT	3/3	3/3	2.149	0.150	7.0	0.330	0.837	0.751	2.10	1.70	1.70	D
7440-50-8	COPPER	28/28	14/28	1.822	0.830	6.0	0.640	21.164	48.9	42.2	205.0	42.2	LN
57-12-5	CYANIDE	10/10	7/10	0.270	0.110	0.540	0.130	1.070	1.014	1.66	2.40	1.66	N
1861-32-1	DACTHAL-Herb	1/1	0/1	0.022	0.012	0.027	0.460	0.460	-	0.460	0.460	0.460	D
319-86-8	DELTA-BHC	13/13	12/13	0.828	0.002	370.0	0.00004	0.00040	0.001	0.001	0.004	0.001	N
333-41-5	DIAZINON-Insec	1/1	0/1	0.393	0.036	0.840	0.044	0.044	-	0.044	0.044	0.044	D
60-57-1	DIELDRIN*	230/230	73/230	1.348	0.002	370.0	0.00002	0.320	0.913	1.03	7.640	1.01	LN
84-74-2	DI-N-BUTYL PHTHALATE	2/2	2/2	0.423	0.170	2.10	0.080	0.08100	0.001	0.09	0.082	0.09	D

CAS #	Analyte	Proportion Detected	Proportion J" Detected	Average MDL	Min MDL	Max MDL	Min Detect	Arithmetic Mean	Std. Dev.	95% UCL of Mean	Max Detect	Reasonable Maximum Exposure	Rationale for Dist.
298-04-4	DISULFOTON-Insec	1/1	0/1	0.49	0.03	15.0	0.087	0.08700	-	0.087	0.087	0.087	D
33213-65-9	ENDOSULFAN II	3/3	2/3	0.947	0.003	370.0	0.0002	0.00148	0.002	0.005	0.004	0.004	D
72-20-8	ENDRIN	5/5	5/5	0.956	0.003	370.0	0.0001	0.00026	0.0002	0.0005	0.001	0.0005	N
206-44-0	FLUORANTHENE	1/1	1/1	1.258	0.170	37.0	0.170	0.170	-	0.170	0.170	0.170	D
58-89-9	GAMMA-BHC (LINDANE)*	2/2	1/2	0.812	0.002	370.0	0.001	0.055	0.077	0.400	0.110	0.110	D
12789-03-6	GAMMA-CHLORDANE*	206/206	94/206	1.227	0.002	370.0	0.0002	2.141	6.63	11.90	54.2	11.9	LN
1024-57-3	HEPTACHLOR EPOXIDE*-Insec	49/49	41/49	0.87	0.002	370.0	0.0001	0.153	0.240	0.210	1.070	0.210	N
193-39-5	INDENO(1,2,3-C,D)PYRENE	1/1	1/1	1.271	0.170	37.0	0.055	0.055	-	0.055	0.055	0.055	N
7439-89-6	IRON	51/51	12/51	-	-	-	85.6	1903.6	3708.6	3080.8	23478.7	3080.8	LN
7439-92-1	LEAD	51/51	4/51	-	-	-	1.30	11.4	15.0	15.0	80.4	15.0	LN
7439-95-4	MAGNESIUM	44/44	30/44	27.0	27.0	27.0	18.4	836.8	3221.0	1648.3	17500.0	1648.3	N
7439-96-5	MANGANESE	51/51	27/51	-	-	-	0.930	1.8	1.4	30.0	317.0	30.0	LN
94-74-6	MCPA {2-METHYL-4-CHLOROPHENOXY ACETIC ACID}-Herb	1/1	0/1	3.172	0.500	8.30	47.0	47.0	-	47.0	47.0	47.0	D
93-65-2	MCPP {2-(2-METHYL-4-CHLOROPHENOXY) PROPIONIC ACID}- Herb	1/1	0/1	3.943	0.620	10.00	33.0	33.0	-	33.0	33.0	33.0	D
7439-97-6	MERCURY	27/27	9/7	0.067	0.010	0.120	0.016	0.692	1.27	1.11	5.40	1.11	N
72-43-5	METHOXYCHLOR	5/5	5/5	1.332	0.004	370.0	0.0002	0.0004	0.010	0.0004	0.001	0.0004	N
78-93-3	METHYL ETHYL KETONE (2-Butanone)	1/1	0/1	0.026	0.006	0.660	0.017	0.017	-	0.017	0.017	0.017	D
108-10-1	METHYL ISOBUTYL KETONE (4-Methyl-2-Pentanone)	5/5	4/5	0.026	0.010	0.660	0.006	0.024	0.028	1.00	0.074	0.074	LN
75-09-2	METHYLENE CHLORIDE	41/41	26/41	0.034	0.005	0.660	0.002	0.151	0.404	0.258	2.40	0.258	N
91-20-3	NAPHTHALENE	1/1	0/1	0.447	0.001	3.70	0.003	0.003	-	0.003	0.003	0.003	D
7440-02-0	NICKEL	17/17	11/17	2.581	0.470	10.03	0.750	2.554	1.66	3.76	6.90	3.76	LN
TTNUS029	NITRITE/NITRATE	1/1	0/1	-	-	-	9.800	9.800	-	9.80	9.80	9.80	D
7727-37-9	NITROGEN, AS AMMONIA	1/1	0/1	-	-	-	30.0	30.0	-	30.0	30.0	30.0	D
87-86-5	PENTACHLOROPHENOL	5/5	3/5	0.817	0.001	10.00	0.020	0.044	0.033	1.00	0.100	0.100	LN
108-95-2	PHENOL	1/1	0/1	7.662	0.170	370.0	2.0	2.00	-	2.00	2.00	2.00	D
7723-14-0	PHOSPHORUS	1/1	0/1	-	-	-	20.0	20.0	-	20.0	20.0	20.0	D
7440-09-7	POTASSIUM	35/35	25/35	3.925	0.009	49.9	10.5	71.8	77.1	100.1	389.0	389.0	LN
129-00-0	PYRENE	3/3	3/3	0.003	0.170	37.0	0.064	0.101	0.038	0.165	0.140	0.140	D
7782-49-2	SELENIUM	10/10	10/10	2.675	0.280	4.00	0.300	0.534	0.278	0.748	1.100	0.748	LN
7440-22-4	SILVER	6/6	1/6	2.675	0.230	3.00	0.160	0.493	0.299	1.27	0.990	0.990	LN
7440-23-5	SODIUM	14/14	9/14	3.03	14.80	102.53	17.0	156.7	137.2	221.6	371.0	221.6	N
100-42-5	STYRENE	2/2	2/2	-	-	-	0.006	0.019	0.018	0.100	0.032	0.032	D
63705-05-5	SULFUR-Fung	2/14	2/14	-	-	-	0.000	0.066	0.170	0.147	0.510	0.147	D
7440-28-0	THALLIUM	3/3	3/3	0.596	0.330	2.000	0.550	0.727	0.153	0.985	0.820	0.985	D
108-88-3	TOLUENE	6/6	5/6	0.003	0.000	0.130	0.001	0.002	0.001	1.00	0.004	0.004	LN
57-74-9	TOTAL CHLORDANE	9/9	0/9	0.007	0.001	0.130	0.004	1.3	3.2	9.70	9.7	1.01	N[1]
TTNUS041	TOTAL KJELDAHL NITROGEN	1/1	0/1	-	-	-	390.0	390.0	-	390.0	390.0	390.0	D
TTNUS003	TOTAL ORGANIC CARBON	2/2	0/2	-	-	-	8430.0	9715.0	1817.3	17828.5	11000.0	11000.0	D
TTNUS001	TOTAL PETROLEUM HYDROCARBONS	10/10	0/10	0.012	0.012	0.012	25.0	0.673	3600.0	1.01	3600.0	1.01	LN
8001-35-2	TOXAPHENE*	16/16	9/16	9.11	0.07	460.0	0.100	571.2	2169.6	1522.0	8700.0	1522.0	N
TTNUS001	TPH (C8-C40)	28/28	7/28	0.06	0.01	0.10	10.8	141.4	85.0	168.8	381.0	168.8	N
79-01-6	TRICHLOROETHYLENE (TCE)	13/13	3/13	0.002	0.001	0.130	0.003	0.012	0.008	0.016	0.028	0.016	N
7440-62-2	VANADIUM	59/59	28/59	1.839	0.650	1.680	1.000	4.163	4.69	4.80	20.5	4.80	LN
1330-20-7	XYLENES	2/2	2/2	0.002	0.005	0.021	0.002	0.003	0.001	0.005	0.003	0.003	D
7440-66-6	ZINC	49/49	18/49	5.00	5.00	5.00	0.620	36.4	129.6	67.3	910.0	67.3	N

Carcinogen

-No MDL information available

[1]UCL>Max Detect

APPENDIX B. Final Constituents of Concern – Golf Course Data

Analyte	Min Conc	Max Conc	Unit	PRG or RBC	PRG or RBC value	MAX > PRG OR RBC	CF BKGD	2X Bkg	Max>2X Bkg	SCTL Value	MAX > SCTL	COPC
1,1-DICHLOROETHANE	0.001	0.001	MG/KG	0.1*PRG	5.89E+01	NO	NA	NA	NA	390	NO	NO
1,2-DIBROMO-3-CHLOROPROPANE*	0.001	0.003	MG/KG	PRG	4.54E-01	NO	NA	NA	NA	0.7	NO	NO
1,2-DICHLOROBENZENE	0.004	0.004	MG/KG	PRG-SAT	3.70E+02	NO	NA	NA	NA	880	NO	NO
1,3-DICHLOROBENZENE	0.006	0.006	MG/KG	0.1*PRG	1.32E+00	NO	NA	NA	NA	14	NO	NO
1,4-DICHLOROBENZENE*	0.004	0.006	MG/KG	PRG	3.40E+00	NO	NA	NA	NA	6.4	NO	NO
2,4,5-TP SILVEX {2-(2,4,5-TRICHLORO PHENOXY) PROPIONIC ACID}	0.080	0.080	MG/KG	0.1*PRG	4.89E+01	NO	NA	NA	NA	660	NO	NO
2,4-D (2,4-DICHLOROPHENOXY ACETIC ACID)	0.047	0.047	MG/KG	0.1*PRG	6.86E+01	NO	NA	NA	NA	770	NO	NO
2,4'-DDD	0.00	0.290	MG/KG	PRG [1]	2.40E+00	NO	NA	NA	NA	-	-	NO
2-METHYLPHENOL	0.110	0.110	MG/KG	0.1*PRG	3.06E+02	NO	NA	NA	NA	2900	NO	NO
4,4'-DDD*	0.0001	1400.0	MG/KG	PRG	2.40E+00	YES	NA	NA	NA	4.2	**YES**	**YES**
4,4'-DDE*	0.0002	0.858	MG/KG	PRG	1.70E+00	NO	NA	NA	NA	2.9	NO	NO
4,4'-DDT*	0.0002	152.0	MG/KG	PRG	1.70E+00	YES	NA	NA	NA	2.9	**YES**	**YES**
4-NITROPHENOL	0.390	0.390	MG/KG	0.1*PRG	4.89E+01	NO	NA	NA	NA	560	NO	NO
ACETONE	0.015	0.199	MG/KG	0.1*PRG	1.57E+02	NO	NA	NA	NA	1300	NO	NO
ALDRIN*	0.0001	0.006	MG/KG	PRG	2.90E-02	NO	NA	NA	NA	0.06	NO	NO
ALPHA-BHC [HCH (alpha)]*	0.0002	0.009	MG/KG	PRG	9.00E-02	NO	NA	NA	NA	0.1	NO	NO
ALPHA-CHLORDANE*	0.0001	54.00	MG/KG	PRG [1]	1.60E+00	YES	NA	NA	NA	-	-	**YES**
ALUMINUM	178.0	14500.0	MG/KG	0.1*PRG	7.61E+03	YES	4430	8860	**YES**	8000	**YES**	**YES**
ANTIMONY	0.530	0.640	MG/KG	0.1*PRG	3.13E+00	NO	9.44	18.88	NO	27	NO	NO
AROCLOR 1254*	0.776	1.36	MG/KG	PRG	2.20E-01	YES	NA	NA	NA	0.5	**YES**	**YES**
AROCLOR 1260*	0.064	0.064	MG/KG	PRG	2.20E-01	NO	NA	NA	NA	0.5	NO	**YES**
ARSENIC*	0.360	449.00	MG/KG	PRG	3.90E-01	YES	2.04	4.08	**YES**	0.7	**YES**	**YES**
BARIUM	1.400	64.00	MG/KG	0.1*PRG	5.37E+02	NO	14.4	28.8	**YES**	120	NO	NO
BENZENE*	0.003	0.003	MG/KG	PRG	6.50E-01	NO	NA	NA	NA	1.2	NO	NO
BENZO(A)ANTHRACENE*	0.071	0.071	MG/KG	PRG	6.20E-01	NO	NA	NA	NA	1.3	NO	**YES**
BENZO(A)PYRENE*	0.067	0.087	MG/KG	PRG	6.20E-02	YES	NA	NA	NA	0.1	NO	**YES**
BENZO(B)FLUORANTHENE*	0.056	0.420	MG/KG	PRG	6.20E-01	NO	NA	NA	NA	1.3	NO	**YES**
BENZO(K)FLUORANTHENE*	0.087	0.410	MG/KG	PRG	6.20E+00	NO	NA	NA	NA	13	NO	**YES**
BENZOIC ACID	0.800	34.0	MG/KG	PRG-SAT	1.00E+05	NO	NA	NA	NA	180000	NO	NO
BETA-BHC [HCH (beta)]*	0.120	0.120	MG/KG	PRG	3.20E-01	NO	NA	NA	NA	0.5	NO	NO
BIS(2-ETHYLHEXYL) PHTHALATE*	0.035	0.210	MG/KG	PRG	3.50E+01	NO	NA	NA	NA	72	NO	NO
CADMIUM	0.480	4.50	MG/KG	0.1*PRG	3.70E+00	YES	1.72	3.44	**YES**	82	NO	**YES**
CALCIUM	53.7	110000.0	MG/KG	NUTRIENT	NA	NO	NA	NA	NA	NA	NA	NO
CHLORDANE* (57-74-9)	0.007	122.00	MG/KG	PRG	1.60E+00	YES	NA	NA	NA	-	-	**YES**
CHLORDANE (12789-03-6)	0.856	48.3	MG/KG	PRG	1.60E+00	YES	NA	NA	NA	-	-	**YES**
CHLOROFORM*	0.001	0.002	MG/KG	PRG	2.40E-01	NO	NA	NA	NA	0.3	NO	NO
CHROMIUM*	0.480	30.0	MG/KG	PRG	3.00E+01	NO	7.75	15.5	**YES**	110000	NO	NO
CHRYSENE*	0.081	0.096	MG/KG	PRG	6.20E+01	NO	NA	NA	NA	130	NO	**YES**
COBALT	0.330	1.70	MG/KG	0.1*PRG	4.69E+02	NO	3.11	6.22	NO	5200	NO	NO
COPPER	0.640	205.0	MG/KG	0.1*PRG	2.91E+02	NO	5.97	11.94	**YES**	150	**YES**	**YES**
CYANIDE	0.130	2.40	MG/KG	0.1*PRG	1.08E+00	YES	1.19	2.38	**YES**	34	NO	**YES**
DACTHAL	0.460	0.460	MG/KG	0.1*PRG	6.11E+01	NO	NA	NA	NA	-	-	NO
DELTA-BHC	0.00004	0.004	MG/KG	NA	NA	NO	NA	NA	NA	24	NO	**YES**
DIAZINON	0.044	0.044	MG/KG	0.1*PRG	5.50E+00	NO	NA	NA	NA	70	NO	NO
DIELDRIN*	0.00002	7.640	MG/KG	PRG	3.00E-02	YES	NA	NA	NA	0.06	**YES**	**YES**
DI-N-BUTYL PHTHALATE	0.080	0.082	MG/KG	0.1*PRG	6.11E+02	NO	NA	NA	NA	-	-	NO
DISULFOTON	0.087	0.087	MG/KG	0.1*PRG	2.44E-01	NO	NA	NA	NA	3.3	NO	NO

CAS #	# of Detects	# of "J" Detects	Analyte	Min Conc	Max Conc	Unit	PRG or RBC	PRG or RBC value	MAX > PRG OR RBC	CF BKGD	2X Bkg	Max>2X Bkg	SCTL Value	MAX > SCTL	COPC
33213-65-9	3/3	2/3	ENDOSULFAN II	0.0002	0.004	MG/KG	0.1*PRG[1]	3.67E+01	NO	NA	NA	NA	-	-	NO
72-20-8	5/5	5/5	ENDRIN	0.0001	0.001	MG/KG	0.1*PRG	1.83E+00	NO	NA	NA	NA	25	NO	NO
206-44-0	1/1	1/1	FLUORANTHENE	0.170	0.170	MG/KG	0.1*PRG	2.29E+02	NO	NA	NA	NA	3200	NO	NO
58-89-9	2/2	1/2	GAMMA-BHC (LINDANE)*	0.001	0.110	MG/KG	PRG	4.40E-01	NO	NA	NA	NA	0.7	NO	NO
12789-03-6	206/206	94/206	GAMMA-CHLORDANE*	0.0002	54.2	MG/KG	PRG	1.60E+00	YES	NA	NA	NA	-	-	**YES**
1024-57-3	49/49	41/49	HEPTACHLOR EPOXIDE*	0.0001	1.070	MG/KG	PRG	5.30E-02	YES	NA	NA	NA	0.1	**YES**	**YES**
193-39-5	1/1	1/1	INDENO(1,2,3-C,D)PYRENE*	0.055	0.055	MG/KG	PRG	6.20E-01	NO	NA	NA	NA	1.3	NO	**YES**
7439-89-6	51/51	12/51	IRON	85.6	23478.7	MG/KG	0.1-*PRG	2.35E+03	YES	1490	2980	**YES**	25000	NO	**YES**
7439-92-1	51/51	4/51	LEAD	1.30	80.4	MG/KG	OSWER	4.00E+02	NO	197	394	NO	400	NO	NO
7439-95-4	44/44	30/44	MAGNESIUM	18.4	17500.0	MG/KG	NUTRIENT	NA	NO	NA	NA	NA	NA	NA	NO
7439-96-5	51/51	27/51	MANGANESE	0.930	317.0	MG/KG	0.1*PRG	1.76E+02	YES	22	44	**YES**	8800	NO	**YES**
94-74-6	1/1	0/1	MCPA {2-METHYL-4-CHLOROPHENOXY ACETIC ACID}	47.0	47.0	MG/KG	0.1*PRG	3.06E+00	YES	NA	NA	NA	35	**YES**	**YES**
93-65-2	1/1	0/1	MCPP {2-(2-METHYL-4-CHLOROPHENOXY) PROPIONIC ACID}	33.0	33.0	MG/KG	0.1*PRG	6.11E+00	YES	NA	NA	NA	64	NO	**YES**
7439-97-6	27/27	9/7	MERCURY	0.016	5.40	MG/KG	0.1*PRG	6.11E-01	YES	0.16	0.32	**YES**	4.6	**YES**	**YES**
72-43-5	5/5	5/5	METHOXYCHLOR	0.0002	0.001	MG/KG	0.1*PRG	3.06E+01	NO	NA	NA	NA	420	NO	NO
78-93-3	1/1	0/1	METHYL ETHYL KETONE (2-Butanone)	0.017	0.017	MG/KG	0.1*PRG	7.33E+02	NO	NA	NA	NA	4200	NO	NO
108-10-1	5/5	4/5	METHYL ISOBUTYL KETONE (4-Methyl-2-Pentanone)	0.006	0.074	MG/KG	0.1*PRG	7.87E+01	NO	NA	NA	NA	300	NO	NO
75-09-2	41/41	26/41	METHYLENE CHLORIDE*	0.002	2.40	MG/KG	PRG	8.90E+00	NO	NA	NA	NA	17	NO	NO
91-20-3	1/1	0/1	NAPHTHALENE	0.003	0.003	MG/KG	0.1*PRG	5.60E+01	NO	NA	NA	NA	55	NO	NO
7440-02-0	17/17	11/17	NICKEL	0.750	6.90	MG/KG	0.1*PRG	1.56E+02	NO	3.89	7.78	NO	340	NO	NO
TTNUS029	1/1	0/1	NITRITE/NITRATE	9.800	9.80	MG/KG	**0.1*RBC**	7.82E+02	NO	NA	NA	NA	140000	NO	NO
87-86-5	5/5	3/5	PENTACHLOROPHENOL*	0.020	0.100	MG/KG	PRG	3.00E+00	NO	NA	NA	NA	7.2	NO	NO
108-95-2	1/1	0/1	PHENOL	2.0	2.00	MG/KG	0.1*PRG	3.67E+03	NO	NA	NA	NA	1000	NO	NO
7723-14-0	1/1	0/1	PHOSPHORUS	20.0	20.0	MG/KG	0.1*PRG	1.56E-01	YES	NA	NA	NA	NA	NA	**YES**
7440-09-7	35/35	25/35	POTASSIUM	10.5	389.0	MG/KG	NUTRIENT	NA	NO	NA	NA	NA	NA	NA	NO
129-00-0	3/3	3/3	PYRENE	0.064	0.140	MG/KG	0.1*PRG	2.30E+03	NO	NA	NA	NA	2400	NO	NO
7782-49-2	10/10	10/10	SELENIUM	0.300	1.100	MG/KG	0.1*PRG	3.91E+01	NO	1.68	3.36	NO	440	NO	NO
7440-22-4	6/6	1/6	SILVER	0.160	0.990	MG/KG	0.1*PRG	3.91E+01	NO	2.13	4.26	NO	410	NO	NO
7440-23-5	14/14	9/14	SODIUM	17.0	371.0	MG/KG	NUTRIENT	NA	NO	343	686	NO	NA	NA	NO
100-42-5	2/2	2/2	STYRENE	0.006	0.032	MG/KG	PRG-SAT	1.70E+03	NO	NA	NA	NA	3600	NO	NO
63705-05-5	2/14	2/14	SULFUR	0.000	0.510	MG/KG	NA	NA	NO	NA	NA	NA	-	-	NO
7440-28-0	3/3	3/3	THALLIUM	0.550	0.820	MG/KG	0.1*PRG	5.16E-01	YES	2.84	5.68	NO	6.1	NO	**YES**
108-88-3	6/6	5/6	TOLUENE	0.001	0.004	MG/KG	PRG-SAT	5.20E+02	NO	NA	NA	NA	520	NO	NO
57-74-9	9/9	0/9	TOTAL CHLORDANE*	0.004	9.7	MG/KG	PRG	1.60E+01	NO	NA	NA	NA	-	-	**YES**
8001-35-2	16/16	9/16	TOXAPHENE*	0.100	8700.0	MG/KG	PRG	4.40E-01	YES	NA	NA	NA	0.9	**YES**	**YES**
79-01-6	13/13	3/13	TRICHLOROETHYLENE (TCE)	0.003	0.028	MG/KG	PRG	2.80E+00	NO	NA	NA	NA	6.4	NO	NO
7440-62-2	59/59	28/59	VANADIUM	1.000	20.5	MG/KG	0.1*PRG	5.47E+01	NO	6.3	12.6	**YES**	67	NO	NO
1330-20-7	2/2	2/2	XYLENES	0.002	0.003	MG/KG	PRG-SAT	2.10E+02	NO	NA	NA	NA	8000	NO	NO
7440-66-6	49/49	18/49	ZINC	0.620	910.0	MG/KG	0.1*PRG	2.35E+03	NO	37	74	**YES**	26000	NO	NO

Carcinogen

-No MDL information available

1- Proxy Human Health Screening Analyte Used

APPENDIX C. Reasonable Maximum Exposure Summary

Scenario Timeframe: Current

Receptor Population: On-Unit Worker

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk Ingestion	Carcinogenic Risk Inhalation	Carcinogenic Risk Dermal	Carcinogenic Risk Exposure Routes Total	Chemical	Non-Carcinogenic Hazard Quotient Ingestion	Non-Carcinogenic Hazard Quotient Inhalation	Non-Carcinogenic Hazard Quotient Dermal	Non-Carcinogenic Hazard Quotient Exposure Routes Total
Surface Soil	Surface Soil & Air Particulates	Cecil Fields	ALUMINUM	-	-	-	-	ALUMINUM	2.4E-03	5.1E-04	1.6E-03	4.5E-03
			ARSENIC	**3.8E-06**	1.2E-08	3.1E-07	**4.1E-06**	ARSENIC	2.4E-02	-	1.9E-03	2.6E-02
			CADMIUM	-	-	-	-	CADMIUM	3.0E-03	3.5E-06	1.9E-02	2.2E-02
			COPPER	-	-	-	-	COPPER	5.6E-04	-	-	5.6E-04
			CYANIDE	-	-	-	-	CYANIDE	4.1E-05	-	1.5E-05	5.6E-05
			DELTA-BHC	-	-	-	-	DELTA-BHC	-	-	-	-
			IRON	-	-	-	-	IRON	5.0E-03	-	2.1E-03	7.2E-03
			MANGANESE	-	-	-	-	MANGANESE	6.1E-04	3.1E-04	1.0E-03	1.9E-03
			MCPA	-	-	-	-	MCPA	4.6E-02	-	5.9E-03	5.2E-02
			MCPP	-	-	-	-	MCPP	1.6E-02	-	2.1E-03	1.8E-02
			MERCURY	-	-	-	-	MERCURY	5.4E-03	1.9E-06	5.0E-03	1.0E-02
			SULFUR	-	-	-	-	SULFUR	-	-	-	-
			THALLIUM	-	-	-	-	THALLIUM	6.0E-03	-	1.9E-03	8.0E-03
			(Sub-Total)	**3.8E-06**	1.2E-08	3.1E-07	4.1E-06	**(Subtotal)**	1.1E-01	8.3E-04	4.0E-02	1.5E-01
			4,4'-DDD*	**5.0E-06**	1.3E-08	**4.6E-06**	9.6E-06	4,4'-DDD*	1.2E-01	-	1.1E-01	2.2E-01
			4,4'-DDT*	3.9E-07	6.9E-10	3.5E-07	7.4E-07	4,4'-DDT*	6.4E-03	1.9E-06	5.8E-03	1.2E-02
			ALPHA-CHLORDANE*	5.8E-07	1.8E-10	7.5E-07	1.3E-06	ALPHA-CHLORDANE*	9.3E-03	7.1E-06	1.2E-02	2.1E-02
			AROCLOR 1254*	4.8E-07	1.4E-10	3.4E-07	8.1E-07	AROCLOR 1254*	3.3E-02	-	2.4E-02	5.7E-02
			AROCLOR 1260*	2.2E-08	6.8E-12	1.6E-08	3.8E-08	AROCLOR 1260*	1.6E-03	-	1.1E-03	2.7E-03
			BENZO(A)ANTHRACENE*	9.1E-09	1.2E-12	1.9E-08	2.8E-08	BENZO(A)ANTHRACENE*	1.2E-06	-	2.4E-06	3.5E-06
			BENZO(A)PYRENE*	1.1E-07	1.4E-11	2.3E-07	3.4E-07	BENZO(A)PYRENE*	1.4E-06	-	2.9E-06	4.3E-06
			BENZO(B)FLUORANTHENE*	4.6E-08	5.8E-12	9.4E-08	1.4E-07	BENZO(B)FLUORANTHENE*	5.8E-06	-	1.2E-05	1.8E-05
			BENZO(K)FLUORANTHENE*	5.2E-09	6.7E-13	1.1E-08	1.6E-08	BENZO(K)FLUORANTHENE*	6.7E-06	-	1.4E-05	2.0E-05
			CHLORDANE* (57-74-9)	**2.4E-06**	7.1E-10	**3.0E-06**	5.4E-06	CHLORDANE* (57-74-9)	3.8E-02	2.8E-05	4.8E-02	8.6E-02
			CHLORDANE* (12789-03-6)	**1.6E-06**	5.0E-10	**2.1E-06**	3.7E-06	CHLORDANE* (12789-03-6)	2.6E-02	2.0E-05	3.4E-02	6.0E-02
			CHRYSENE*	1.3E-10	1.6E-14	2.7E-10	3.9E-10	CHRYSENE*	1.6E-06	-	3.4E-06	5.0E-06
			DIELDRIN*	**2.9E-06**	8.7E-10	**3.7E-06**	6.6E-06	DIELDRIN*	1.0E-02	3.1E-06	1.3E-02	2.3E-02
			GAMMA-CHLORDANE*	7.3E-07	2.2E-10	9.3E-07	1.7E-06	GAMMA-CHLORDANE*	1.2E-02	8.8E-06	1.5E-02	2.6E-02
			HEPTACHLOR EPOXIDE*	3.3E-07	1.0E-10	3.0E-07	6.3E-07	HEPTACHLOR EPOXIDE*	7.9E-03	2.4E-06	7.0E-03	1.5E-02
			INDENO(1,2,3-C,D)PYRENE*	7.0E-09	9.0E-13	1.4E-08	2.1E-08	INDENO(1,2,3-C,D)PYRENE*	9.0E-07	-	1.9E-06	2.7E-06
			TOTAL CHLORDANE*	1.8E-07	5.5E-11	2.3E-07	4.2E-07	TOTAL CHLORDANE*	2.9E-03	2.2E-06	3.7E-03	6.7E-03
			TOXAPHENE*	**2.8E-04**	8.7E-08	**3.6E-04**	6.4E-04	TOXAPHENE*	-	-	-	-
			(Sub-Total)	3.0E-04	1.0E-07	3.8E-04	6.7E-04	**(Sub-Total)**	2.6E-01	7.4E-05	2.7E-01	5.3E-01
			(Total)	**3.0E-04**	**1.1E-07**	**3.8E-04**	**6.8E-04**	**(Total)**	3.7E-01	9.0E-04	3.1E-01	6.8E-01
						Total Media Risk (TMR) Across Surface Soil	**6.8E-04**		Total Media Hazard Index Across Surface Soil			**6.8E-01**

Scenario Timeframe: Future
Receptor Population: Excavation Worker
Receptor Age: Adult

Medium	Exposure	Exposure	Chemical	Carcinogenic Risk			Exposure Routes Total	Chemical	Non-Carcinogenic Hazard Quotient			Expsoure Routes Total
	Medium	Point		Ingestion	Inhalation	Dermal			Ingestion	Inhalation	Dermal	
Surface	Surface	Cecil Fields	ALUMINUM	-	-	-	-	ALUMINUM	1.6E-02	5.1E-04	4.8E-04	1.7E-02
Soil	Soil		ARSENIC	**1.0E-06**	4.7E-10	3.8E-09	1.0E-06	ARSENIC	1.6E-01	-	5.9E-04	1.6E-01
			CADMIUM	-	-	-	-	CADMIUM	2.0E-02	3.5E-06	5.9E-03	2.5E-02
			COPPER	-	-	-	-	COPPER	3.7E-03	-	-	3.7E-03
	&		CYANIDE	-	-	-	-	CYANIDE	2.7E-04	-	4.7E-06	2.7E-04
			DELTA-BHC	-	-	-	-	DELTA-BHC	-	-	-	-
	Air		IRON	-	-	-	-	IRON	3.3E-02	-	6.6E-04	3.4E-02
	Particulates		MANGANESE	-	-	-	-	MANGANESE	4.0E-03	3.1E-04	3.2E-04	4.7E-03
			MCPA	-	-	-	-	MCPA	3.0E-01	-	1.8E-03	3.1E-01
			MCPP	-	-	-	-	MCPP	1.1E-01	-	6.4E-04	1.1E-01
			MERCURY	-	-	-	-	MERCURY	3.6E-02	1.9E-06	1.5E-03	3.7E-02
			SULFUR	-	-	-	-	SULFUR	-	-	-	-
			THALLIUM	-	-	-	-	THALLIUM	4.0E-02	-	6.0E-04	4.0E-02
			(Sub-Total)	1.0E-06	4.7E-10	3.8E-09	1.0E-06	**(Subtotal)**	7.2E-01	8.3E-04	1.3E-02	7.3E-01
			4,4'-DDD*	**1.3E-06**	8.6E-11	5.7E-08	1.4E-06	4,4'-DDD*	7.7E-01	-	3.3E-02	8.1E-01
			4,4'-DDT*	1.0E-07	4.7E-12	4.4E-09	1.1E-07	4,4'-DDT*	4.2E-02	1.9E-06	1.8E-03	4.4E-02
			ALPHA-CHLORDANE*	1.5E-07	7.1E-12	9.2E-09	1.6E-07	ALPHA-CHLORDANE*	6.2E-02	7.1E-06	3.7E-03	6.5E-02
			AROCLOR 1254*	1.3E-07	5.8E-12	4.2E-09	1.3E-07	AROCLOR 1254*	2.2E-01	-	7.3E-03	2.3E-01
			AROCLOR 1260*	5.9E-09	2.7E-13	2.0E-10	6.1E-09	AROCLOR 1260*	1.0E-02	-	3.4E-04	1.1E-02
			BENZO(A)ANTHRACENE*	2.4E-09	4.6E-14	2.3E-10	2.6E-09	BENZO(A)ANTHRACENE*	7.6E-06	-	7.4E-07	8.4E-06
			BENZO(A)PYRENE*	2.9E-08	5.7E-13	2.8E-09	3.2E-08	BENZO(A)PYRENE*	9.4E-06	-	9.1E-07	1.0E-05
			BENZO(B)FLUORANTHENE*	1.2E-08	2.3E-13	1.2E-09	1.3E-08	BENZO(B)FLUORANTHENE*	3.8E-05	-	3.7E-06	4.2E-05
			BENZO(K)FLUORANTHENE*	1.4E-09	2.7E-14	1.3E-10	1.5E-09	BENZO(K)FLUORANTHENE*	4.4E-05	-	4.3E-06	4.8E-05
			CHLORDANE* (57-74-9)	6.2E-07	2.8E-11	3.7E-08	6.6E-07	CHLORDANE* (57-74-9)	2.5E-01	2.8E-05	1.5E-02	2.6E-01
			CHLORDANE* (12789-03-6)	4.3E-07	2.0E-11	2.6E-08	4.6E-07	CHLORDANE* (12789-03-6)	1.7E-01	2.0E-05	1.0E-02	1.8E-01
			CHRYSENE*	3.4E-11	6.6E-16	3.3E-12	3.7E-11	CHRYSENE*	1.1E-05	-	1.0E-06	1.2E-05
			DIELDRIN*	7.6E-07	3.5E-12	4.6E-08	8.1E-07	DIELDRIN*	6.7E-02	3.1E-06	4.0E-03	7.1E-02
			GAMMA-CHLORDANE*	1.9E-07	8.8E-12	1.1E-08	2.0E-07	GAMMA-CHLORDANE*	7.7E-02	8.8E-06	4.6E-03	8.1E-02
			HEPTACHLOR EPOXIDE*	8.8E-08	4.1E-12	3.7E-09	9.2E-08	HEPTACHLOR EPOXIDE*	5.2E-02	2.4E-06	2.2E-03	5.4E-02
			INDENO(1,2,3-C,D)PYRENE*	1.9E-09	3.6E-14	1.8E-10	2.0E-09	INDENO(1,2,3-C,D)PYRENE*	5.9E-06	-	5.7E-07	6.5E-06
			TOTAL CHLORDANE*	4.8E-08	2.2E-12	2.9E-09	5.1E-08	TOTAL CHLORDANE*	1.9E-02	2.2E-06	1.2E-03	2.0E-02
			TOXAPHENE*	**7.4E-05**	3.5E-09	**4.4E-06**	7.9E-05	TOXAPHENE*	-	-	-	-
			(Sub-Total)	7.8E-05	3.6E-09	**4.7E-06**	8.3E-05	**(Sub-Total)**	1.7E+00	7.4E-05	8.4E-02	1.8E+00
			(Total)	7.9E-05	4.1E-09	**4.7E-06**	8.4E-05	**(Total)**	2.5E+00	9.0E-04	9.6E-02	2.6E+00
			Total Media Risk (TMR) Across Surface Soil				**8.4E-05**	Total Media Hazard Index Across Surface Soil				**2.6E+00**

Scenario Timeframe: Current

Receptor Population: Golfer

Receptor Age: Adult

Medium	Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
Surface	Surface	Cecil Fields	ALUMINUM	-	-	-	-	ALUMINUM	9.7E-04	9.4E-05	4.1E-05	1.1E-03
Soil	Soil		**ARSENIC**	**1.2E-06**	1.7E-09	6.4E-09	1.2E-06	ARSENIC	9.5E-03	-	5.0E-05	9.6E-03
			CADMIUM	-	-	-	-	CADMIUM	1.2E-03	6.4E-07	5.0E-04	1.7E-03
			COPPER	-	-	-	-	COPPER	2.2E-04	-	-	2.2E-04
	&		CYANIDE	-	-	-	-	CYANIDE	1.6E-05	-	4.0E-07	1.7E-05
			DELTA-BHC	-	-	-	-	DELTA-BHC	-	-	-	-
	Air		IRON	-	-	-	-	IRON	2.0E-03	-	5.6E-05	2.1E-03
	Particulates		MANGANESE	-	-	-	-	MANGANESE	2.4E-04	5.7E-05	2.7E-05	3.3E-04
			MCPA	-	-	-	-	MCPA	1.8E-02	-	1.5E-04	1.9E-02
			MCPP	-	-	-	-	MCPP	6.5E-03	-	5.4E-05	6.5E-03
			MERCURY	-	-	-	-	MERCURY	2.2E-03	3.5E-07	1.3E-04	2.3E-03
			SULFUR	-	-	-	-	SULFUR	-	-	-	-
			THALLIUM	-	-	-	-	THALLIUM	2.4E-03	-	5.1E-05	2.5E-03
			(Sub-Total)	**1.2E-06**	1.7E-09	6.4E-09	**1.2E-06**	**(Subtotal)**	**4.4E-02**	**1.5E-04**	**1.1E-03**	**4.5E-02**
			4,4'-DDD*	**1.6E-06**	3.1E-10	9.6E-08	1.7E-06	4,4'-DDD*	4.7E-02	-	2.8E-03	5.0E-02
			4,4'-DDT*	1.2E-07	1.7E-11	7.4E-09	1.3E-07	4,4'-DDT*	2.6E-03	3.5E-07	1.5E-04	2.7E-03
			ALPHA-CHLORDANE*	1.9E-07	2.6E-11	1.6E-08	2.0E-07	ALPHA-CHLORDANE*	3.7E-03	1.3E-06	3.1E-04	4.0E-03
			AROCLOR 1254*	1.5E-07	2.1E-11	7.1E-09	1.6E-07	AROCLOR 1254*	1.3E-02	-	6.2E-04	1.4E-02
			AROCLOR 1260*	7.2E-09	9.9E-13	3.3E-10	7.5E-09	AROCLOR 1260*	6.3E-04	-	2.9E-05	6.6E-04
			BENZO(A)ANTHRACENE*	2.9E-09	1.7E-13	3.9E-10	3.3E-09	BENZO(A)ANTHRACENE*	4.6E-07	-	6.3E-08	5.3E-07
			BENZO(A)PYRENE*	3.6E-08	2.1E-12	4.8E-09	4.0E-08	BENZO(A)PYRENE*	5.7E-07	-	7.7E-08	6.4E-07
			BENZO(B)FLUORANTHENE*	1.5E-08	8.5E-13	2.0E-09	1.7E-08	BENZO(B)FLUORANTHENE*	2.3E-06	-	3.2E-07	2.6E-06
			BENZO(K)FLUORANTHENE*	1.7E-09	9.8E-14	2.3E-10	1.9E-09	BENZO(K)FLUORANTHENE*	2.7E-06	-	3.6E-07	3.0E-06
			CHLORDANE* (57-74-9)	7.5E-07	1.0E-10	6.3E-08	8.2E-07	CHLORDANE* (57-74-9)	1.5E-02	5.2E-06	1.3E-03	1.6E-02
			CHLORDANE* (12789-03-6)	5.3E-07	7.3E-11	4.4E-08	5.7E-07	CHLORDANE* (12789-03-6)	1.1E-02	3.6E-06	8.8E-04	1.1E-02
			CHRYSENE*	4.1E-11	2.4E-15	5.6E-12	4.7E-11	CHRYSENE*	6.6E-07	-	8.9E-08	7.5E-07
			DIELDRIN*	9.2E-07	1.3E-11	7.7E-08	1.0E-06	DIELDRIN*	4.0E-03	5.6E-08	3.4E-04	4.4E-03
			GAMMA-CHLORDANE*	2.3E-07	3.2E-11	2.0E-08	2.5E-07	GAMMA-CHLORDANE*	4.6E-03	1.6E-06	3.9E-04	5.0E-03
			HEPTACHLOR EPOXIDE*	1.1E-07	1.5E-11	6.2E-09	1.1E-07	HEPTACHLOR EPOXIDE*	3.2E-03	4.4E-07	1.8E-04	3.4E-03
			INDENO(1,2,3-C,D)PYRENE*	2.2E-09	1.3E-13	3.0E-10	2.5E-09	INDENO(1,2,3-C,D)PYRENE*	3.6E-07	-	4.9E-08	4.1E-07
			TOTAL CHLORDANE*	5.9E-08	8.1E-12	4.9E-09	6.3E-08	TOTAL CHLORDANE*	1.2E-03	4.0E-07	9.8E-05	1.3E-03
			TOXAPHENE*	**9.0E-05**	1.3E-08	**7.5E-06**	9.7E-05	**TOXAPHENE***	-	-	-	-
			(Sub-Total)	9.5E-05	1.3E-08	7.9E-06	1.0E-04	**(Sub-Total)**	1.1E-01	1.3E-05	7.1E-03	1.1E-01
			(Total)	**9.6E-05**	1.5E-08	**7.9E-06**	**1.0E-04**	**(Total)**	1.5E-01	1.6E-04	8.1E-03	1.6E-01
					Total Media Risk (TMR) Across Surface Soil		**1.0E-04**			Total Media Hazard Index Across Surface Soil		**1.6E-01**

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult/Child

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
Surface	Surface	Cecil Fields	ALUMINUM	-	-	-	-	ALUMINUM	6.8E-03	4.5E-04	3.4E-03	1.1E-02
Soil	Soil		**ARSENIC**	**3.4E-05**	2.0E-08	9.2E-07	**3.5E-05**	ARSENIC	6.7E-02	-	4.2E-03	7.1E-02
			CADMIUM	-	-	-	-	CADMIUM	8.3E-03	3.0E-06	4.2E-02	5.0E-02
			COPPER	-	-	-	-	COPPER	1.6E-03	-	-	1.6E-03
	&		CYANIDE	-	-	-	-	CYANIDE	1.1E-04	-	3.3E-05	1.5E-04
			DELTA-BHC	-	-	-	-	DELTA-BHC	-	-	-	-
	Air		IRON	-	-	-	-	IRON	1.4E-02	-	4.7E-03	1.9E-02
	Particulates		MANGANESE	-	-	-	-	MANGANESE	1.7E-03	2.7E-04	2.2E-03	4.2E-03
			MCPA	-	-	-	-	MCPA	1.3E-01	-	1.3E-02	1.4E-01
			MCPP	-	-	-	-	MCPP	4.5E-02	-	4.5E-03	5.0E-02
			MERCURY	-	-	-	-	MERCURY	1.5E-02	1.7E-06	2.0E-02	3.5E-02
			SULFUR	-	-	-	-	SULFUR	-	-	-	-
			THALLIUM	-	-	-	-	THALLIUM	1.7E-02	-	4.2E-03	2.1E-02
			(Sub-Total)	**3.4E-05**	2.0E-08	9.2E-07	**3.5E-05**	**(Subtotal)**	**3.1E-01**	**7.2E-04**	**9.8E-02**	**4.0E-01**
			4,4'-DDD*	**4.5E-05**	3.7E-09	**1.4E-05**	5.9E-05	4,4'-DDD*	3.3E-01	-	2.3E-01	5.6E-01
			4,4'-DDT*	**3.5E-06**	2.0E-10	**1.1E-06**	4.5E-06	4,4'-DDT*	1.8E-02	1.7E-06	1.3E-02	3.1E-02
			ALPHA-CHLORDANE*	**5.2E-06**	3.0E-10	**2.2E-06**	7.4E-06	ALPHA-CHLORDANE*	2.6E-02	6.2E-06	2.6E-02	5.2E-02
			AROCLOR 1254*	**4.3E-06**	2.5E-10	**1.0E-06**	5.3E-06	AROCLOR 1254*	9.3E-02	-	5.2E-02	1.4E-01
			AROCLOR 1260*	2.0E-07	1.2E-11	4.7E-08	2.5E-07	AROCLOR 1260*	4.4E-03	-	2.4E-03	6.8E-03
			BENZO(A)ANTHRACENE*	8.1E-08	2.0E-12	5.6E-08	1.4E-07	BENZO(A)ANTHRACENE*	3.2E-06	-	5.2E-06	8.5E-06
			BENZO(A)PYRENE*	9.9E-07	2.4E-11	6.8E-07	1.7E-06	BENZO(A)PYRENE*	4.0E-06	-	6.4E-06	1.0E-05
			BENZO(B)FLUORANTHENE*	4.1E-07	1.0E-11	2.8E-07	6.9E-07	BENZO(B)FLUORANTHENE*	1.6E-05	-	2.6E-05	4.3E-05
			BENZO(K)FLUORANTHENE*	4.7E-08	1.1E-12	3.2E-08	7.9E-08	BENZO(K)FLUORANTHENE*	1.9E-05	-	3.0E-05	4.9E-05
			CHLORDANE* (57-74-9)	**2.1E-05**	1.2E-09	**9.0E-06**	3.0E-05	CHLORDANE* (57-74-9)	1.1E-01	2.5E-05	1.1E-01	2.1E-01
			CHLORDANE* (12789-03-6)	**1.5E-05**	8.6E-10	**6.3E-06**	2.1E-05	CHLORDANE* (12789-03-6)	7.4E-02	1.7E-05	7.4E-02	1.5E-01
			CHRYSENE*	1.1E-09	2.8E-14	7.9E-10	1.9E-09	CHRYSENE*	4.6E-06	-	7.4E-06	1.2E-05
			DIELDRIN*	**2.6E-05**	1.5E-10	**1.1E-05**	**3.7E-05**	DIELDRIN*	2.8E-02	2.7E-06	2.8E-02	5.6E-02
			GAMMA-CHLORDANE*	**6.5E-06**	3.8E-10	**2.8E-06**	9.3E-06	GAMMA-CHLORDANE*	3.3E-02	7.7E-06	3.3E-02	6.5E-02
			HEPTACHLOR EPOXIDE*	**3.0E-06**	1.7E-10	8.9E-07	3.9E-06	HEPTACHLOR EPOXIDE*	2.2E-02	2.1E-06	1.5E-02	3.8E-02
			INDENO(1,2,3-C,D)PYRENE*	6.3E-08	1.5E-12	4.3E-08	1.1E-07	INDENO(1,2,3-C,D)PYRENE*	2.5E-06	-	4.1E-06	6.6E-06
			TOTAL CHLORDANE*	**1.6E-06**	9.5E-11	**7.0E-07**	2.3E-06	TOTAL CHLORDANE*	8.2E-03	1.9E-06	8.2E-03	1.6E-02
			TOXAPHENE*	**2.5E-03**	1.5E-07	**1.1E-03**	**3.6E-03**	TOXAPHENE*	-	-	-	-
			(Sub-Total)	2.6E-03	1.6E-07	1.1E-03	3.8E-03	**(Sub-Total)**	7.4E-01	6.4E-05	5.9E-01	**1.3E+00**
			(Total)	**2.7E-03**	1.8E-07	**1.1E-03**	**3.8E-03**	**(Total)**	**1.0E+00**	7.9E-04	6.9E-01	**1.7E+00**
						Total Media Risk (TMR) Across Surface Soil	**3.8E-03**				Total Media Hazard Index Across Surface Soil	**1.7E+00**

Scenario Timeframe: Future

Receptor Population: Resident

Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
Surface	Surface	Cecil Fields	NA	-	-	-	-	ALUMINUM	6.3E-02	1.9E-03	5.7E-03	7.1E-02
Soil	Soil		NA	-	-	-	-	ARSENIC	6.2E-01	-	7.0E-03	6.3E-01
			NA	-	-	-	-	CADMIUM	7.7E-02	1.3E-05	7.0E-02	1.5E-01
								COPPER	1.5E-02	-	-	1.5E-02
	&		NA	-	-	-	-	CYANIDE	1.1E-03	-	5.6E-05	1.1E-03
			NA	-	-	-	-	DELTA-BHC	-	-	-	-
	Air		NA	-	-	-	-	IRON	1.3E-01	-	7.9E-03	1.4E-01
	Particulates		NA	-	-	-	-	MANGANESE	1.6E-02	1.1E-03	3.8E-03	2.1E-02
			NA	-	-	-	-	**MCPA**	**1.2E+00**	-	2.2E-02	**1.2E+00**
			NA	-	-	-	-	MCPP	4.2E-01	-	7.6E-03	4.3E-01
			NA	-	-	-	-	MERCURY	1.4E-01	7.1E-06	1.8E-02	1.6E-01
			NA	-	-	-	-	SULFUR	-	-	-	-
			NA	-	-	-	-	THALLIUM	1.6E-01	-	7.1E-03	1.6E-01
			(Sub-Total)	NA	NA	NA	NA	**(Subtotal)**	**2.8E+00**	3.1E-03	1.5E-01	**3.0E+00**
			NA	-	-	-	-	**4,4'-DDD***	**3.1E+00**	-	3.9E-01	3.5E+00
			NA	-	-	-	-	4,4'-DDT*	1.7E-01	7.1E-06	2.1E-02	1.9E-01
			NA	-	-	-	-	ALPHA-CHLORDANE*	2.4E-01	2.6E-05	4.4E-02	2.9E-01
			NA	-	-	-	-	AROCLOR 1254*	8.7E-01	-	8.7E-02	9.6E-01
			NA	-	-	-	-	AROCLOR 1260*	4.1E-02	-	4.1E-03	4.5E-02
			NA	-	-	-	-	BENZO(A)ANTHRACENE*	3.0E-05	-	8.8E-06	3.9E-05
			NA	-	-	-	-	BENZO(A)PYRENE*	3.7E-05	-	1.1E-05	4.8E-05
			NA	-	-	-	-	BENZO(B)FLUORANTHENE*	1.5E-04	-	4.4E-05	2.0E-04
			NA	-	-	-	-	BENZO(K)FLUORANTHENE*	1.7E-04	-	5.1E-05	2.3E-04
			NA	-	-	-	-	CHLORDANE* (57-74-9)	**9.8E-01**	1.0E-04	1.8E-01	1.2E+00
			NA	-	-	-	-	CHLORDANE* (12789-03-6)	6.9E-01	7.3E-05	1.2E-01	8.1E-01
			NA	-	-	-	-	CHRYSENE*	4.3E-05	-	1.2E-05	5.5E-05
			NA	-	-	-	-	DIELDRIN*	2.6E-01	1.1E-05	4.7E-02	3.1E-01
			NA	-	-	-	-	GAMMA-CHLORDANE*	3.0E-01	3.2E-05	5.5E-02	3.6E-01
			NA	-	-	-	-	HEPTACHLOR EPOXIDE*	2.1E-01	8.8E-06	2.6E-02	2.3E-01
			NA	-	-	-	-	INDENO(1,2,3-C,D)PYRENE*	2.3E-05	-	6.8E-06	3.0E-05
			NA	-	-	-	-	TOTAL CHLORDANE*	7.6E-02	8.1E-06	1.4E-02	9.0E-02
			NA	-	-	-	-	TOXAPHENE*	-	-	-	-
			(Sub-Total)	NA	NA	NA	NA	**(Sub-Total)**	6.9E+00	2.7E-04	9.9E-01	7.9E+00
			(Total)	NA	NA	NA	NA	**(Total)**	**9.8E+00**	3.3E-03	**1.1E+00**	**1.1E+01**
					Total Media Risk (TMR) Across Surface Soil		**NA**			Total Media Hazard Index Across Surface Soil		**1.1E+01**

APPENDIX D. Refined Constituents Of Concern Summary

Scenario Timeframe: Current

Receptor Population: On-Unit Worker

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
Soil	Soil		**ARSENIC**	**4.E-06**	1.E-08	3.E-07	**4.E-06**	ARSENIC	0.024	-	0.002	0.026
			(Sub-Total)	**4.E-06**	1.E-08	3.E-07	4.E-06	**(Subtotal)**	0.024	0.000	0.002	0.026
			4,4'-DDD*	**5.E-06**	1.E-08	**5.E-06**	1.E-05	4,4'-DDD*	0.117	-	0.107	0.224
			CHLORDANE* (57-74-9)	**2.E-06**	7.E-10	**3.E-06**	5.E-06	CHLORDANE* (57-74-9)	0.038	0.00003	0.048	0.086
			CHLORDANE* (12789-03-6)	**2.E-06**	5.E-10	**2.E-06**	4.E-06	CHLORDANE* (12789-03-6)	0.026	0.00002	0.034	0.060
			DIELDRIN*	**3.E-06**	9.E-10	**4.E-06**	6.E-06	DIELDRIN*	0.010	0.000003	0.013	0.023
			TOXAPHENE*	**3.E-04**	9.E-08	**4.E-04**	6.E-04	TOXAPHENE*	-	-	-	-
			(Sub-Total)	3.E-04	1.E-07	4.E-04	7.E-04	**(Sub-Total)**	0.191	0.0001	0.202	0.393
			(Total)	**3.E-04**	**1.E-07**	**4.E-04**	**7.E-04**	**(Total)**	0.215	0.0001	0.204	0.418
				Total Media Risk (TMR) Across Surface Soil			**7.E-04**	Total Media Hazard Index Across Surface Soil				**0.418**

Scenario Timeframe: Future
Receptor Population: Excavation Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
			ARSENIC	**1.E-06**	5.E-10	4.E-09	1.E-06	ARSENIC	0.157	-	0.001	0.158
			4,4'-DDD*	**1.E-06**	9.E-11	6.E-08	1.E-06	4,4'-DDD*	0.773	-	0.033	0.806
			TOXAPHENE*	**7.E-05**	3.E-09	**4.E-06**	8.E-05	TOXAPHENE*	-	-	-	-
			(Sub-Total)	7.41E-05	3.47E-09	**4.E-06**	8.E-05	**(Sub-Total)**	9.30E-01	-	3.37E-02	9.64E-01
			(Total)	7.E-05	3.E-09	**4.E-06**	8.E-05	**(Total)**	0.930	-	0.034	0.964
			Total Media Risk (TMR) Across Surface Soil				**8.E-05**	Total Media Hazard Index Across Surface Soil				**0.964**

Scenario Timeframe: Current
Receptor Population: Golfer
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
Soil	Soil		**ARSENIC**	**1.E-06**	2.E-09	6.E-09	1.E-06	ARSENIC	0.010	-	0.0001	0.0096
			(Sub-Total)	**1.E-06**	2.E-09	6.E-09	**1.E-06**	**(Subtotal)**	0.010	-	0.0001	0.010
			4,4'-DDD*	**2.E-06**	3.E-10	1.E-07	2.E-06	4,4'-DDD*	0.047	-	0.003	0.050
			TOXAPHENE*	**9.E-05**	1.E-08	**8.E-06**	1.E-04	**TOXAPHENE***	-	-	-	**-**
			(Sub-Total)	9.E-05	1.E-08	8.E-06	1.E-04	**(Sub-Total)**	0.047	-	0.003	0.050
			(Total)	**9.E-05**	1.E-08	**8.E-06**	**1.E-04**	**(Total)**	0.056	-	0.003	0.059
				Total Media Risk (TMR) Across Surface Soil			**1.E-04**	Total Media Hazard Index Across Surface Soil				**0.059**

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult/Child

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
Soil	Soil		ARSENIC	3.E-05	2.E-08	9.E-07	4.E-05	ARSENIC	0.067	-	0.004	0.071
			(Sub-Total)	3.E-05	2.E-08	9.E-07	4.E-05	(Subtotal)	0.067	-	0.004	0.071
			4,4'-DDD*	4.E-05	4.E-09	1.E-05	6.E-05	4,4'-DDD*	0.328	-	0.234	0.562
			4,4'-DDT*	3.E-06	2.E-10	1.E-06	5.E-06	4,4'-DDT*	0.018	0.000002	0.013	0.031
			ALPHA-CHLORDANE*	5.E-06	3.E-10	2.E-06	7.E-06	ALPHA-CHLORDANE*	0.026	0.00001	0.026	0.052
			CHLORDANE* (57-74-9)	2.E-05	1.E-09	9.E-06	3.E-05	CHLORDANE* (57-74-9)	0.105	0.00002	0.105	0.211
			CHLORDANE* (12789-03-6)	1.E-05	9.E-10	6.E-06	2.E-05	CHLORDANE* (12789-03-6)	0.074	0.00002	0.074	0.147
			DIELDRIN*	3.E-05	2.E-10	1.E-05	4.E-05	DIELDRIN*	0.028	0.00000	0.028	0.056
			GAMMA-CHLORDANE*	7.E-06	4.E-10	3.E-06	9.E-06	GAMMA-CHLORDANE*	0.033	0.00001	0.033	0.065
			HEPTACHLOR EPOXIDE*	3.E-06	2.E-10	9.E-07	4.E-06	HEPTACHLOR EPOXIDE*	0.022	0.000002	0.015	0.038
			TOTAL CHLORDANE*	2.E-06	1.E-10	7.E-07	2.E-06	TOTAL CHLORDANE*	0.008	0.000002	0.008	0.016
			TOXAPHENE*	3.E-03	1.E-07	1.E-03	4.E-03	TOXAPHENE*	-	-	-	-
			(Sub-Total)	3.E-03	2.E-07	1.E-03	4.E-03	(Sub-Total)	0.642	0.000	0.536	1.178
			(Total)	3.E-03	2.E-07	1.E-03	4.E-03	(Total)	0.709	0.0001	0.540	1.249
			Total Media Risk (TMR) Across Surface Soil				4.E-03	Total Media Hazard Index Across Surface Soil				1.249

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical	Carcinogenic Risk				Chemical	Non-Carcinogenic Hazard Quotient			
				Ingestion	Inhalation	Dermal	Exposure Routes Total		Ingestion	Inhalation	Dermal	Expsoure Routes Total
			NA	-	-	-	-	**4,4'-DDD***	**3.06**	-	**0.393**	3.45
			NA	-	-	-	-	CHLORDANE* (57-74-9)	**0.98**	0.0001	0.177	1.16
			(Total)	NA	NA	NA	NA	**(Total)**	**4.04**	**0.0001**	**0.570**	**4.61**
						Total Media Risk (TMR) Across Surface Soil	**NA**				Total Media Hazard Index Across Surface Soil	**4.61**

APPENDIX E. Naval Air Station Cecil Field Golf Course Map

NAS Cecil Field Sample Locations (1991 - 2000 Sampling Investigations)