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April 19, 2000

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VIA HAND DELIVERY

Hon. Debra Renner
Acting Secretary
New York State Board on Electric
Generation Siting and the Environment
Three Empire State Plaza
Albany, New York 12223-1350

Re: Case 99-F-1164: In the Matter of the Application of Southern Energy Bowline, L.L.C., for a Certificate of Environmental Compatibility and Public Need to Construct and Operate a Nominal 750 Megawatt Combined Cycle Combustion Turbine Electric Generating Plant in Haverstraw, Rockland County, New York

Dear Secretary Renner:

Southern Energy Bowline, L.L.C. ("Southern Energy") hereby provides an original and 10 copies of the following:

1. Site Assessment of Electric and Magnetic Fields (EMF);

2. Multipathway Risk Assessment; and

3. An analysis demonstrating that with the construction of the facilities that are subject to the "Application of Southern Energy Bowline L.L.C. Pursuant to Subpart 85-1.3 of the Public Service Commission's Rules of Procedure to Construct a Fuel Gas Transmission Line Which is Less Than 10 Miles Long" ("Article VII Application") (Case 99-T-1814) there will be sufficient gas supply and interstate and intrastate gas transmission capacity to support the requirements of Bowline Unit 3.

2000 APR 19 PM 4:32

The "Site Assessment of Electric and Magnetic Fields (EMF)" is being provided in accordance with clause 20 of Stipulation No. 4: Electric Transmission Facilities. The stipulations executed by Southern Energy, the New York State Department of Public Service, the New York State Department of Environmental Conservation and the New York State Department of Health are annexed as Appendix 1A to Southern Energy's Article X Application, which was filed on March 20, 2000. The "Multipathway Risk Assessment" is being filed in accordance with clause 6(g) of Stipulation No. 1: Air Quality and Meteorology. The analysis of the natural gas supply and interstate and intrastate gas transportation capacity is being filed in accordance with clause 5 of Stipulation No. 5: Gas Transmission Facilities.

Please contact me if there are any questions regarding these matters. Kindly date-stamp the additional copy of this letter and return it to our messenger.

Very truly yours,

COUCH WHITE, LLP

Barbara S. Brenner

Barbara S. Brenner

LHS/dap
cc: Parties on Attached List (via U.S. Mail w/enc.)
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CASE 99-F-1164
SOUTHERN ENERGY BOWLINE, L.L.C. ARTICLE X
SERVICE LIST

APRIL 19, 2000

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BOWLINE UNIT 3
TOWN HAVERSTRAW
ROCKLAND COUNTY, NEW YORK

Application for Certification of a Major Electric Generating Facility Under Article X of the New York State Public Service Law

Multipathway Risk Assessment

Submitted by:

Southern Energy Bowline, L.L.C.
400 Rella Boulevard, Suite 157
Suffern, New York 10901

Prepared by:

TRC Environmental Corporation

April 2000

BOWLINE UNIT 3
TOWN OF HAVERSTRAW
ROCKLAND COUNTY, NEW YORK

Application for Certification of a Major Electric Generating Facility Under Article X of the New York State Public Service Law

Multipathway Risk Assessment

Submitted by:

Southern Energy Bowline, L.L.C.
400 Rella Boulevard, Suite 157
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TRC Environmental Corporation

April 2000

EXECUTIVE SUMMARY

A Multipathway Risk Assessment (MRA) was conducted on behalf of Southern Energy Bowline, L.L.C. (Southern Energy) for the Bowline Unit 3 facility (Bowline) in accordance with the USEPA's most recent draft guidance, "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities."- (USEPA, 1998) and errata (USEPA, 1999).

In accordance with Clause 6 of Stipulation No. 1: Air Quality and Meteorology, filed as part of Appendix 1A of the Article X Application filed by Southern Energy in case no. 99-F-1164 at the New York State Board on Electric Generating Siting and the Environment, a comparison of predicted ground level air concentrations of non-criteria pollutants to benchmark air concentrations for both short- and long-term exposures was conducted. As a result of this evaluation, it was shown that arsenic, a Persistent, Bioaccumulative, Toxic (PBT) chemical, exceeded 1% of its corresponding health risk-based benchmark air concentration, and thus a multipathway risk assessment was conducted for this constituent.

This MRA was conducted using the dispersion modeling approach described in the approved modeling protocol submitted for the project and stack emissions presented in the Article X Application. It includes ISCST3 air dispersion modeling to estimate the potential impact of stack emissions at the worst case receptor site which was assumed conservatively to be representative of the exposure pathways considered in the draft HHRA Guidance.

This MRA evaluates potential receptors based on three exposure scenarios. These scenarios are:

1. Residential (adult and child) - direct inhalation exposure and indirect exposures through incidental ingestion of soil, ingestion of homegrown produce, and ingestion of drinking water.

2. Subsistence fisher (adult and child) - direct inhalation exposure and indirect exposures through the incidental ingestion of soil, ingestion of homegrown produce, ingestion of locally caught fish, and ingestion of drinking water.

3. Subsistence farmer (adult and child) - direct inhalation exposure and indirect exposures through the incidental ingestion of soil, ingestion of homegrown produce, ingestion of homegrown beef and dairy; and ingestion of drinking water.

Calculations presented in this document show that estimated cancer and non-cancer risks from anticipated emissions of Bowline Units 1 and 2 and Bowline Unit 3 are well below acceptable USEPA guideline levels of 1.00E-05 and 0.25, respectively. Tables ES-1 and ES-2 provide a summary of the cancer and non-cancer risk computations for all three exposure scenarios for indirect and direct exposure pathways, respectively. Table ES-3 provides the cumulative cancer and non-cancer risk estimates from both the direct and indirect pathways.

TABLE ES-1. CANCER RISKS AND NON-CANCER HIs FROM INDIRECT PATHWAYS
EVALUATON OF ARSENIC
BOWLINE RISK ASSESSMENT

	Resident		Subsistence Fisher		Subsistence Farmer	
	Adult	Child	Adult	Child	Adult	Child
Total Cancer Risk:	3E-007	1E-007	3E-007	1E-007	2E-006	3E-007
Critical Effect HIs:	1.3E-003	3.3E-003	1.6E-003	3.5E-003	8.1E-003	8.4E-003

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

TABLE ES-2. CANCER RISKS AND NON-CANCER HIs FROM DIRECT PATHWAYS
EVALUATON OF ARSENIC
BOWLINE RISK ASSESSMENT

	Resident		Subsistence Fisher		Subsistence Farmer	
	Adult	Child	Adult	Child	Adult	Child
Total Cancer Risk:	5E-008	2E-008	5E-008	2E-008	5E-008	2E-008
Critical Effect HIs:	NA	NA	NA	NA	NA	NA

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

TABLE ES-3. CUMULATIVE CANCER RISKS AND NON-CANCER HIs (a) FROM DIRECT AND INDIRECT PATHWAYS EVALUATON OF ARSENIC BOWLINE RISK ASSESSMENT

	Resident		Subsistence Fisher		Subsistence Farmer	
	Adult	Child	Adult	Child	Adult	Child
Total Cancer Risk:	3E-007	1E-007	4E-007	2E-007	2E-006	3E-007
Critical Effect HIs:	1.3E-003	3.3E-003	1.6E-003	3.5E-003	8.1E-003	8.4E-003

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

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1.0 INTRODUCTION

In support of the Article X Application for Bowline Unit 3, which will be located at the existing Bowline Generating Station property in Haverstraw, New York, the potential impacts of non-criteria pollutant emissions were calculated and compared to risk-based benchmark air concentrations developed in accordance with procedures discussed with the New York State Department of Health (NYSDOH). The analysis was conducted to in accordance with Stipulation No. 1, Clause 6, of the stipulations executed by Southern Energy and the New York State Department of State (NYSDPS), New York State Department of Environmental Conservation (NYSDEC), and NYSDOH in case no 99-F-1164.

Results of the non-criteria pollutant modeling analysis indicated that maximum modeled concentrations of arsenic, cadmium, chromium VI, mercury, and nickel potential emitted from the Bowline Unit 3 turbine stack and cooling tower, and the existing Bowline Units 1 and 2 stacks, were greater than 1% of their respective risk-based concentrations. Thus, in accordance with clause 6 of Stipulation No. 1, an evaluation of the need for a multipathway risk assessment had to be evaluated for these pollutants. On March 3, 2000, Southern Energy and TRC Environmental Corporation (TRC Environmental) met with NYSDOH to discuss the need for a multipathway risk assessment for each of these pollutants.

According to the NYSDOH, although chromium VI and nickel are considered highly toxic through the inhalation pathway; their toxicity is very low through other pathways such as ingestion. Therefore, the NYSDOH concluded that multipathway risk assessments for chromium VI and nickel were not necessary providing that the inhalation risk-based concentrations were not exceeded. As presented in the Article X Application, the maximum modeled concentrations of chromium VI and nickel are well below their respective risk-based concentrations, thus no further analyses were required.

Further discussions with NYSDOH indicated that the NYSDEC has developed a more refined approach for determining if a multipathway risk assessment is necessary. A June 10, 1993, NYSDEC Guidance Memorandum (Implementation of Subparts 219-3 and 219-4. Regulated Medical Waste (RMW) Incineration Facilities and Crematories/Pathological Incinerators) from Mr. Tom Allen to the Regional Air Pollution Control Engineer (RAPCE) provided screening factors based on a percentage of the risk-based concentrations for arsenic, cadmium, and mercury, which, if exceeded, would trigger the need for a multipathway risk assessment. These screening factors are 1%, 100%, and 25% of the risk-based concentrations for arsenic, cadmium, and mercury, respectively.

The maximum modeled concentrations of cadmium and mercury are well below these associated screening factors; therefore, NYSDOH agreed that multipathway risk assessments for these pollutants were not necessary. However, maximum modeled arsenic concentrations exceeded the 1% screening factor. Thus, a multipathway risk assessment was required for arsenic emissions from Bowline Unit 3 and the existing Bowline Units 1 and 2.

This MRA was conducted using the dispersion modeling approach described in the approved modeling protocol submitted for Bowline Unit 3 and stack emissions presented in the Article X Application. It includes ISCST3 air dispersion modeling to estimate the potential impact of stack emissions at the worst case receptor site that was assumed conservatively to be representative of the exposure pathways considered in the draft HHRA Guidance.

The draft HHRA Guidance provides theoretical estimates of individual risk based on "high-end" (for reasonable maximum exposure (RME)) exposure scenarios and includes an evaluation of potential risks associated with direct and indirect exposures. For the purposes of this document, direct exposures are defined as those associated with the inhalation of constituents released via stack emissions. Exposures to constituents in surface soils, food (produce, beef, dairy and fish), and drinking water following deposition on to soils, plants, and surface water bodies are considered indirect exposures.

In addition to the draft HHRA Guidance, USEPA has published additional guidance methodologies and resource documents, which can be used to evaluate potential risks from combustor emissions. Table 1-1 lists the current risk assessment guidance documents. These documents provide additional guidance and the basis for a more definitive, site-specific risk assessment.

TABLE 1-1. CURRENT RISK ASSESSMENT GUIDANCE DOCUMENTS

U.S. Environmental Protection Agency (USEPA). 1989a. Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. December.

U.S. Environmental Protection Agency (USEPA). 1990a. Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions. Interim Final. EPA/600/6-90/003. January.

U.S. Environmental Protection Agency (USEPA). 1990b. Exposure Factors Handbook EPA/600/8-89/043.

U.S. Environmental Protection Agency (USEPA). 1991. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". OSWER Directive 9285.6-03.

U.S. Environmental Protection Agency (USEPA). 1992a. Estimating Exposure to Dioxin-like Compounds. EPA/600/6-88/005B.

U.S. Environmental Protection Agency (USEPA). 1992b. Guidelines For Exposure Assessment. FR 57[104]: 22888-22936.

U.S. Environmental Protection Agency (USEPA). 1993a. Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure. Preliminary Review Draft. May 5.

U.S. Environmental Protection Agency (USEPA). 1993b. Addendum to the Methodology for Assessing Risks Associated with Indirect Exposure to Combustor Emissions. Draft. EPA/600/AP-93/003.

U.S. Environmental Protection Agency (USEPA). 1993c. Interim Report on Data and Methods for Assessment of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Risks to Aquatic Life and Associated Wildlife. EPA/600/R-93/055.

U.S. Environmental Protection Agency (USEPA). 1994a. Implementation Guidance for Conducting Indirect Exposure Analysis at RCRA Combustion Units. Revised Draft. April 22.

U.S. Environmental Protection Agency (USEPA). 1994b. Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Errata. Revised Draft. October 4.

U.S. Environmental Protection Agency (USEPA). 1994c. Memorandum: Further Issues for Indirect Exposure Assessment Modeling. OHEA and ECAO, September.

U.S. Environmental Protection Agency (USEPA). 1995a. Memorandum: Further Issues for Modeling the Indirect Exposure Impacts from Combustor Emissions. OHEA and ECAO, January 20.

U.S. Environmental Protection Agency (USEPA). 1997a. Protocol for Screening Level Human Health Risk Assessment at Hazardous Waste Combustion Facilities. OSW, February 28.

U.S. Environmental Protection Agency (USEPA). 1998. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Peer Review Draft. OSWER, July.

U.S. Environmental Protection Agency (USEPA). 1999a. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Peer Review Draft. Errata. OSW, August 2.

2.0 SELECTION OF CONSTITUENTS OF POTENTIAL CONCERN

2.1 Selection Of The Dataset For Inclusion in the Risk Assessment

An evaluation of predicted ground level air concentrations of non-criteria pollutants was conducted. These air concentrations were compared to benchmark air concentrations for both short- and long-term exposures. Clause 6(g) of Stipulation No. 1: Air Quality and Meteorology, provides that:

> "If the maximum modeled annual average ground level air concentration of a non-criteria pollutant exceeds one (1) percent (for persistent, bioaccumulative toxic chemicals) or ten (10) percent (for all other chemicals) of the corresponding health risk-based benchmark air concentration, the Application will include and evaluation for the need for a multipathway risk assessment. If Southern Energy can demonstrate with adequate documentation that the modeled plume will not substantially impact beef or dairy farms, or areas that could support such farms, the ten (10) percent screening factor may be used for all non-criteria pollutants. The Application will include a multipathway risk assessment for those pollutants that exceed these criteria..."[1]

Based upon this evaluation, arsenic exceeded one (1) percent of its corresponding health risk-based benchmark air concentration, and, thus, a multipathway risk assessment was conducted for this constituent. Consistent with the draft HHRA Guidance (USEPA 1998), arsenic was evaluated for potential risks associated with indirect and direct exposure in accordance with available USEPA toxicity criteria and chemical/physical property data. Appendix A presents the algorithms used to calculate environmental concentrations and estimated intakes for both indirect exposure and direct exposure pathways.

2.2 Selection of Toxicity Criteria

A hierarchical approach was used to select toxicity criteria from USEPA sources for arsenic. This approach was selected to ensure that the most current information was used for the MRA.

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[1] The NYSDOH indicated that Southern Energy would satisfy the stipulation if the multipathway risk assessment were submitted to the Siting Board within 30 days of the date of filing the Article X Application

Listed in order, these data sources are as follows:

1. USEPA's Integrated Risk Information System (IRIS) (USEPA, 2000).
2. USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997b).

2.3 Chemical/Physical Properties

The draft HHRA Guidance provides chemical/physical parameter values needed to assess potential risks in indirect pathways for a subset of chemicals. A table of physical/chemical properties used in the MRA is presented in Appendix B.

3.0 Modeling Methodology and Inputs

Modeling was performed following guidance provided in the USEPA documents: Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA, 1998a) and Guideline on Air Quality Models (Revised) (USEPA, 1999a). In addition, TRC utilized guidance and recommendations provided by the NYSDOH.

As discussed with the NYSDOH and pursuant to USEPA guidance, the following methodology was incorporated into the assessment:

- Conducting a load screening analysis to determine the worst case operating load (i.e., operating scenario that yields the maximum annual arsenic concentration) for each fuel type fired in the Bowline Unit 3 turbines;
- Annualize the potential emissions from the Bowline Unit 3 turbines' worst case operating loads for each fuel type by assuming the equivalent of 45 days of oil firing per year and the remaining 320 days the turbines are firing natural gas;
- Assuming simultaneous worst case load operation (determined in a load screening analysis) of the Bowline Unit 3 turbines and normal operation of the existing Bowline Units 1 and 2 for an entire year (8,760 hours per year); and,
- Assuming the locations of the overall maximum arsenic concentration and deposition values occur at the same location which represents the location for all the health risk pathways (e.g., inhalation and ingestion).

Specifically, the overall maximum modeled annual arsenic concentrations and deposition values calculated were used in a screening level analysis in the health risk assessment. If the health risk would have been determined to be unacceptable using the overall maximum values, then a more refined analysis would have been conducted to separate the specific pathways. However, results from the screening level analysis yielded a human health risk less than the NYSDOH and USEPA recommended value (1:100,000).

3.1 Surrounding Terrain and Land Use

Bowline Unit 3 will be located adjacent to the existing Bowline Units 1 and 2 in Rockland County, New York, in the Town of Haverstraw. The site is bounded by the Hudson River on the east, the existing Bowline Units 1 and 2 on the south, the Minisceongo Creek on the north, and the Village of West Haverstraw on the west.

A land use classification analysis was performed to determine whether urban or rural dispersion parameters should be used in quantifying ground-level concentrations. The analysis conformed to the procedures contained in the A.H. Auer paper "Correlation of Land Use and Cover with Meteorological Anomalies" (Auer, 1978). This procedure was followed by visually determining the uses of various industrial, commercial, residential, and agricultural/natural areas within a three kilometer radius circle centered on the Project Site in order to assess the land use around the Project Site. Essentially, if more than 50 percent of the area within this circle is designated I1, I2, C1, R2 and R3 (industrial, light industrial, commercial, and compact residential), urban dispersion parameters should be used; otherwise, the modeling should use rural dispersion parameters.

Approximately 46 percent of the area surrounding the facility is water (A5 according to the Auer classification technique). Water surfaces are considered rural along with metropolitan natural (A1), undeveloped (A3), and common residential (R1) which make up 15%, 4%, and 3%, respectively of the land use within 3 km of the proposed site. Thus a total of 68% of the land use surrounding the Bowline Unit 3 is classified as rural. Therefore, the rural dispersion coefficients were used for the air quality modeling analysis.

3.2 Model Selection and Options

The Industrial Source Complex Short-Term (ISCST3, Version 99155) model was used to calculate the maximum arsenic concentration and deposition values from Bowline Unit 3 and the existing Bowline Units 1 and 2. The ISCST3 model was applied in accordance with the recommendations made in USEPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA, 1998a) and Guideline on Air Quality Models (Revised) (USEPA, 1999a).

The ISCST3 model is a Gaussian plume model capable of calculating impacts in simple (below stack top), intermediate (above stack top and below final plume rise), and complex (above final plume rise) terrain. However, according to the USEPA's Guideline on Air Quality Models (Revised) (USEPA, 1999a), the ISCST3 model can only be used to calculate impacts in intermediate and complex terrain if on-site meteorological data for one continuous year or more is available. In the January 27, 2000 letter from Mr. Steven C. Riva, USEPA Region 2 Chief of the Permitting Section of the Air Programs Branch, to Mr. Leon Sedefian of the NYSDEC, USEPA approved the use of one year of on-site meteorological data for modeling Bowline Unit 3. Thus, the ISCST3 model was used to determine maximum impacts in simple, intermediate, and complex terrain.

The COMPLEX I option of the ISCST3 model was used to calculate impacts in any complex terrain areas. For intermediate terrain, the ISCST3 model compares the maximum impacts calculated using the simple terrain algorithm and the COMPLEX I algorithm and presents the maximum of these impacts as a conservative estimate.

ISCST3 includes various input and output options. Additional options are available for specific methods and were used in the plume model equations. The model was applied using the regulatory default options as prescribed in the USEPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA, 1998a). These included the following:

- Using stack-tip downwash (except for Schulman-Scire downwash);
- Using buoyancy-induced dispersion (except for Schulman-Scire downwash);
- Not using gradual plume rise (except for building downwash);
- Using the calms processing routines;
- Using upper-bound concentration estimates for sources influenced by building downwash from super-squat buildings;
- Using default rural wind speed profile exponents; and
- Using default rural vertical potential temperature gradients.

Also input to the model were the commands to calculate the dry and wet deposition values and account for plume depletion resulting from dry and wet deposition. Terrain heights for each receptor were input to the ISCST3 model to account for the varying terrain surrounding Bowline Unit 3.

3.3 Source Parameters

3.3.1 Bowline Unit 3 Sources

Bowline Unit 3 consists of four potential arsenic sources: three GE Frame 7FA combustion turbines and a cooling tower. The maximum heat input for a GE turbine firing natural gas at -10°F, is 2,225 million British thermal units per hour (mmBtu/hr), Higher Heating Value (HHV). Hot exhaust gases from the combustion turbines will flow into supplementary fired (duct burners) heat recovery steam generators (HRSGs). The turbine will be capable of firing either natural gas or distillate oil, while the duct burners will only burn natural gas. The HRSGs will produce steam to be used in the steam turbine. During periods of peak summer time demand, the duct burners will fire natural gas to provide additional steam for the steam turbine to generate additional electricity. This will occur only when the combustion turbines are operating at 100% load. The three combustion turbines are capable of producing up to 171 MW each of electric power at an ambient temperature of -10°F burning distillate fuel oil. The steam turbine is capable of producing 250 MW of electric power at -10°F. Upon leaving the HRSGs, the turbine exhaust gases will be directed to one 286-foot stack with three 18-foot flues.

Bowline Unit 3 will be dispatchable but will be designed to operate on a continuous basis. Because of the dispatchable nature of Bowline Unit 3 operation, periods of part load operation and multiple startups/shutdowns per week could occur. However, as detailed further in Section 2.4.1, emissions of arsenic were calculated only when the turbines are firing natural gas along with the duct burners and when the turbines are firing distillate fuel oil. Arsenic emissions could not be estimated when the turbine was firing natural gas at 100% load without the duct burners or at reduced loads (e.g., 50% and 75% load). To ensure the maximum impacts from these operating scenarios were determined, the natural gas-fired operating scenarios were modeled for three ambient temperatures (-10°F, 50°F, and100°F) in a screening analysis.

The three natural gas-fired operating scenarios were refined further to account for one turbine/one duct burner (one flue) operating, two turbine/two duct burners (two flues) operating, and three turbines/three duct burners (three flues) operating for a total of nine natural gas fired operating scenarios. Flue diameters for the two and three flue cases were adjusted to reflect the effective diameter for simulating plume merging. Exhaust characteristics of the common stack when one, two, and three turbines are firing natural gas with the duct burners operating are provided in Table 2-1.

When the turbines are firing distillate fuel oil, operation will be restricted to two turbines at 50% load, with the third turbine firing natural gas at 100% load with duct burners. This operating scenario was modeled for the three ambient temperatures to ensure the maximum impacts from this operating scenario were determined. The impacts from one turbine operating at 50% load on fuel oil and one turbine firing natural gas at 100% load plus duct firing also were calculated to ensure the maximum impacts were determined for the fuel oil firing operating scenarios. A total of six oil-fired operating scenarios were included in the modeling. No other fuel oil firing operating scenarios are proposed to be permitted with this permit application.

The fuel-specific operating condition that resulted in the maximum arsenic impact (i.e., worst case operating scenario) was modeled along with the existing Bowline Units 1 and 2 to determine the maximum arsenic concentration and deposition values for use in the arsenic multipathway risk assessment.

A mechanical draft linear type cooling tower will cool the circulating water used to condense the exhaust steam from the steam turbine. Arsenic contained in Hudson River water, which will be used as make-up water for the cooling tower, will be emitted in water droplets from the tower drift. The quantity of arsenic in the tower drift is equivalent to the level found in the river. Any emissions of arsenic from the cooling tower will be minimal and because the cooling tower contributed less than 0.2% to the overall maximum modeled arsenic concentration presented in the Article X Application, the cooling tower was not included in the multipathway risk assessment. However, conservatively assuming that the cooling tower would increase linearly the maximum calculated risk from Bowline Unit 3 and existing the Bowline Units 1 and 2 by 0.2% would result in a human health risk still well below the 1:100,000 required by NYSDOH and USEPA

3.3.2 Bowline Units 1 and 2

Exhaust characteristics for the existing units were initially obtained from the NYSDEC's emission inventory database and then updated using Bowline on-site records. Both units have 286-foot stacks with 18.7-foot diameters through which their emissions are exhausted to the atmosphere. The exhaust temperature of Unit 1 was estimated to be 292°F and the exhaust temperature of Unit 2 was 268°F. Exit velocities for Bowline Units 1 and 2 were calculated to be 111.3 feet per second and 107.7 feet per second, respectively.

3.4 Potential Arsenic Emission Rates

3.4.1 Bowline Unit 3

Potential arsenic emission rates from the Bowline Unit 3 were calculated using the USEPA's AP-42 - Stationary Internal Combustion Sources (USEPA, 1996) arsenic emission factors for natural gas and distillate fuel oil fired turbines and the maximum heat rate of the turbines. For the duct burners, AP-42 - External Combustion Sources (USEPA, 1998b) arsenic emission factors for natural gas fired boilers were used along with the maximum heat rate of the duct burners. No emission factors for arsenic are provided in AP-42 - Stationary Internal Combustion Sources (USEPA, 1996) for natural gas fired turbines. Therefore, arsenic emissions were calculated only from the duct burners for the natural gas-fire turbine operating scenarios. Table 2-1 also includes the potential arsenic emission rate for each of the modeled operating cases.

3.4.2 Bowline Units 1 and 2

Bowline Units 1 and 2 are permitted to burn both natural gas and No. 6 fuel oil. Using the USEPA's AP-42 - External Combustion Sources (USEPA, 1998 (gas-fired) and USEPA, 1998c (oil-fired)) arsenic emission factors for these fuels in conjunction with the two-year average fuel consumption recorded for each of the units, the maximum arsenic emission rates were calculated. Bowline Unit 1 has a maximum arsenic emission rate of 1.74×10^{-2} tons per year and Bowline Unit 2 has a maximum arsenic emission rate of 1.46×10^{-2} tons per year.

3.5 Arsenic Emission Characteristics

Health risk assessments are conducted for pollutants that are emitted as vapor, particulate, or for some substances both. The particulate phase can be further split to mass weighting and surface area weighting. Mass weighting accounts for those pollutants that are emitted as solids (e.g., metals), while surface area weighting accounts for semivolatile organic compounds that have volatilized and then condensed onto an existing particulate.

The arsenic contained in the natural gas and fuel oils (distillate and residual) is a metal which sublimates at 613°C. Exhaust temperatures within the Bowline Unit 3 turbines' stack and existing boiler stacks do not exceed 150°C. Thus, all the arsenic exhausting from the turbine and boiler stacks will be as a particulate and were modeled as such.

Both wet and dry deposition depend on the particle size. Larger particles will fall out faster (i.e., nearer the source) and will be removed, or scavenged, more easily by precipitation. Therefore, the ISCST3 model requires the particle size distribution, based on particle diameter, to determine the deposition values.

3.5.1 Particle Size Distribution

The particle size distribution input to the ISCST3 model was based on the distributions provided in the USEPA's AP-42. Specifically, distributions for large uncontrolled natural gas and distillate fuel oil fired turbines were used for the Bowline Unit 3 turbines and the residual oil fired utility boiler AP-42 distributions were used for the existing Bowline Units 1 and 2. The AP-42 particulate size distributions for natural gas fired utility boilers were not selected because the arsenic emissions from residual oil firing are greater than from natural gas firing (i.e., Bowline Units 1 and 2 were modeled assuming residual oil firing only). Tables 2-2 and 2-3 present the particle size distributions used to model Bowline Unit 3 turbines and the existing Bowline Units 1 and 2 boilers, respectively.

3.5.2 Particle Density

As suggested in the USEPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA, 1998a), a default value of 1.0 gram per cubic centimeter was input for each of the particulate sizes modeled.

3.5.3 Scavenging Coefficients

Precipitation falling through a plume of suspended particulates will capture (scavenge) some of the particles and carry them to the ground (wet deposition). The proportion of the particles that are captured is related to the particle size and the type of precipitation. The measure of this effect is known as the scavenging coefficient. The wet deposition values are calculated using the vertically integrated concentrations, the precipitation rate, and the scavenging coefficient. Scavenging coefficients vary with particle size. Scavening coefficients were determined for each of the particle sizes presented in Tables 2-2 and 2-3 from the best fit curve created from the work of Jindel and Heinhold (1991). This best fit curve is presented in the ISC3 User's Guide (USEPA, 1999b). Because the curve does not extend to particle sizes less than 0.1 microns, the scavenging coefficients for 0.1 microns were used for smaller particles (e.g., 0.05 microns).

Liquid and frozen precipitation will have different scavenging coefficients for the different particle sizes. However, as a conservative estimate, the frozen scavenging coefficients were assumed to be equal to the liquid scavenging coefficients (PEI and Cramer, 1986). The scavenging coefficients used in the modeling analysis are shown in Table 2-4.

3.6 Good Engineering Practice Stack Height Analysis

In the Guidance for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations) (EPA-450/4-80-023R, June, 1985), the USEPA provides specific guidance for determining good engineering practice (GEP) stack height and for determining whether building downwash will occur. GEP is defined as "the height necessary to ensure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of the source as a result of atmospheric downwash, eddies, and wakes that may be created by the source itself, or nearby structures, or nearby terrain "obstacles".

The GEP definition is based on the observed phenomenon of atmospheric flow in the immediate vicinity of a structure. It identifies the minimum stack height at which significant adverse aerodynamics (downwash) are avoided.

The USEPA GEP stack height regulations specify that the GEP formula stack height is calculated in the following manner:

$$H_{GEP} = H_B + 1.5L$$

where:

H_B = the height of adjacent or nearby structures, and

L = the lesser dimension (height or projected width of the adjacent or nearby structures)

The controlling structure for the Bowline Unit 3 stack is the Bowline Units 1 and 2 electric generating building which, at a height of 223.5 feet, would result in a GEP stack height of 559.8 feet. The Bowline Unit 3 Article X Application indicates that Southern Energy will construct one common 286-foot high non-GEP stack to serve the Bowline Unit 3 turbines. Existing Bowline Units 1 and 2 also have non-GEP stacks, with a height of 286 feet above grade. Therefore, direction-specific building downwash was included for the Bowline Unit 3 stack and the existing Bowline Units 1 and 2 stacks. The USEPA approved Building Profile Input Program - BPIP (Version 95086) was used to determine the directionally dependent building dimensions for input to the ISCST3 model. A plot plan of the Bowline Unit 3 and the existing Bowline Units 1 and 2 is included in the Article X Application.

3.7 Meteorological Data

The modeling analysis for the multipathway risk assessment used the available meteorological data collected at a meteorological tower at the Bowline Generating Station property by Enviroplan, Inc. for Orange and Rockland Utilities, Inc. from June 1985 through May 1986. These data also were used in the Prevention of Significant Deterioration (PSD) modeling analysis and non-criteria pollutant modeling included in the Article X Application. The hourly surface data was approved by both NYSDEC and USEPA for modeling Bowline Unit 3 as well as Bowline Units 1 and 2. A wind rose depicting the distribution of surface wind speed and wind direction from the on-site meteorological data was presented in the Article X Application.

In addition to surface meteorological data, the modeling analysis required a concurrent year of upper air meteorological data which were utilized to calculate atmospheric mixing height. Upper air observations are taken by the National Weather Service (NWS) at a limited number of locations throughout the United States. The NWS upper air observation stations closest to the Bowline Unit 3 site with available data for 1985 and 1986 are Albany, NY and Atlantic City, New Jersey. A review of summarized mixing height data for 62 upper air stations in the United States, which was prepared by Holzworth, Mixing Height, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States (Holtzworth, 1972), indicates that the Atlantic City mixing height data would be the most representative of site conditions (based on the Holzworth study, it was concluded that mixing heights for the Haverstraw area are best represented by a coastal upper air station than an inland station). As such, Atlantic City mixing height data were used in the modeling analysis.

To calculate deposition values, the ISCST3 model requires additional meteorological data and site-specific information. In addition to wind speed, wind direction, and dry bulb temperature (all available from the on-site surface data), the ISCST3 model needs opaque cloud cover, cloud ceiling height, and precipitation types and amounts. Surface data from the White Plains NWS station were used to supplement the Bowline on-site meteorological data with the opaque cloud cover and cloud ceiling height for the concurrent time period (June 1, 1985 to May 31, 1986).

Precipitation amounts were obtained from the Yorktown Heights co-operative meteorological station for the June 1, 1985 through May 31, 1986 time period. Because the White Plains NWS station and the Yorktown Heights co-operative station did not record precipitation type for each precipitation event, TRC Environmental assumed that any precipitation event when the ambient temperature was less than 32°F was a frozen (i.e., snow) event. Whenever the precipitation event occurred with ambient temperatures greater than 32°F, it was assumed to be a liquid (i.e., rain) event. There were less than 10 hours where the temperature was 32°F during a precipitation event. These precipitation types were interpreted by examining the temperatures of the hours prior to and after the hour in question.

White Plains is approximately 15 miles southeast of the Bowline Generating Station property and is generally affected by the same large scale weather systems as the Bowline Unit 3 site. Therefore, the cloud data recorded at White Plains should be representative of cloud conditions at the Bowline Generating Station property.

The co-operative station in Yorktown Heights is located approximately 9 miles northeast of the Bowline Generating Station property. The station is the closest hourly precipitation monitoring site to the Bowline Unit 3 site and is generally affected by the same small and large scale weather systems as the Bowline site. Thus, the precipitation amounts recorded in Yorktown Heights should be representative of the amounts occurring at the Bowline Unit 3 site.

Site-specific information required to calculate deposition values include the Monin-Obukhov length, surface roughness length, non-time albedo, Bowen ratio, anthropogenic heat flux, and the fraction of net radiation absorbed at the surface. Guidance from the PCRAMMET User's Guide (EPA, 1995) was used to determine each of the site-specific values. Namely, from the land uses categories available in the PCRAMMET User's Guide (EPA, 1995), it was assumed that the Bowline Unit 3 site is located in rural land use (deciduous forest) with average conditions. The appropriate values for these conditions are presented in Table 2-5.

3.8 Receptor Grid

The ISCST3 model requires receptor data consisting of location coordinates and ground-level elevations. As agreed upon with the NYSDEC, a receptor grid consisting of 1,822 receptors was developed using a polar grid with receptors spaced as follows :

100 meters to 2,000 meters at 100 meter spacing;
2,000 meters to 5,000 meters at 250 meter spacing; and,
5,000 meters to 20,000 meters at 1,000 meter spacing.

In addition to the polar grid, the Bowline Generating Station property has a fenced property line. Ambient air is therefore defined as the area at and beyond the fence. The modeling receptor grid includes receptors spaced at 25 meter intervals along the entire fenceline.

Terrain heights were determined from a U.S. Geological Survey 3-arc second digital elevation CD-ROM for all the receptor locations.

3.9 Modeling Results

3.9.1 Bowline Unit 3 Screening Analysis

In order to assess the worst case arsenic impacts for the range of the Bowline Unit 3 turbine operating scenarios, a screening analysis was performed using the ISCST3 model with one year of on-site meteorology. As was discussed in Section 2.3.1, 15 combinations of operating conditions and ambient operating temperature are possible when the turbines are firing natural gas with duct burners operating and distillate fuel oil. Note that the exhaust characteristics and arsenic emission rates for these 15 cases are identified in Table 2-1. The worst case operating loads were determined to be when one turbine is firing distillate fuel oil at 50% load at 50°F (case 14) and one turbine is firing natural gas at 100% load with duct burner at 100°F (case 9). These two operating cases yielded the maximum annual arsenic concentrations assuming that the turbine(s) were firing each fuel type the entire year (8,760 hours per year). Results of the load screening analysis are presented in Table 2-6.

Even though operating more than one turbine simultaneously would increase the total emissions of arsenic from the stack, the increased plume rise due to plume merging would cause the ground-level concentrations to be reduced. Thus, a combination of one turbine firing distillate fuel oil at 50% load at 50°F and one turbine firing natural gas with a duct burner at 100% load (100°F) were modeled as operating concurrently. However, no plume merging was assumed.

3.9.2 Bowline Units 1, 2 and 3 Modeling Analysis

The worst case operating loads determined for the proposed Bowline Unit 3 turbines were then modeled with the existing Bowline Units 1 and 2. Because Southern Energy proposes a distillate fuel oil restriction equivalent to 45 days per year, the arsenic emissions modeled from the Bowline Unit 3 turbines were scaled to assume 45 days per year of distillate fuel oil operation (i.e., emissions modeled with case 14 exhaust parameters) and 320 days per year of natural gas firing (i.e., emissions modeled with case 9 exhaust parameters).

Results of the modeling analysis were used as input to the multipathway risk assessment. The overall maximum annual average arsenic concentration and wet and dry arsenic deposition values were calculated using the modeling methodology and inputs described.

The overall maximum annual average arsenic concentration was determined to be 3.8×10^{-5} $\mu g/m^3$. Annual wet and dry arsenic deposition values were calculated to be 5.9×10^{-4} g/m^2 and 7.1×10^{-6} g/m^2, respectively.

3.9.3 Modeling Data Files

All input and output modeling files for the load screening analysis used to determine the "worst-case" operating scenario and then subsequently, the overall maximum arsenic concentrations and deposition values are included on diskette. The diskette is included with the NYSDOH and NYSDEC copies of this document that are addressed to Dr. Antonia Novello, the Commissioner of the NYSDOH, and Mr. John P. Cahill, the Commissioner of the NYSDEC.

TABLE 3-1
SOUTHERN ENERGY BOWLINE, L.L.C.
MODELED SOURCE PARAMETERS[a] AND EMISSION RATES

Turbine/ Duct Burner Case No.[b]	Fuel Type	Ambient Temperature (°F)	Duct Burner Load (%)	Turbine Load (%)	Exhaust Temperature (°F)	Stack Velocity[c] (ft/s)	Potential Arsenic Emission Rate[d] (lb/hr)
1,16,31	Natural Gas	-10	100	100	190	71.8	4.67×10^{-5}
5,20,35	Natural Gas	50	100	100	190	66.0	4.67×10^{-5}
9,24,39	Natural Gas	100	100	100	190	60.1	4.67×10^{-5}
13,28	Distillate Oil	-10	0	50	240	62.4	6.24×10^{-3}
14,29	Distillate Oil	50	0	50	240	57.3	5.60×10^{-3}
15,30	Distillate Oil	100	0	50	240	64.0	4.98×10^{-3}

[a] Stack height is 286 feet above grade, grade elevation is 10 feet above sea level.

[b] Cases 1,5,9,13-15 reflect one turbine and duct burner operating. Cases 16,20,24,28-30 reflect two turbines and duct burners operating (modeled with an effective diameter of 25.5 ft). Cases 31,35,39 reflect three turbines and duct burners operating (modeled with an effective diameter of 31.2 ft).

[c] Exhaust velocity per flue are based on a 18 foot diameter for each flue.

[d] Potential arsenic emission rates are per combustion turbine.

TABLE 3-2
SOUTHERN ENERGY BOWLINE, L.L.C.
PARTICLE SIZE DISTRIBUTION FOR COMBUSTION TURBINES[a]

Particle Size (µm)	Natural Gas Fired Turbines Mass Fraction	Distillate Fuel Oil Mass Fraction
0.05	15%	16%
0.10	25%	32%
0.15	23%	24%
0.20	15%	13%
0.25	11%	8%
1.0	11%	7%

[a] Data from Table 3.1-1. Emission Factors for Large Uncontrolled Gas Turbines. USEPA AP-42 - Stationary Internal Combustion Sources.

TABLE 3-3

SOUTHERN ENERGY BOWLINE, L.L.C.

PARTICLE SIZE DISTRIBUTION FOR UTILITY BOILERS FIRING RESIDUAL OIL[a]

Particle Size (μm)	Uncontrolled Boiler Mass Fraction
0.63	20%
1.0	19%
1.25	4%
2.5	9%
6.0	6%
10.0	13%
15.0	9%
20.0[b]	20%

[a] Data from Table1.3-4. Cumulative Particle Size Distribution and Size-Specific Emission Factors for Utility Boilers Firing Residual Oil. USEPA AP-42 - External Combustion Sources.

[b] Assumed particles greater than 15 μm had a aerodynamic equivalent diameter of 20 μm for modeling purposes.

TABLE 3-4
SOUTHERN ENERGY BOWLINE, L.L.C.
SCAVENGING COEFFICIENTS FOR PARTICULATES[a]

Combustion Turbines		Utility Boilers	
Particle Size (μm)	Wet Scavenging Rate Coefficient ($s^{-1}/mm\text{-}h^{-1}$)	Particle Size (μm)	Wet Scavenging Rate Coefficient ($s^{-1}/mm\text{-}h^{-1}$)
0.05	1.7×10^{-4}[b]	0.63	4.5×10^{-5}
0.10	1.7×10^{-4}	1.0	4.0×10^{-5}
0.15	1.5×10^{-4}	1.25	6.0×10^{-5}
0.20	1.3×10^{-4}	2.5	1.8×10^{-4}
0.25	1.1×10^{-4}	6.0	4.2×10^{-4}
1.0	4.0×10^{-5}	10.0	6.7×10^{-4}
--	--	15.0	6.7×10^{-4}
--	--	20.0[c]	6.7×10^{-4}

[a] Conservatively assumed that the scavenging rate coefficient for frozen precipitation was equal to the scavenging rate for liquid precipitation.

[b] Assumed the scavenging rate was equal to the scavenging rate for 0.1 μm particles due to the limitations of the best fit curve presented in the ISC3 User's Guide (USEPA, 1999b).

[c] Assumed particles greater than 15 μm had a aerodynamic equivalent diameter of 20 μm for modeling purposes.

TABLE 3-5
SOUTHERN ENERGY BOWLINE, L.L.C.
METEOROLOGICAL DATA INPUTS

Meteorological Data	Input
Years	1985-1986
Surface Data	On-Site Meteorological Data[a] (Southern Energy Bowline Facility)
Mixing Height Data	Atlantic City, New Jersey (NWS Station 93755)
Precipitation Data	Yorktown Heights, New York (Co-operative Station 30967)
Minimum Monin-Obukhov Length	25 meters[b]
Anemometer Height	100 meters
Surface Roughness Length - Measurement Site	0.9 meters[c]
Surface Roughness Length - Application Site	0.9 meters[c]
Noon-Time Albedo	0.22[c]
Bowen Ratio	0.88[c]
Anthropogenic Heat Flux	0 watts/square meters[c]
Fraction of Net Radiation Absorbed at the Ground	0.15[d]

[a] Opaque cloud cover and cloud ceiling height obtained from the White Plains NWS station.

[b] Value represents a residential area.

[c] Deciduous forest average conditions used for rural land use.

[d] Value representative of a rural area.

TABLE 3-6
SOUTHERN ENERGY BOWLINE, L.L.C.
LOAD SCREENING RESULTS

Turbine/ Duct Burner Case No.[a]	Fuel Type	Ambient Temperature (°F)	Duct Burner Load (%)	Turbine Load (%)	Maximum Annual Arsenic Concentration (μg/m^3)
1	Natural Gas	-10	100	100	5.67x10^{-7}
5	Natural Gas	50	100	100	6.36x10^{-7}
9	Natural Gas	100	100	100	**7.19x10^{-7}**
16	Natural Gas	-10	100	100	4.48x10^{-7}
20	Natural Gas	50	100	100	5.02x10^{-7}
24	Natural Gas	100	100	100	5.70x10^{-7}
31	Natural Gas	-10	100	100	4.36x10^{-7}
35	Natural Gas	50	100	100	4.57x10^{-7}
39	Natural Gas	100	100	100	4.99x10^{-7}
13	Distillate Oil	-10	0	50	6.75x10^{-5}
14	Distillate Oil	50	0	50	**6.75x10^{-5}**
15	Distillate Oil	100	0	50	5.20x10^{-5}
28	Distillate Oil	-10	0	50	5.32x10^{-5}
29	Distillate Oil	50	0	50	5.32x10^{-5}
30	Distillate Oil	100	0	50	4.11x10^{-5}

[a] Cases 1,5,9,13-15 reflect one turbine and duct burner operating. Cases 16,20,24,28-30 reflect two turbines and duct burners operating (modeled with an effective diameter of 25.5 ft). Cases 31,35,39 reflect three turbines and duct burners operating (modeled with an effective diameter of 31.2 ft).

4.0 EXPOSURE ASSESSMENT

The draft HHRA Guidance exposure assessment estimates the magnitude of potential exposures based on identified receptor locations using "high end" intake parameters defined in the guidance. The draft HHRA Guidance requires that receptor locations and potential exposure pathways are identified, the concentrations of constituents detected in source emissions are modeled in various environmental media, and potential constituent-specific intakes by identified receptors are estimated. This methodology uses theoretically possible exposures, not actual exposures, and overstates what any individual is likely to experience.

4.1 Potential Receptors and Exposure Pathways

For the purposes of this MRA, potential receptor locations were not specifically identified. The MRA utilized the maximum deposition parameters and maximum air concentrations (which were conservatively assumed to be coincident) to be representative of the impact to each receptor. Thus, each receptor was run using the maximum deposition and maximum air concentrations to represent the most conservative scenario. A discussion of the draft HHRA exposure scenarios and pathways is provided as follows:

- Residential (adult and child) adult and child direct inhalation exposure and indirect exposures through incidental ingestion of soil, ingestion of drinking water and ingestion of homegrown produce.

- Subsistence fisher (adult and child) adult and child direct inhalation exposure and indirect exposures through incidental ingestion of soil, ingestion of drinking water, ingestion of home-grown produce, and ingestion of locally caught fish.

- Subsistence farmer (adult and child) adult and child direct inhalation exposure and indirect exposures through incidental ingestion of soil, ingestion of drinking water, ingestion of home-grown produce, and ingestion of home-grown beef and dairy.

4.1.1 Residential Exposure Scenario

As noted previously, residential adult and child exposures are modeled for inhalation and ingestion of soil, homegrown produce and drinking water. These potential exposures were modeled using maximum impacts.

4.1.2 Subsistence Fisher Exposure Scenario

Subsistence fishing in the Hudson River has been included in this scenario due to its close proximity to the Bowline Generating Station property.

The subsistence fisher is assumed to be the same residential adult and child receptors noted in Section 4.1.1 that also fishes locally on a subsistence basis. As such, direct inhalation exposures and indirect exposures to soil, homegrown produce and drinking water are assumed to be equivalent to residential exposures. As with residential receptors, these exposures were modeled using maximum impacts.

4.1.3 Subsistence Farmer Exposure Scenario

The subsistence farmer adult and child receptors are potentially exposed through direct inhalation and through ingestion of soil, homegrown produce, homegrown beef and milk products and drinking water. It is assumed that the subsistence farmer will obtain drinking water from the same reservoir as the residents in section 4.1.1. As with residential receptors, these exposures were modeled using maximum impacts.

4.2 Exposure Concentrations and Dose

The equations and parameters that were used to quantify exposure via each pathway are provided in Appendix A and screening input parameters are provided in Table 4-1. Calculations vary depending on the environmental media or food type evaluated. The predicted annual air concentration was used in the direct pathway, while concentrations in soil, water, plant, or animal tissue were derived using the annual wet and dry deposition rates also for vapor, particle and particle bound phases.

TABLE 4-1
INPUT PARAMETERS
BOWLINE RISK ASSESSMENT

CATEGORY/PARAMETER	VALUE	REFERENCES
Total Waterbody Load		
Waterbody area (m2):	7.2E+007	site specific
Impervious watershed area receiving fallout (m2):	4.00E+008	conservative estimate
Average annual surface runoff (cm/yr):	27	Baes, et al., 1984
Soil bulk density (g/cm3)	1.5	default, USEPA, 1998
Soil moisture content, theta sw, (cm3/cm3):	0.2	default, USEPA, 1998
Constituent enrichment ratio (--):	See below	
Inorganics:	1	default, USEPA, 1998
Universal soil loss (kg/m2/yr):	1.8E+000	calculated, USEPA, 1998
Water body temperature (K):	298	default, USEPA, 1998
Temperature correction factor, theta (--):	1	default, USEPA, 1998
Gas phase transfer coefficient for flowing rivers or streams (m/yr):	36500	default, USEPA, 1998
Current velocity (m/s):	0.5	site specific
Total waterbody depth (m):	7.63	calculated, USEPA, 1998
Water Concentration		
Average volumetric flow rate (m3/yr):	1.11E+011	site specific
Depth of water column (m):	7.6	site specific
Depth of benthic layer (m):	0.03	default, USEPA, 1998
Waterbody area (m2):	7.2E+007	site specific
Total suspended solids (mg/L):	135	USGS, 1999
Bed sediment porosity (Lwater/L):	0.6	default, USEPA, 1998
Bed sediment concentration (g/cm3):	1	default, USEPA, 1998
Watershed area receiving fallout (m2):	4.0E+008	site specific
kb = Benthic Burial Rate Constant (yr-1):	0.0E+000	calculated, USEPA, 1998
Fish Concentration		
Fish lipid content:	0.07	default, USEPA, 1998
Fraction organic carbon in bottom sediment:	0.04	default, USEPA, 1998
FORAGE UPTAKE		
Interception factor for above ground vegetation (--):	0.5	default, USEPA, 1998
Plant surface loss coefficient (yr-1):	18	default, USEPA, 1998
Length of growing season for above ground vegetation (yr):	0.12	default, USEPA, 1998
Vegetation yield for above ground vegetation (kg DW/m2):	0.24	default, USEPA, 1998
Air density (g/m3):	1200	default, USEPA, 1998
Above ground vegetable correction factor (--):	1	default, USEPA, 1998
SILAGE UPTAKE		
Interception factor for above ground vegetation (--):	0.46	default, USEPA, 1998
Plant surface loss coefficient (yr-1):	18	default, USEPA, 1998
Length of growing season for above ground vegetation (yr):	0.16	default, USEPA, 1998
Vegetation yield for above ground vegetation (kg DW/m2):	0.8	default, USEPA, 1998
Air density (g/m3):	1200	default, USEPA, 1998
Above ground vegetable correction factor (--):	0.5	default, USEPA, 1998

TABLE 4-1
INPUT PARAMETERS
BOWLINE RISK ASSESSMENT

CATEGORY/PARAMETER	VALUE	REFERENCES
BEEF AND MILK UPTAKE		
Quantity of soil eaten each day (kg soil/d):	See below	
Beef cattle:	0.5	default, USEPA, 1998
Dairy cattle:	0.4	default, USEPA, 1998
Quantity of forage eaten each day (kg plant DW/d):	See below	
Beef cattle:	8.8	default, USEPA, 1998
Dairy cattle:	13.2	default, USEPA, 1998
Quantity of silage eaten each day (kg plant DW/d):	See below	
Beef cattle:	2.5	default, USEPA, 1998
Dairy cattle:	4.1	default, USEPA, 1998
Quantity of grain eaten each day (kg plant DW/d):	See below	
Beef cattle:	0.47	default, USEPA, 1998
Dairy cattle:	3	default, USEPA, 1998
Fraction of forage grown on contaminated soil:	1	default, USEPA, 1998
Soil bioavailability factor (--):	1	default, USEPA, 1998
Metabolism factor (--):	1	default, USEPA, 1998
HUMAN INTAKE		
Residential Scenario		
Soil consumption rate (kg/d):	See below	
adult:	0.0001	default, USEPA, 1999, errata
child:	0.0002	default, USEPA, 1999, errata
Fraction of consumed soil that is contaminated:	1	default, USEPA, 1998
Consumption rate of above ground vegetables (kg/kgBW-d):	See below	
adult:	0.0003	default, USEPA, 1998
child:	0.00042	default, USEPA, 1998
Consumption rate of protected above ground vegetables (kg/kgBW-d):	See below	
adult:	0.00057	default, USEPA, 1998
child:	0.00077	default, USEPA, 1998
Fraction of above ground vegetables that are contaminated:	0.25	default, USEPA, 1998
Consumption rate of below ground vegetables (kg/kgBW-d):	See below	
adult:	0.00014	default, USEPA, 1998
child:	0.0002	default, USEPA, 1998
Fraction of below ground vegetables that are contaminated:	0.25	default, USEPA, 1998
Ingestion of Drinking Water (All Scenarios)		
Consumption rate of drinking water(L/d):	See below	
adult:	1.40	
child:	0.67	
Fraction of drinking water that is contaminated:	1.00	

TABLE 4-1
INPUT PARAMETERS
BOWLINE RISK ASSESSMENT

CATEGORY/PARAMETER	VALUE	REFERENCES
Subsistence Fisher Scenario		
Soil consumption rate (kg/d):	See below	
adult:	0.0001	default, USEPA, 1999, errata
child:	0.0002	default, USEPA, 1999, errata
Fraction of consumed soil that is contaminated:	1	default, USEPA, 1998
Consumption rate of above ground vegetables (kg/kgBW-d):	See below	
adult:	0.0003	default, USEPA, 1998
child:	0.00042	default, USEPA, 1998
Consumption rate of protected above ground vegetables (kg/kgBW-d):	See below	
adult:	0.00057	default, USEPA, 1998
child:	0.00077	default, USEPA, 1998
Fraction of above ground vegetables that are contaminated:	0.25	default, USEPA, 1998
Consumption rate of below ground vegetables (kg/kgBW-d):	See below	
adult:	0.00014	default, USEPA, 1998
child:	0.0002	default, USEPA, 1998
Fraction of below ground vegetables that are contaminated:	0.25	default, USEPA, 1998
Consumption rate of fish (kg/kgBW-d):	See below	
Adult:	1.17E-003	default, USEPA, 1998
Child:	7.59E-004	default, USEPA, 1998
Fraction of ingested fish that is contaminated:	1	default, USEPA, 1998
Subsistence Farmer Scenario		
Soil consumption rate (kg/d):	See below	
adult:	0.0001	default, USEPA, 1999, errata
child:	0.0002	default, USEPA, 1999, errata
Fraction of consumed soil that is contaminated:	1	default, USEPA, 1998
Consumption rate of above ground vegetables (kg/kgBW-d):	See below	
adult:	0.0003	default, USEPA, 1998
child:	0.00042	default, USEPA, 1998
Consumption rate of protected above ground vegetables (kg/kgBW-d):	See below	
adult:	0.00057	default, USEPA, 1998
child:	0.00077	default, USEPA, 1998
Fraction of above ground vegetables that are contaminated:	1	default, USEPA, 1998
Consumption rate of below ground vegetables (kg/kgBW-d):	See below	
adult:	0.00014	default, USEPA, 1998
child:	0.0002	default, USEPA, 1998
Fraction of below ground vegetables that are contaminated:	1	default, USEPA, 1998
Consumption rate of beef (kg/kgBW-d):	See below	
adult:	0.00114	default, USEPA, 1998
child:	0.00051	default, USEPA, 1998
Fraction of beef that is contaminated:	1	default, USEPA, 1998
Subsistence Farmer Scenario (cont'd)		
Consumption rate of milk (kg/kgBW-d):	See below	
adult:	0.00842	default, USEPA, 1998
child:	0.01857	default, USEPA, 1998
Fraction of milk that is contaminated:	1	default, USEPA, 1998

TABLE 4-1
INPUT PARAMETERS
BOWLINE RISK ASSESSMENT

CATEGORY/PARAMETER	VALUE	REFERENCES
SOIL CONCENTRATION		
Time period over which average concentration occurs (yr):	30	default, USEPA, 1998
Time period at beginning of combustion (yr):	0	default, USEPA, 1998
Soil bulk density (g/cm3):	1.5	default, USEPA, 1998
Soil mixing depth, untilled (cm):	1	default, USEPA, 1998
Soil mixing depth, tilled (cm):	20	default, USEPA, 1998
COC loss constant due to erosion (yr-1):	0	default, USEPA, 1998
Average annual precipitation (cm/yr):	120	NOAA, 1997
Average annual irrigation (cm/yr):	0	Baes, et al., 1984
Average annual surface runoff (cm/yr):	27	Baes, et al., 1984
Average annual evapotranspiration (cm/yr):	70	Baes, et al., 1984
Soil Infiltration (Recharge) Rate for the Northeast (m/yr):	0.22	default, USEPA, 1996
Soil moisture content, theta sw, (cm3/cm3):	0.2	default, USEPA, 1998
Ideal Gas Constant (atm-m3/mole-K):	8.2E-005	default, USEPA, 1998
Ambient air temperature, Kelvin (K):	3.0E+002	default, USEPA, 1998
Soil void fraction, theta v (cm3/cm3):	2.4E-001	calculated, USEPA, 1998
Solids particle density (g/cm3):	2.7E+000	default, USEPA, 1998
PLANT UPTAKE		
Interception factor for above ground vegetation (--):	0.39	default, USEPA, 1998
Plant surface loss coefficient (yr-1):	18	default, USEPA, 1998
Length of growing season for above ground vegetation (yr):	0.164	default, USEPA, 1998
Vegetation yield for above ground vegetation (kg DW/m2):	2.24	default, USEPA, 1998
Air density (g/m3):	1200	default, USEPA, 1998
Empirical correction factor for above ground produce (--):	See below:	
log Kow >4:	0.01	default, USEPA, 1998
log Kow <4:	1	default, USEPA, 1998
WATERBODY CONCENTRATION - HUDSON RIVER		
Watershed Soil Constituent Concentration		
Time to attain average concentration (yr):	30	default, USEPA, 1998
Soil bulk density (g/cm3):	1.5	default, USEPA, 1998
Soil mixing depth, untilled (cm):	1	default, USEPA, 1998
Dry Deposition Velocity (cm/s):	3	default, USEPA, 1998
COC loss constant due to erosion (yr-1):	0	default, USEPA, 1998
Average annual precipitation (cm/yr):	81	NOAA, 1997
Average annual irrigation (cm/yr):	0	Baes, et al., 1984
Average annual surface runoff (cm/yr):	27	Baes, et al., 1984
Average annual evapotranspiration (cm/yr):	55	Baes, et al., 1984
Ideal Gas Constant (atm-m3/mole-K):	8.2E-005	default, USEPA, 1998
Ambient air temperature, Kelvin (K):	3.0E+002	default, USEPA, 1998
Soil moisture content, theta sw, (cm3/cm3):	0.2	default, USEPA, 1998
Ideal Gas Constant (atm-m3/mole-K):	8.2E-005	default, USEPA, 1998
Soil void fraction, theta v (cm3/cm3):	2.4E-001	calculated, USEPA, 1998
Solids particle density (g/cm3):	2.7E+000	default, USEPA, 1998
Empirical intercept coefficient (--)	0.6	default, USEPA, 1998
Empirical slope coefficient (--):	0.125	default, USEPA, 1998
Sediment Delivery Ratio (--):	5.0E-002	calculated, USEPA, 1998
Watershed area receiving fallout (Surface area of affected area)(m2):	4.00E+008	site specific
Constituent enrichment ratio (--):	See below:	
Inorganics:	1	default, USEPA, 1998
USLE Erosivity factor (yr-1):	150	Baes, et al., 1984
USLE Erodability factor (tons/acre):	0.36	default, USEPA, 1998
USLE Topographic or Slope Length Factor (--):	1.5	default, USEPA, 1998
USLE Cover management factor (--):	0.1	default, USEPA, 1998
USLE Supporting practice factor (--):	1	default, USEPA, 1998

TABLE 4-1
INPUT PARAMETERS
BOWLINE RISK ASSESSMENT

CATEGORY/PARAMETER	VALUE	REFERENCES
EXPOSURE PARAMETERS		
Averaging time (yr):		default, USEPA, 1998
Carcinogens:	70	default, USEPA, 1998
Non-carcinogens:	ED	default, USEPA, 1998
Exposure Duration (yr):	See below	default, USEPA, 1998
Adult Resident:	30	default, USEPA, 1998
Child Resident:	6	default, USEPA, 1998
Infant Resident:	1	default, USEPA, 1998
Adult Subsistence Fisher:	30	default, USEPA, 1998
Child Subsistence Fisher:	6	default, USEPA, 1998
Adult Subsistence Farmer:	40	default, USEPA, 1998
Child Subsistence Farmer:	6	default, USEPA, 1998
Exposure Frequency (d/yr):		
Residential Scenario:	350	default, USEPA, 1998
Breastmilk Scenario:	365	default, USEPA, 1998
Recreational Fisher Scenario:	350	default, USEPA, 1998
Subsistence Farmer Scenario:	350	default, USEPA, 1998
Body weight (kg):	See below	
Adult:	70	default, USEPA, 1998
Child :	15	default, USEPA, 1998
Infant:	10	default, USEPA, 1998
Exposure Time (hr/d):	24	default, USEPA, 1998
Inhalation Rate (m3/hr):	See below	
Adult:	0.63	default, USEPA, 1998a
Child:	0.3	

5.0 DOSE-RESPONSE ASSESSMENT

The chronic toxicity criteria for each Constituents of Concerns (COC) evaluated in the preliminary screening-level risk assessment are summarized in tabular form (Tables 5-1 through 5-4). These toxicity criteria characterize the dose-response or the relationship between the level of exposure and the magnitude of toxic effect; they include cancer slope factors for estimating the potential risk of cancer and reference doses for estimating the potential for non-carcinogenic (systemic) effects. As indicated in Section 2.4, the toxicity criteria were obtained from USEPA's on-line IRIS (USEPA, 2000), or the current HEAST (USEPA, 1997b).

TABLE 5-1
SUMMARY OF TOXICITY VALUES ASSOCIATED WITH CARCINOGENIC EFFECTS: ORAL
BOWLINE RISK ASSESSMENT

Constituent	Slope Factor (SF) Oral (mg/kg-day)-1	Weight-Of Evidence Class	Type of Cancer	SF Basis/ Source
Inorganics				
Arsenic	1.5E+000	A	Skin	Water/IRIS

IRIS = U.S. EPA, 2000, Integrated Risk Information System (IRIS) Database

TABLE 5-2
SUMMARY OF TOXICITY VALUES ASSOCIATED WITH CARCINOGENIC EFFECTS: INHALATION
BOWLINE RISK ASSESSMENT

Constituent	Unit Risk (UR) (ug/m3)-1	Inhalation Slope Factor (mg/kg-day)-1	Weight-Of Evidence Class	Type Of Cancer	UR Basis/ Source
Inorganics					
Arsenic	4.3E-003	1.5E+001	A	Lung	Inhalation/IRIS

IRIS = U.S. EPA, 2000, Integrated Risk Information System (IRIS) Database

TABLE 5-3
SUMMARY OF TOXICITY VALUES ASSOCIATED WITH NONCARCINOGENIC CHRONIC EFFECTS: ORAL
BOWLINE RISK ASSESSMENT

Constituent	Chronic RfD (Oral) (mg/kg-day)	Critical Effect	Oral RfD Basis/Source
Inorganics			
Arsenic	3.0E-004	Hyperpigmentation, keratosis, possible vascular effects	Water/IRIS

IRIS = U.S. EPA, 2000, Integrated Risk Information System (IRIS) Database

TABLE 5-4
SUMMARY OF TOXICITY VALUES ASSOCIATED WITH NONCARCINOGENIC CHRONIC EFFECTS: INHALATION
BOWLINE RISK ASSESSMENT

Constituent	Chronic RfC (Inhalation) (mg/m3)	Inhalation RfD (mg/kg/d)	Critical Effect/Target Organ(s)	Inhalation RfC Basis/Source
Inorganics				
Arsenic	NA	NA		NA/IRIS,HEAST

IRIS = U.S. EPA, 1999, Integrated Risk Information System (IRIS) Database
HEAST = U.S. EPA, 1997, Health Effects Assessment Summary Tables (HEAST): Annual Update
NA = Toxicity value not available

6.0 RISK CHARACTERIZATION

The risk characterization step combines estimates of exposure and constituent toxicity to produce estimates of carcinogenic and non-carcinogenic risks. Theoretical individual carcinogenic risk is generally estimated as the product of the calculated lifetime average daily dose (mg/kg/d) and the constituent-specific slope factor ($(mg/kg/d)^{-1}$). Theoretical cancer risks typically are presented in scientific notation, e.g., 1E-05, which means an incremental lifetime cancer risk of one in one hundred thousand. Calculated cancer risks for each receptor are then added to yield a cumulative risk estimate for each pathway, e.g., inhalation and oral. These estimates are combined to derive an overall cumulative risk estimate for each receptor. The target calculated cancer risk estimate presented in the draft HHRA and errata is 1E-05.

The potential for non-carcinogenic effects is represented by a hazard quotient (HQ), derived by dividing an estimated average daily dose by the constituent-specific reference dose (RfD). HQs are typically added together by target organ or critical effect for each receptor to yield an overall target organ specific hazard index (HI). The target HI presented in the draft HHRA and errata is 0.25 (2.5E-01).

6.1 Results

Results of the preliminary screening-level risk assessment are presented in Tables 6-1, 6-2 and 6-3 and discussed in the following sections.

6.1.1 Residential Scenario

The residential scenario assumes that the adult and child resident were exposed directly to COCs by inhalation and exposed indirectly to the COCs via the incidental ingestion of soil, the consumption of homegrown produce and the ingestion of drinking water.

As shown in Tables 6-1, 6-2 and 6-3, cumulative cancer risks and target organ HIs associated with indirect and direct exposures for the adult and child resident scenarios are well below target levels of 1E-05 for cancer risk and 2.5E-01 for the non-cancer HI. Calculated cancer risk estimates were 3E-07 and 1E-07 for the adult and child receptors, respectively. Maximum hazard indices were 1.3E-03 and 3.3E-03 for the adult and child residential receptors, respectively.

TABLE 6-1. CANCER RISKS AND NON-CANCER HIs FROM INDIRECT PATHWAYS
EVALUATON OF ARSENIC
BOWLINE RISK ASSESSMENT

	Resident		Subsistence Fisher		Subsistence Farmer	
	Adult	Child	Adult	Child	Adult	Child
Total Cancer Risk:	3E-007	1E-007	3E-007	1E-007	2E-006	3E-007
Critical Effect HIs:	1.3E-003	3.3E-003	1.6E-003	3.5E-003	8.1E-003	8.4E-003

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

TABLE 6-2. CANCER RISKS AND NON-CANCER HIs FROM DIRECT PATHWAYS
EVALUATON OF ARSENIC
BOWLINE RISK ASSESSMENT

	Resident		Subsistence Fisher		Subsistence Farmer	
	Adult	Child	Adult	Child	Adult	Child
Total Cancer Risk:	5E-008	2E-008	5E-008	2E-008	5E-008	2E-008
Critical Effect HIs:	NA	NA	NA	NA	NA	NA

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

TABLE 6-3. CUMULATIVE CANCER RISKS AND NON-CANCER HIs (a) FROM DIRECT AND INDIRECT PATHWAYS
EVALUATON OF ARSENIC
BOWLINE RISK ASSESSMENT

	Resident		Subsistence Fisher		Subsistence Farmer	
	Adult	Child	Adult	Child	Adult	Child
<u>Total Cancer Risk:</u>	3E-007	1E-007	4E-007	2E-007	2E-006	3E-007
<u>Critical Effect HIs:</u>	1.3E-003	3.3E-003	1.6E-003	3.5E-003	8.1E-003	8.4E-003

▭ = Cancer Risk > 1E-05 or HI >2.5E-01

6.1.2 Subsistence Fisher Scenario

The subsistence fisher scenario assumes the fisher lives in the residential area and eats fish from the Hudson River. Thus, the subsistence fisher is assumed to be directly exposed to COCs by inhalation and indirectly exposed to constituents via the incidental ingestion of soil, the consumption of homegrown produce and ingestion of drinking water from the residential area and via the consumption of fish caught in the Hudson River. Since the subsistence fisher is assumed to live in the residential area, the direct inhalation pathway was modeled using the residential impacts.

As shown in Tables 6-1, 6-2 and 6-3, cumulative cancer risks and target organ HIs associated with indirect and direct exposures for the adult and child subsistence fishing scenarios are well below target levels of 1E-05 for cancer risk and 2.5E-01 for the non-cancer HI. Calculated cancer risk estimates were 3E-07 and 1E-07 for the adult and child receptors, respectively. Maximum hazard indices were 1.6E-03 and 3.5E-03 for the adult and child subsistence fisher receptors, respectively.

6.1.3 Subsistence Farmer Scenario

The subsistence farmer is assumed to live on a farm and is assumed to be directly exposed to COCs by inhalation and indirectly exposed to the COCs via the incidental ingestion of soil, the consumption of homegrown produce, beef and dairy and the ingestion of drinking water. It is assumed that the farmer receives drinking water from the same reservoir as the resident and subsistence fisher.

As shown in Tables 6-1, 6-2 and 6-3, cumulative cancer risks and target organ HIs associated with indirect and direct exposures for the adult and child subsistence farming scenarios are well below target levels of 1E-05 for cancer risk and 2.5E-01 for the non-cancer HI. Calculated cancer risk estimates were 2E-06 and 3E-07 for the adult and child receptors, respectively. Maximum hazard indices were 8.1E-03 and 8.4E-03 for the adult and child subsistence farmer receptors, respectively.

7.0 UNCERTAINTY ASSESSMENT

Typically, screening-level assessments are undertaken to identify those receptors, pathways, compounds, etc., that do not require further evaluation and to identify those items that would benefit from additional evaluation. As such, screening-level assessments use "high-end" exposure factors to derive potential constituent intakes at the upper end of the intake distribution. This approach yields intakes that are considered overestimates when compared to potential intakes in actually exposed populations. Sources of uncertainty are discussed in further detail in the following sections.

7.1 Risk-Based Concentrations

The USEPA's inhalation cancer risk for inorganic arsenic is based on five studies of copper smelter workers. Smelter workers are exposed to higher concentrations of arsenic than the general population. This is due to the arsenic within the metal ore, heating the ore releases the inorganic arsenic. All five studies showed excess risks of lung cancer related to the intensity, duration of exposure and the duration of the latency period. The EPA has confidence in the arsenic inhalation cancer risk since the studies were based on a large number of people and the lung cancer incidence was significantly increased over expected values.

However, the inhalation risk based air concentration developed by the EPA is conservative. One large factor in the conservatism is that all of these studies are based on research of industrial workers, who are more likely to smoke cigarettes than the general population. This has been well documented and increases the risk to the workers of developing lung cancer above that of the general population. Also, the workers were exposed to varied amounts of arsenic throughout a workday instead of a stable constant air concentration. These varied exposure levels are difficult to measure and document for each individual smelter worker. Therefore, actual exposures for each worker are difficult to ascertain and industry workers are already at higher risk due to their increased likelihood to smoke cigarettes.

7.2 Uncertainty Associated With Exposure Assessment

The major areas of uncertainty associated with the exposure assessment include selection of the receptors, selection of the receptor location and selection of specific exposure parameter values.

7.2.1 Selection of Receptors

The subsistence fisher was assumed to be the same residential adult and child receptors who fished locally on a subsistence basis. There is no indication that subsistence fishing actually occurs in this area, and a recreational fisher may be a more suitable receptor. Therefore, actual risks associated with potential ingestion of fish would actually be less.

7.2.2 Selection of Receptor Location

For this assessment, the maximum impact (air concentration, dry deposition and wet deposition) was assumed to occur at the same location which represented all three receptor locations (the residence, the waterbody/watershed area, and the farm). This is overly conservative and would tend to reflect "worst-case" potential impacts. Actual risks associated with these receptor locations would therefore be less.

7.2.3 Exposure Factor Parameters

The draft HHRA guidance prescribes "high-end" exposure factors including intake rates, exposure frequencies and exposure durations for use in evaluating the prescribed receptors. These include both human, plant and animal intake parameters.

These "high-end" exposure factors will overestimate potential intakes by actual exposed populations. Therefore, risk estimates based on a combination of "high-end" intake values overestimate potential risks to actual exposed populations.

8.0 SUMMARY

This report presents the human health risk assessment, which evaluated the predicted arsenic emissions associated with Bowline Unit 3. The results of the screening-level risk assessment demonstrate that estimated risks associated with anticipated Bowline Unit 3 emissions are all below USEPA targets for all receptors examined.

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APPENDIX A

ENVIRONMENTAL CONCENTRATION AND EXPOSURE INTAKE/DOSE EQUATIONS

A.1 Inhalation of Airborne Constituents

The algorithm presented in the HHRA Guidance for estimating cancer risk from direct inhalation allows for calculation of potential cancer and non-cancer risks to children. Thus, an exposure dose algorithm was used to calculate the potential cancer risks to all receptors (adult and child resident, adult and child subsistence fisher, and adult and child subsistence farmer). In order to calculate potential risks due to the inhalation of constituents, inhalation unit risk factors and reference concentrations (RfCs) were converted to inhalation slope factors and reference doses (RfDs) according to the draft HHRA Guidance. The algorithm and input values presented in the draft HHRA Guidance for calculating cancer risks using inhalation slope factors and RfDs was then used. The input values for the inhalation pathway can be found in Table 4-1. The conversion for inhalation unit risk values to slope factors and RfCs to RfDs follows:

Slope Factors:

$$\mathrm{CSF_i}\ (\mathrm{mg/kg\text{-}d})^{-1} = \frac{\mathrm{URF}\ (\mu\mathrm{g/m^3}) \times 70\ \mathrm{kg} \times 1000\ (\mu\mathrm{g/mg})}{20\ (\mathrm{m^3/d})}$$

RfDs:

$$\mathrm{RfD_i}\ (\mathrm{mg/kg\text{-}d}) = \frac{\mathrm{RfC}\ (\mu\mathrm{g/m^3}) \times 20\ (\mathrm{m^3/d}) \times 0.001\ (\mathrm{mg}/\mu\mathrm{g})}{70\ \mathrm{kg}}$$

The modeled ambient air concentrations were the maximum estimated constituent concentration in air at the impact point where residential or farmland use is currently or may be reasonably assumed to occur in the future. The cancer risks and hazard quotients for the inhalation pathway were calculated as follows:

A.1.1 Daily Intake of Constituents by Inhalation

Daily intake of facility emissions by inhalation was estimated based on annual ambient impact, the inhalation rate, and exposure time:

$$ADI = \frac{Ca \times IR \times ET \times EF \times ED \times UC1}{BW \times AT \times UC2}$$

Where:

ADI = average daily intake of constituent by inhalation (mg/kg-d)
Ca = total air concentration ($\mu g/m^3$)
IR = inhalation rate (m^3/hr)
ET = exposure time (hr/d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
UC1 = units conversion (mg/μg)
BW = body weight (kg)
AT = averaging time (yr)
UC2 = units conversion (d/yr)

A.1.2 Cancer Risks and Hazard Quotients for Individual Chemicals by Inhalation

Cancer Risk:

$$CR_i = ADI \times CSF$$

Where:

CR_i = individual excess lifetime cancer risk, inhalation (unitless)
ADI = average daily intake of constituent by inhalation (mg/kg-d)
CSF = cancer slope factor, inhalation ($(mg/kg\text{-}d)^{-1}$)

Hazard Quotient:

$$HQ_i = \frac{ADI}{RfD_i}$$

Where:

HQ_i = hazard quotient, inhalation (unitless)
ADI = average daily intake of constituent by inhalation (mg/kg-d)

RfD_i = reference dose, inhalation (mg/kg-d)

A.2 Residential Scenario

The residential scenario, assumes that the resident inadvertently ingests soil, consumes produce grown in the residential area, ingests drinking water from a local reservoir and inhales the constituents c in air at the residential impact point. Exposure doses for the inadvertent ingestion of soil, produce consumption and ingestion of drinking water are calculated both for the adult resident and child resident. The input values for the residential scenario can be found in Table 4-1.

A.2.1 Incidental Ingestion of Soil

Soil Concentration

Constituent levels in soil are estimated as a function of wet and dry deposition of particles and vapors onto soil; the time period over which the deposition occurs and the loss of constituents via processes such as leaching, erosion runoff, degradation and volatilization. The average concentration of constituents in soil is estimated as follows:

Carcinogenic Agents:

$$Sc = \frac{[D_s]}{ks \text{ x } (tD - t1)} \text{ x } [(tD + \frac{exp^{(-ks \text{ x } tD)}}{ks}) - (T1 + \frac{exp^{(-ks \text{ x } T1)}}{ks})]$$

Where:

Sc = average soil concentration over exposure duration (mg/kg)

C_{stD} = soil concentration at time tD (mg/kg)

D_s = deposition term (mg constituent/kg soil-yr)

tD = time period over which deposition occurs (yr)

t1 = time period at beginning of combustion (yr)

t2 = exposure duration or ED (yr)

ks = soil loss constant (yr^{-1})

And:

$$Ds = \frac{100 \text{ x } (Dydp + Dywp)}{Zs \text{ x } BD}$$

Where:

DS = deposition term (mg/kg-yr)
Zs = soil mixing zone depth (cm)
BD = soil bulk density (g/cm^3)
UC = units conversion ($mg\text{-}g\text{-}cm^2/g\text{-}kg\text{-}m^2$)
Dydp = yearly average dry deposition from particle or particle bound phase (g/m^2-yr)
Dywp = yearly average wet deposition from particle or particle bound phase (g/m^2-yr)

And:

$$k_s = ksl + ksg + ksr + ksv + kse$$

Where:

k_s = soil loss constant (yr^{-1})
ksl = loss constant due to leaching (yr^{-1})
ksg = loss constant due to degradation (yr^{-1})
ksr = loss constant due to runoff (yr^{-1})
ksv = loss constant due to volatilization (yr^{-1})
kse = loss constant due to soil erosion (yr^{-1})

And:

ksl = $(P + I - RO - Ev) / [\theta_{sw} \text{ x } Zs \text{ x } (1+(Kd_s \text{ x } BD/\theta_{sw})]$
ksr = $RO/ [Zs \text{ x } \theta_{sw}] \text{ x } \{1/1 + (Kd_s \text{ x } BD/\theta_{sw})\}$
ksg = chemical-specific
ksv = $[(UC \text{ x } H) / Zs \text{ x } Kd_s \text{ x } R \text{ x } T \text{ x } BD)] \text{ x } [(Da \text{ x } \theta_v)/Zs]$
kse = default (0); watershed soils =
$[0.1 \text{ x } Xe \text{ x } SD \text{ x } ER/(Kd_s \text{ x } Zs)] \text{ x } [Kd_s \text{ x } BD/(\theta_{sw}+(Kd_s \text{ x } BD))]$

Where:

P = average annual precipitation (cm/yr)

I = average annual irrigation (cm/yr)
RO = average annual surface runoff (cm/yr)
EV = average annual evapotranspiration (cm/yr)
Zs = soil mixing zone depth (cm)
θ_{sw} = soil volumetric water content (cm^3/cm^3)
Kd_s = soil-water partition coefficient (ml/g or cm^3/g)
BD = soil bulk density (g/cm^3 or g/ml)
UC = units conversion (s/yr), 3.1536E+07
H = Henry's Law constant ($atm\text{-}m^3/mole$)
R = ideal gas constant ($atm\text{-}m^3/mole\text{-}k$)
T = ambient temperature in Kelvin (K)
Da = diffusion coefficient of constituent in air (cm^2/s)
θ_v = soil void fraction (cm^3/cm^3)
Xe = unit soil loss ($kg/m^2\text{-}yr$)
SD = sediment delivery ratio (unitless)
ER = enrichment ratio (unitless)

Soil properties such as bulk density, are taken from the draft HHRA Guidance (USEPA, 1998, 1999a). Constituent physical/chemical properties are presented in Appendix B and other input values are presented in Table 4-1.

Soil Intake

Daily constituent intake from surface soil is calculated based on the estimated concentrations in untilled soil (i.e., in the top 1 cm of soil (USEPA, 1998)), the rate of soil ingestion, and the fraction of ingested soil that is assumed to be contaminated:

$$I_{soil} = \frac{Sc \times CR_{soil} \times F_{soil}}{BW}$$

Where:

I_{soil} = daily intake of contaminant from soil (mg/kg-d)
Sc = concentration of constituent in soil (untilled) (mg/kg)
CR_{soil} = soil consumption rate (kg/d)
F_{soil} = fraction of consumed contaminated soil (unitless)
BW = body weight (kg)

A.2.2 Ingestion of Produce

Garden Produce Concentration

Constituent concentrations in edible plants raised in a backyard garden (i.e., above ground and root vegetables) are calculated based on one or more of the following: potential root uptake of constituents from soil (above ground and root vegetables), potential direct deposition of particulates onto plant surfaces (above ground vegetables), and potential air-to-plant transfer of constituents (above ground vegetables). These calculations are based on the equations outlined below, input values from the draft HHRA guidance (see Table 4-1) and various constituent-specific factors (see Appendix B).:

Concentration in Above Ground Vegetation

$$\mathrm{CAGV} = \mathrm{PD} + \mathrm{PV} + \mathrm{PRa}$$

Where:

CAGV = total concentration of constituent in above ground vegetables (mg/kg),
PD = concentration of constituent due to direct deposition (mg/kg)
PV = concentration of constituent due to air-to-plant transfer (mg/kg)
PRa = concentration of constituent in above ground produce due to root uptake (mg/kg)

Potential concentrations in plant tissue due to the direct deposition on plant surfaces are calculated using the following equation:

$$\mathrm{PD} = \frac{\mathrm{UC \ x \ [Dydp + (FW \ x \ Dywp)] \ x \ Rp \ x \ [1 - exp^{(-kp\,x\,TP)})}}{\mathrm{Yp \ x \ kp}}$$

Where:

PD = concentration of constituent due to direct deposition (mg/kg)
UC = units conversion factor (mg/g)
Dydp = yearly average dry deposition from particle phase (g/m^2-yr)
Dywp = yearly average wet deposition from particle phase (g/m^2-yr)
FW = fraction of wet deposition that adheres to plant surfaces (unitless)
Rp_i = interception fraction of the edible portion of plant tissue (unitless)
k_p = rate constant for constituent degradation (yr^{-1})
T_p = length of growing season (yr)
Y_p = yield or standing crop biomass of the edible portion of the plant group (kg DW/m^2)

Air-to-plant transfers of constituents to above ground vegetation are estimated by:

$$Pv = \frac{Cyv \text{ x } Bvag\ VGag}{\rho a}$$

Where:

PV = concentration of constituent due to air-to-plant transfer (mg/kg)

Cyv = unitized yearly air concentration from vapor phase (µg-s/g-m^3)

B_v = air-to-plant biotransfer factor, (mg constituent/kg DW plant tissue)/(mg constituent/kg air)

Vg_{ag} = above ground vegetable correction factor (unitless)

ρa = density of air (g/m^3)

Concentration due to root uptake in exposed and protected aboveground produce are estimated by:

$$PRa = Sc \text{ x } Br$$

Where:

PRa = concentration in above ground produce due to root uptake (mg/kg)

Sc = average soil concentration over exposure duration (mg/kg)

Br = plant-soil bioconcentration factor for aboveground produce (unitless)

Concentration in Below Ground Vegetation:

$$PRb = Sc \text{ x } Br_{rv} \text{ x } VG_{rv}$$

Where:

PRb = total concentration of constituent in below ground vegetables (mg/kg)

Sc = average soil concentration over exposure duration (mg/kg)

Br_{rv} = plant-soil bioconcentration factor for belowground produce (unitless)

VG_{bgv} = below ground vegetable correction factor (unitless)

For root uptake, emissions potentially deposited on soils are assumed to be mixed into the soil to a tilling depth of 20 cm (USEPA, 1998). Information on growing periods and yields was obtained from USEPA, 1998 (see Table 4-1).

Produce Intake

Daily constituent intake from produce is calculated based on the amount of produce ingested per day, the estimated concentration of constituents in the produce, and the percentage of produce ingested that is homegrown as shown in the following equation:

$$I_{agv} = [(CAVG \times CRag) + (PRa \times CRpp) + (PRb \times CRbg)] \times F_{ag}$$

Where:

I_{ag} = daily intake of contaminant from vegetables (mg/kg-d)
CAVG = concentration of constituents in above ground vegetables (mg/kg)
CRag = consumption rate of above ground vegetables (kg/kg-d)
PRa = concentration of constituents in above ground vegetables due to root uptake (mg/kg)
CRpp = consumption rate of protected above ground vegetables (kg/kg-d)
PRbg = concentration of constituents in below ground vegetables due to root uptake (mg/kg)
Crbg = consumption rate of below ground vegetables (kg/kg-d)
F_{ag} = fraction of vegetables that are contaminated (unitless)

Consumption rates of the two plant groups (above ground (exposed and protected) and below ground) and fractions contaminated were based on information presented in the draft HHRA guidance document (USEPA 1998, 1999a) (see Table 4-1).

A.2.3 Ingestion of Drinking Water

Facility emissions may potentially deposit directly on surface water bodies. Thus, it is theoretically possible for receptors to be exposed to facility emissions via the ingestion of surface water as drinking water. Constituent concentrations in drinking water reflect dissolved water column concentrations. Estimation of these concentrations in accordance with the draft HHRA Guidance (USEPA, 1998, 1999a), is undertaken in several steps as illustrated below.

Soil Concentration

The first step is to calculate soil concentrations resulting from potential deposition of contaminants onto soils as described in Section A.2.1. The calculation of soil concentration includes a loss term, which accounts for loss of contaminant from the soil after deposition by several mechanisms, including leaching, runoff, erosion and degradation.

Contaminant Load to the Waterbody

The second step involves calculating the estimated load of contaminant to the waterbody. USEPA's draft HHRA guidance (USEPA, 19998), suggests five pathways cause contaminant loading of the waterbody: 1) direct deposition; 2) runoff from impervious surfaces within the watershed; 3) runoff from pervious surfaces within the watershed; 4) soil erosion from the watershed; and 5) vapor phase constituent diffusion to the waterbody.

$$L_T = L_{Dep} + L_{RI} + L_R + L_E + L_{Dif}$$

Where:

L_T = total contaminant load to the waterbody (g/yr)
L_{Dep} = deposition of particle bound contaminant to the waterbody (g/yr)
L_{RI} = runoff load from impervious surfaces (g/yr)
L_R = runoff load from pervious surfaces (g/yr)
L_E = soil erosion load (g/yr)
L_{dif} = vapor phase constituent diffusion (dry deposition) to water body (g/yr)

And:

L_{dep} = $Dytwp \times WA_w$
L_{RI} = $Dytwp \times WA_i$
L_R = $RO \times WA_L \times \{(Sc \times BD)/(\theta_{sw} + Kd_s * BD)\} \times UC1$
L_E = $X_e \times (WA_L) \times SD \times ER \times \{(Sc * Kd_s * BD)/(\theta_{sw} + Kd_s \times BD) \times UC1$
L_{Dif} = $K_v \times Fv \times Cywv \times WA_w \times UC2/(H/R \times T_{wk})$

And:

$$K_v = [K_L^{-1} + [K_G \times \frac{H}{R \times T_{wk}}]^{-1}]^{-1} \times \Theta^{Twk - 293}$$

For Flowing Rivers or Streams:

$$K_L = \sqrt{\frac{10^{-4} \times Dw \times \mu}{dz}} \times 3.1536 \times 10^{7}$$

For Flowing Rivers or Streams:

$K_G = 36500$ m/yr

Where:

Fv = fraction of air concentration in vapor phase (unitless)
Dytwp = yearly average total (wet and dry) deposition from particle phase for watershed (g/m^2-yr)
WA_w = water body area (m^2)
WA_i = impervious watershed area receiving pollutant deposition (m^2)
UC1 = units conversion factor ($kg-cm^2/mg-m^2$)
WA_L = total watershed area receiving pollutant deposition (m^2)
RO = average annual surface runoff (cm/yr)
Sc = average soil concentration over exposure duration (mg/kg)
BD = soil bulk density (g/cm^3)
θ_{sw} = soil volumetric water content (cm^3/cm^3)
Kd_s = soil-water partition coefficient (cm^3/g or ml/g)
X_e = unit soil loss (from Universal Soil Loss Equation), (kg/m^2-yr)
SD = sediment delivery ratio (unitless)
ER = contaminant enrichment ratio (unitless)
K_v = overall transfer rate coefficient (m/yr)
UC3 = units conversion factor (g/ug)
K_L = liquid phase transfer coefficient (m/yr)
K_G = gas phase transfer coefficient (m/yr)
H = Henry's law constant ($atm-m^3/mol$)
R = universal gas constant ($atm-m^3/mol-K$)
T_{wk} = water body temperature (K)
θ = temperature correction factor
D_w = diffusivity of constituent in water (cm^2/s)
μ = current velocity (m/s)
dz = total water body depth (m)
Cd = drag coefficient (unitless)
W = average annual wind speed (m/s)

ρ_a = density of air (g/cm^3)
ρ_w = density of water (g/cm^3)
k = von Karman's constant (unitless)
λ_z = dimensionless viscous sublayer thickness (unitless)
μ_w = viscosity of water corresponding to water temperature (g/cm-s)
μ_a = viscosity of air (g/cm-s)
D_a = diffusivity of constituent in air (cm^2/s)

Total Waterbody Concentration

The third step involves calculating the total waterbody concentration (in the water column and sediments) from the estimated waterbody load and partitioning the total concentration into a dissolved water concentration, a total water column concentration, and a bed sediment concentration.

Total Waterbody Concentration

$$C_{wtot} = \frac{L_T}{[Vf_x \times f_{wc} + k_{wt} \times WA_w \times (dwc + dbs)]}$$

And:

$$f_{wc} = \frac{(1 + Kd_{sw} \times TSS \times 10^{-6}) \times \frac{dwc}{dz}}{(1 + Kd_{sw} \times TSS \times 10^{-6}) \times \frac{dwc}{dz} + (\theta_{bs} + Kd_{bs} \times C_{BS}) \times \frac{dbs}{dz}}$$

$$k_{wt} = f_{wc} \times k_v + f_{bs} \times k_b$$

$$k_v = \frac{K_v}{dz \times (1 + Kd_{sw} \times TSS \times 10^{6})}$$

$$k_b = \left(\frac{Xe \times WA_L \times SD \times 10^3 - Vf_x \times TSS}{WA_w \times TSS}\right) \times \left(\frac{TSS \times 10^{-6}}{C_{bs} \times d_{bs}}\right)$$

Where:

C_{wtot} = total waterbody concentration (mg/m^3)
L_T = total contaminant load to the waterbody (g/yr)
f_{wc} = fraction of total water body concentration that occurs in the water column (unitless)
k_{wt} = total first order dissipation rate constant (yr^{-1})
Vf_x = average volumetric flow rate through the water body (m^3/yr)
dwc = depth of water column (m)
dbs = depth of benthic layer (m)
WA_w = water body area (m^2)
Kd_{sw} = suspended sediment/surface water partition coefficient (l/kg)
TSS = total suspended solids (mg/l)
dz = total water body depth (m)
C_{BS} = bed sediment concentration (g/cm^3)
θ_{bs} = bed sediment porosity (l_{water}/l)
Kd_{bs} = bed sediment/sediment pore water partition coefficient (l/kg)
d_{bs} = depth of upper benthic sediment layer (m)
k_v = water column volatilization rate constant (yr^{-1})
f_{bs} = fraction of total water body constituent concentration in benthic sediment (unitless)
k_b = benthic burial rate constant (yr^{-1})
Kv = overall constituent transfer rate coefficient (m/yr)
Xe = universal soil loss (kg/m^2-yr)
WA_L = watershed area receiving deposition (m^2)
SD = watershed sediment delivery ration (unitless)
Dywwv = unitized yearly (watershed) average wet deposition from vapor phase (s/m^2-yr)
Dytwp = unitized yearly (watershed) average total (wet and dry) deposition from particle phase (s/m^2/yr)

Water Column Concentration

$$C_{wt} = f_{wc} \times C_{wtot} \times \frac{dwc + dbs}{dwc}$$

Where:

C_{wt} = total constituent concentration in water column (mg/l)
C_{wtot} = total waterbody concentration (mg/m^3)

f_{wc} = fraction of total water body concentration that occurs in the water column (unitless)
dwc = depth of water column (m)
dbs = depth of benthic layer (m)

Dissolved Phase Water Column Concentration

$$C_{dw} = \frac{C_{wt}}{1 + Kd_{sw} \text{ x } TSS \text{ x } 10^{-6}}$$

Where:

C_{dw} = dissolved phase water concentration (mg/l)
C_{wt} = total constituent concentration in water column (mg/l)
Kd_{sw} = suspended sediment/surface water partition coefficient (l/kg)
TSS = total suspended solids (mg/l)

Constituent Concentration Sorbed to Bed Sediment

$$C_{sb} = f_{bs} \text{ x } C_{wtot} \text{ x } \frac{Kd_{bs}}{\theta_{bs} + Kd_{bs} \text{ x } C_{BS}} \text{ x } \frac{dwc + dbs}{dbs}$$

Where:

C_{sb} = concentration sorbed to bed sediments (mg/kg)
C_{wtot} = total waterbody concentration (mg/l)
f_{bs} = fraction of total water body concentration that occurs in the bed sediment (unitless)
dwc = depth of water column (m)
dbs = depth of benthic layer (m)
θ_{bs} = bed sediment porosity (l_{water}/l)
Kd_{bs} = bed sediment/sediment pore water partition coefficient (l/kg)
C_{BS} = bed sediment concentration (g/cm^3)

Drinking Water Intake

Daily constituent intake from drinking water is estimated based on the calculated concentrations in surface water, the rate of drinking water ingestion, and the fraction of ingested drinking water that is assumed to be contaminated:

$$I_{dw} = \frac{C_{dw} \times CR_{dw} \times F_{dw}}{BW}$$

Where:

I_{dw} = daily intake of contaminant from drinking water (mg/kg-d)
C_{dw} = dissolved phase water concentration (untilled) (mg/ℓ)
CR_{dw} = drinking water consumption rate (ℓ/d)
F_{dw} = fraction of consumed contaminated drinking water (unitless)
BW = body weight (kg)

A.2.4 Total Daily Intake for Indirect Pathways: Residential Scenario

The total daily contaminant intake is estimated as:

$$I_{tot} = I_{soil} + I_{ag} + I_{dw}$$

Where:

I_{tot} = total daily intake of contaminant (mg/kg-d)
I_{soil} = daily intake of contaminant from soil (mg/kg-d)
I_{ag} = daily intake of contaminant from vegetables (mg/kg-d)
I_{dw} = daily intake of contaminant from drinking water (mg/kg-d)

A.2.5 Cancer Risks and Hazard Quotients for Individual Chemicals in the Residential Scenario

Cancer Risk:

$$CR_O = \frac{I_{tot} \times EF \times ED \times CSF_O}{AT \times UC}$$

Where:

CR_O = individual excess lifetime cancer risk, oral (unitless)
I_{tot} = total daily intake of contaminant (mg/kg-d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
CSF_O = cancer slope factor, oral $(mg/kg\text{-}d)^{-1}$

AT = time over which the dose is averaged (70 yr)
UC = units conversion (365 d/yr)

Hazard Quotient:

$$HQ_O = \frac{I_{tot} \times ED \times EF}{AT \times RfD_O \times UC}$$

Where:

HQ_O = hazard quotient, oral
I_{tot} = total daily intake of contaminant (mg/kg-d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
RfD_O = reference dose (oral, mg/kg-d)
AT = time over which the dose is averaged (ED)
UC = units conversion (365 d/yr)

A.3 Subsistence Fisher Scenario

The subsistence fishing scenario assumes that the fisher resides in the residential area, thus inhalation, inadvertent ingestion of soil, consumption of produce and ingestion of drinking water are the same as for resident. Consumption of fish from a local waterbody caught is also included. Daily constituent intake via the incidental ingestion of soil and consumption of homegrown produce is calculated as described in Section A.2. The input values for the subsistence fisher scenario can be found in Table 4-1.

A.3.1 Ingestion of Fish

Facility emissions may potentially deposit directly on surface water bodies. Thus, it is theoretically possible for receptors to be exposed to facility emissions via the ingestion of fish caught in those surface water bodies. Contaminant concentrations in fish are calculated from estimated concentrations in the water body, either dissolved or total water column concentrations or sediment concentrations. In accordance with the draft HHRA Guidance (USEPA, 1998, 1999a), several steps are involved as illustrated below.

Soil Concentration

The first step is to calculate soil concentrations resulting from potential deposition of contaminants onto soils as described in Section A.2.1. The calculation of soil concentration includes a loss term which accounts for loss of contaminant from the soil after deposition by several mechanisms, including leaching, runoff, erosion and degradation.

Contaminant Load to the Waterbody

The second step involves calculating the estimated load of contaminant to the waterbody. USEPA's draft HHRA guidance (USEPA, 19998), suggests five pathways cause contaminant loading of the waterbody: 1) direct deposition; 2) runoff from impervious surfaces within the watershed; 3) runoff from pervious surfaces within the watershed; 4) soil erosion from the watershed; and 5) vapor phase constituent diffusion to the waterbody.

$$L_T = L_{Dep} + L_{RI} + L_R + L_E + L_{Dif}$$

Where:

L_T = total contaminant load to the waterbody (g/yr)
L_{Dep} = deposition of particle bound contaminant to the waterbody (g/yr)
L_{RI} = runoff load from impervious surfaces (g/yr)
L_R = runoff load from pervious surfaces (g/yr)
L_E = soil erosion load (g/yr)
L_{dif} = vapor phase constituent diffusion (dry deposition) to water body (g/yr)

And:

L_{dep} = $Dytwp \times WA_w$

L_{RI} = $Dytwp \times WA_i$
L_R = $RO \times (WA_i) \times \{(Sc \times BD)/(\theta_{sw} + Kd_s * BD)\} \times UC1$
L_E = $X_e \times (WA_L) \times SD \times ER \times \{(Sc * Kd_s * BD)/(\theta_{sw} + Kd_s \times BD) \times UC1$
L_{Dif} = $K_v \times Fv \times Cywv \times WA_w \times UC2/(H/R \times T_{wk})$

And:

$$K_v = [K_L^{-1} + [K_G \times \frac{H}{R \times T_{wk}}]^{-1}]^{-1} \times \Theta^{Twk - 293}$$

For Flowing Rivers or Streams:

$$K_L = \sqrt{\frac{10^{-4} \times Dw \times \mu}{dz}} \times 3.1536 \times 10^{7}$$

For Flowing Rivers or Streams:

$K_G = 36500$ m/yr

Where:

Fv = fraction of air concentration in vapor phase (unitless)
Dytwp = yearly average total (wet and dry) deposition from particle phase for watershed (s/m^2-yr)
WA_w = water body area (m^2)
WA_i = impervious watershed area receiving pollutant deposition (m^2)
UC1 = units conversion factor ($kg\text{-}cm^2/mg\text{-}m^2$)
WA_L = total watershed area receiving pollutant deposition (m^2)
RO = average annual surface runoff (cm/yr)
Sc = average soil concentration over exposure duration (mg/kg)
BD = soil bulk density (g/cm^3)
θ_{sw} = soil volumetric water content (cm^3/cm^3)
Kd_s = soil-water partition coefficient (cm^3/g or ml/g)
X_e = unit soil loss (from Universal Soil Loss Equation), (kg/m^2-yr)
SD = sediment delivery ratio (unitless)
ER = contaminant enrichment ratio (unitless)
K_v = overall transfer rate coefficient (m/yr)
UC3 = units conversion factor (g/ug)
K_L = liquid phase transfer coefficient (m/yr)
K_G = gas phase transfer coefficient (m/yr)
H = Henry's law constant ($atm\text{-}m^3/mol$)
R = universal gas constant ($atm\text{-}m^3/mol\text{-}K$)
T_{wk} = water body temperature (K)
θ = temperature correction factor
D_w = diffusivity of constituent in water (cm^2/s)
μ = current velocity (m/s)
dz = total water body depth (m)
Cd = drag coefficient (unitless)
W = average annual wind speed (m/s)
ρ_a = density of air (g/cm^3)
ρ_w = density of water (g/cm^3)
k = von Karman's constant (unitless)
λ_z = dimensionless viscous sublayer thickness (unitless)
μ_w = viscosity of water corresponding to water temperature (g/cm-s)

μ_a = viscosity of air (g/cm-s)
D_a = diffusivity of constituent in air (cm^2/s)

Total Waterbody Concentration

The third step involves calculating the total waterbody concentration (in the water column and sediments) from the estimated waterbody load and partitioning the total concentration into a dissolved water concentration, a total water column concentration, and a bed sediment concentration.

Total Waterbody Concentration

$$C_{wtot} = \frac{L_T}{[Vf_x \times f_{wc} + k_{wt} \times WA_w \times (dwc + dbs)]}$$

And:

$$f_{wc} = \frac{(1 + Kd_{sw} \times TSS \times 10^{-6}) \times \frac{dwc}{dz}}{(1 + Kd_{sw} \times TSS \times 10^{-6}) \times \frac{dwc}{dz} + (\theta_{bs} + Kd_{bs} \times C_{BS}) \times \frac{dbs}{dz}}$$

$$k_{wt} = f_{wc} \times k_v + f_{bs} \times k_b$$

$$k_v = \frac{K_v}{dz \times (1 + Kd_{sw} \times TSS \times 10^{6})}$$

$$k_b = \left(\frac{Xe \times WA_L \times SD \times 10^3 - Vf_x \times TSS}{WA_w \times TSS}\right) \times \left(\frac{TSS \times 10^{-6}}{C_{bs} \times d_{bs}}\right)$$

Where:

C_{wtot} = total waterbody concentration (mg/m^3)
L_T = total contaminant load to the waterbody (g/yr)

f_{wc} = fraction of total water body concentration that occurs in the water column (unitless)
k_{wt} = total first order dissipation rate constant (yr^{-1})
Vf_x = average volumetric flow rate through the water body (m^3/yr)
dwc = depth of water column (m)
dbs = depth of benthic layer (m)
WA_w = water body area (m^2)
Kd_{sw} = suspended sediment/surface water partition coefficient (l/kg)
TSS = total suspended solids (mg/l)
dz = total water body depth (m)
C_{BS} = bed sediment concentration (g/cm^3)
θ_{bs} = bed sediment porosity (l_{water}/l)
Kd_{bs} = bed sediment/sediment pore water partition coefficient (l/kg)
d_{bs} = depth of upper benthic sediment layer (m)
k_v = water column volatilization rate constant (yr^{-1})
f_{bs} = fraction of total water body constituent concentration in benthic sediment (unitless)
k_b = benthic burial rate constant (yr^{-1})
Kv = overall constituent transfer rate coefficient (m/yr)
Xe = universal soil loss (kg/m^2-yr)
WA_L = watershed area receiving deposition (m^2)
SD = watershed sediment delivery ration (unitless)
Dywwv = unitized yearly (watershed) average wet deposition from vapor phase (s/m^2-yr)
Dytwp = unitized yearly (watershed) average total (wet and dry) deposition from particle phase ($s/m^2/yr$)

Water Column Concentration

$$C_{wt} = f_{wc} \mathrm{\ x\ } C_{wtot} \mathrm{\ x\ } \frac{dwc + dbs}{dwc}$$

Where:

C_{wt} = total constituent concentration in water column (mg/l)
C_{wtot} = total waterbody concentration (mg/m^3)

f_{wc} = fraction of total water body concentration that occurs in the water column (unitless)
dwc = depth of water column (m)
dbs = depth of benthic layer (m)

Dissolved Phase Water Column Concentration

$$C_{dw} = \frac{C_{wt}}{1 + Kd_{sw} \times TSS \times 10^{-6}}$$

Where:

C_{dw} = dissolved phase water concentration (mg/l)
C_{wt} = total constituent concentration in water column (mg/l)
Kd_{sw} = suspended sediment/surface water partition coefficient (l/kg)
TSS = total suspended solids (mg/l)

Constituent Concentration Sorbed to Bed Sediment

$$C_{sb} = f_{bs} \times C_{wtot} \times \frac{Kd_{bs}}{\theta_{bs} + Kd_{bs} \times C_{BS}} \times \frac{dwc + dbs}{dbs}$$

Where:

C_{sb} = concentration sorbed to bed sediments (mg/kg)
C_{wtot} = total waterbody concentration (mg/l)
f_{bs} = fraction of total water body concentration that occurs in the bed sediment (unitless)
dwc = depth of water column (m)
dbs = depth of benthic layer (m)
θ_{bs} = bed sediment porosity (l_{water}/l)
Kd_{bs} = bed sediment/sediment pore water partition coefficient (l/kg)
C_{BS} = bed sediment concentration (g/cm^3)

Fish Concentration

The final step involves calculating the estimated constituent concentrations in fish from the total water column concentration, the dissolved water concentration, or the bed sediment concentration using a constituent-specific bioconcentration factor, bioaccumulation factor, or a sediment bioaccumulation factor as appropriate.

$$C_{fishdw} = C_{dw} \times BCF$$

Where:

C_{fishdw} = fish concentration from dissolved water concentration (mg/kg)
C_{dw} = dissolved water concentration (mg/l)
BCF = bioconcentration factor (l/kg)

Intake of Fish

The daily constituent intake from fish was estimated based on the calculated constituent concentration in fish tissue, the fish consumption rate, and the fraction of ingested fish that assumed to come from the impacted waterbody :

$$I_{fish} = C_{fish} \times CR_{fish} \times F_{fish}$$

Where:

I_{fish} = daily intake of contaminant from fish (mg/kg-d)

C_{fish} = fish concentration (mg/kg)
CR_{fish} = consumption rate of fish (kg/kg-d)
F_{fish} = fraction of fish contaminated (unitless)

A.3.2 Total Daily Intake for Indirect Pathway: Subsistence Fishing Scenario

The total daily contaminant intake is estimated as:

$$I_{tot} = I_{soil} + I_{ag} + I_{fish} + I_{dw}$$

Where:

I_{tot} = total daily intake of contaminant (mg/kg-d)
I_{soil} = daily intake of contaminant from soil (mg/kg-d)
I_{ag} = daily intake of contaminant from vegetables (mg/kg-d)
I_{fish} = daily intake of contaminant from fish (mg/kg-d)
I_{dw} = daily intake of contaminant from drinking water (mg/kg-d)

A.3.3 Cancer Risks and Hazard Quotients for Individual Chemicals in the Fisher Scenario

Cancer Risk:

$$CR_O = \frac{I_{tot} \text{ x } EF \text{ x } ED \text{ x } CSF_O}{AT \text{ x } UC}$$

Where:

CR_O = individual excess lifetime cancer risk, oral (unitless)
I_{tot} = total daily intake of contaminant (mg/kg-d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
CSF_O = cancer slope factor, oral $(mg/kg\text{-}d)^{-1}$
AT = time over which the dose is averaged (70 yr)
UC = units conversion (365 d/yr)

Hazard Quotient:

$$HQ_O = \frac{I_{tot} \times ED \times EF}{AT \times RfD_O \times UC}$$

Where:

HQ_O = hazard quotient, oral (unitless)
I_{tot} = total daily intake of contaminant (mg/kg-d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
AT = time over which the dose is averaged (ED)
UC = units conversion (365 d/yr)
RfD_O = reference dose, oral (mg/kg-d)

A.4 Subsistence Farmer Scenario

The subsistence farming scenario assumes that farmer inadvertently ingests soil, consumes produce, beef, and dairy specific to the farm and inhales constituents in air at the farm impact point. Daily constituent intake via incidental soil ingestion and consumption of homegrown produce, beef and dairy products is calculated as described in Section A.2. The input values for the subsistence farmer scenario can be found in Table 4-1.

A.4.1 Ingestion of Beef and Dairy

Beef and Dairy Concentrations

Constituent concentration in animal tissue is estimated based on the calculated concentrations in forage, silage, grain and soils ingested by cattle and constituent-specific biotransfer factors as shown in the following equation:

$$A_{beef} = (\Sigma(F_i \times Qp_i \times P_i) + (Qs \times Sc \times Bs)) \times Ba_{beef} \times MF$$

$$A_{milk} = (\Sigma(F_i \times Qp_i \times P_i) + (Qs \times Sc \times Bs)) \times Ba_{milk} \times MF$$

Where:

A_{beef} = concentration of constituent in beef tissue (mg/kg)

A_{milk} = concentration of constituent in milk (mg/kg)
P_i = concentration of constituent in plant type i consumed by the animal (mg/kg DW)
Qp_i = quantity of plant type i eaten each day (kg DW/d)
F_i = fraction of consumed plant type i grown on contaminated soil (unitless)
Sc = soil concentration (mg/kg)
Qs = quantity of soil eaten each day (kg soil/d)
Bs = soil bioavailability factor (unitless)
Ba_{beef} = beef biotransfer factor (d/kg)
Ba_{milk} = milk biotransfer factor (d/kg)
MF = metabolism factor (unitless)

Estimated concentrations in forage and silage are calculated using algorithms for estimating concentrations in exposed aboveground vegetation and concentrations in grain are estimated using algorithms for estimating levels in protected aboveground vegetation. Algorithm inputs for estimating concentrations in forage, silage and grain are taken from the draft HHRA guidance as are feed and soil consumption rates, and constituent-specific beef and milk biotransfer factors. These values are presented in Table 4-1 and Appendix B.

Constituent Intake from Beef

The daily constituent intake from beef tissue was estimated based on the calculated constituent concentration in beef tissue, the beef consumption rate, and the fraction of consumed beef that is assumed to be impacted:

$$I_{beef} = A_{beef} \times CR_{beef} \times F_{beef}$$

Where:

I_{beef} = daily intake of contaminant from beef (mg/kg-d)
A_{beef} = beef concentration (mg/d)
CR_{beef} = consumption rate of beef (kg/kg-d)
F_{beef} = fraction of beef contaminated (unitless)

Beef ingestion rates are based on default values presented in the draft HHRA Guidance (USEPA, 1998).

Constituent Intake from Milk

Daily constituent intake form milk is estimated based on the calculated constituent concentration in milk, the milk consumption rate, and the fraction of ingested milk that is assumed to be impacted::

$$I_{milk} = A_{milk} \times CR_{milk} \times F_{milk}$$

Where:

I_{milk} = daily intake of contaminant from milk (mg/kg-d)
A_{milk} = milk concentration (mg/d)
CR_{milk} = consumption rate of milk (kg/kg-d)
F_{milk} = fraction of milk contaminated (unitless)

A.4.2 Total Daily Intake from Indirect Pathways: Subsistence Farming Scenario

The total daily contaminant intake was estimated as:

$$I_{tot} = I_{soil} + I_{ag} + I_{beef} + I_{milk} + I_{dw}$$

Where:

I_{tot} = total daily intake of contaminant (mg/kg-d)
I_{soil} = daily intake of contaminant from soil (mg/kg-d)
I_{ag} = daily intake of contaminant from vegetables (mg/kg-d)
I_{bgv} = daily intake of contaminant from root vegetables (mg/kg-d)
I_{beef} = daily intake of contaminant from beef (mg/kg-d)
I_{milk} = daily intake of contaminant from milk (mg/kg-d)
I_{dw} = daily intake of contaminant from drinking water (mg/kg-d)

A.4.3 Cancer Risks and Hazard Quotients for Individual Chemicals in the Subsistence Farmer Scenario

Cancer Risk:

$$CR_O = \frac{I_{tot} \times EF \times ED \times CSF_O}{AT \times UC}$$

Where:

CR_O = individual excess lifetime cancer risk, oral (unitless)

I_{tot} = total daily intake of contaminant (mg/kg-d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
CSF_O = oral cancer slope factor, $(mg/kg\text{-}d)^{-1}$
AT = time over which the dose is averaged (70 yr)
UC = units conversion (365 d/yr)

Hazard Quotient:

$$HQ_O = \frac{I_{tot} \times EF \times ED}{AT \times RfD_O \times UC}$$

Where:

HQ_O = hazard quotient, oral (unitless)
I_{tot} = total daily intake of contaminant (mg/kg-d)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
RfD_O = reference dose, oral (mg/kg-d)
AT = time over which the dose is averaged (ED)
UC = units conversion (365 d/yr)

APPENDIX B

PHYSICAL/CHEMICAL PROPERTIES

APPENDIX B-1
PHYSICAL-CHEMICAL PARAMETERS

												Soil-Water Part. Coefficients							
Constituent	CAS No.	Henry's Law Constant (atm-m^3/mol)	Ref	LogKow Value	Ref	Koc (L/kg)	Ref	Dair (cm^2/sec)	Ref	Dwater (cm^2/sec)	Ref	Soil (mL/g) Kds	Ref	Susp. Sed. (mL/g) Kdsw	Ref	Bot. Sec. (mL/g) Kdbs	Ref	Soil Loss ksg (yr-1)	Ref
Inorganics																			
Arsenic	7440-38-2	NA	NA	NA	NA	NA	NA	1.07E-001	1	1.24E-005	1	2.90E+001	1	2.90E+001	1	2.90E+001	1	NA	NA

NA = Not Available
1. 1998 HHRAP
2. 1998 HHRAP (calculated)
3. 1998 HHRAP (Errata)
4. 1994 SSL
5. 1997 NCP
6. SCDM
7. 1997 SSL
8. CHEMDAT8
9. WATER8
10. CHEMDAT9

APPENDIX B-1
PHYSICAL-CHEMICAL PARAMETERS

	Plant Uptake Factors from Soil													
Constituent	RCF (µg/g plant)/ (µg/mL pore H2O)	Ref	Br ag (µg/g plant)/ (µg/g soil)/	Ref	Br rootveg (µg/g plant)/ (µg/g soil)/	Ref	Br forage (µg/g plant)/ (µg/g soil)/	Ref	Br grain (µg/g plant)/ (µg/g soil)/	Ref	Bv ag (µg/g plant)/ (µg/g air)	Ref	Bv forage (µg/g plant)/ (µg/g air)	Ref
Inorganics														
Arsenic	NA	NA	6.33E-003	1	8.00E-003	1	3.60E-002	1	4.00E-003	1	NA	NA	NA	NA

NA = Not Available
1. 1998 HHRAP
2. 1998 HHRAP (calculated)
3. 1998 HHRAP (Errata)
4. 1994 SSL
5. 1997 NCP
6. SCDM
7. 1997 SSL
8. CHEMDAT8
9. WATER8
10. CHEMDAT9

APPENDIX B-1
PHYSICAL-CHEMICAL PARAMETERS

					Beef and Dairy Biotransfer Factors						Fish Biotransfer Factors					
Constituent	Fraction Wet Dep. Adherence Fw (Unitless)	Ref	Fraction Vapor Fv (Unitless)	Ref	Babeef (d/kg)	Ref	Bamilk (d/kg)	Ref	Beef and Milk Modifying Factor (Unitless)	Ref	BCF (L/kg)	Ref	BAF (L/kg)	Ref	BSAF (L/kg)	Ref
Inorganics																
Arsenic	0.6	5	0.000	1	2.00E-003	1	6.00E-005	3	1	1	2.00E+001	3	NA	NA	NA	NA

NA = Not Available
1. 1998 HHRAP
2. 1998 HHRAP (calculated)
3. 1998 HHRAP (Errata)
4. 1994 SSL
5. 1997 NCP
6. SCDM
7. 1997 SSL
8. CHEMDAT8
9. WATER8
10. CHEMDAT9

APPENDIX C

BOWLINE RISK ASSESSMENT

RESIDENTIAL SCENARIO

CONTAMINANT CONCENTRATION IN SOIL
SUBSISTENCE FARMER SCENARIO

Parameters

Carcinogens

$$Sc=[Ds/(ks*(tD-T1))]*[(tD+(exp(-ks*tD)/ks))-(T1+(exp(-ks*T1))/ks)]$$

where:

$$Ds = [UC1*(Dydp+Dywp)/Zs*BD]$$

and:

Values Specific to Contaminant:	CS*
Sc = Average Soil Concentration Over Exposure Duration (mg/kg soil):	CS*
Ds = Deposition Term (mg/kg soil/yr):	CS*
T1 = Time Peroid At Beginning Of Combustion (yr):	0
ks = COC Soil Loss Constant (yr-1):	CS*
tD = Time Period Over Which Depositon Occurs (yr):	30
Sc(tD) = Soil Concentration At Time tD (mg/kg):	CS*
Zs = Soil Mixing Depth (cm):	see below
Tilled Soil:	2.0E+001
Untilled Soil:	1.0E+000
UC1 = Units Conversion Factor (mg-g-cm2/g-kg-m2):	1.0E+002
BD = Soil Bulk Density (g soil/cm3 soil):	1.5E+000
Dydp = Yearly Average Dry Deposition From Particle Phase (g/m2-yr):	7.09E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (g/m2-yr):	5.937E-004

CONTAMINANT CONCENTRATION IN SOIL
SUBSISTENCE FARMER SCENARIO

Contaminant	Sc Tilled (20 cm)	Sc Untilled (1 cm)	Ds Tilled (20 cm)	Ds Untilled (1 cm)	ks Tilled (yr-1)	ks Untilled (yr-1)
Inorganics						
Arsenic	1.8E-002	3.4E-002	2.0E-003	4.0E-002	5.65E-002	1.13E+000

CALCULATION OF SOIL LOSS CONSTANT

Parameters

ks = ksl + ksg + ksr + kse + ksv

where:
ksl = IR/ Z * (theta sw + Kds * BD)
ksr = (RO/*theta sw*Zs)*(1/(1.0+(Kds*BD/theta sw)))
ksv = Ke*Kt

where:
Ke = (UC1 * H) /(Zs * Koc * foc * R * T * BD)
Kt = (Da * theta v)/ Zs
theta v = 1 - (BD/ps) - theta sw

and:

Values Specific to Contaminant:	CS*
ks = COC Soil Loss Constant (yr-1):	CS*
ksl = COC Loss Constant Due to Leaching (yr-1):	CS*
ksr = COC Loss Constant Due to Runoff (yr-1):	CS*
kse = COC Loss Constant Due to Erosion (yr-1) (default):	0
ksg = COC Loss Constant Due to Biotic and Abiotic Degradation (yr-1):	CS*
ksv = COC Loss Constant Due to Volitilization (yr-1) (default):	CS*
P = Average Annual Precipitation (cm/yr):	8.1E+001
I = Average Annual Irrigation (cm/yr):	0.0E+000
RO = Average Annual Surface Water Runoff (cm/yr):	2.7E+001
Ev = Average Annual Evapotranspiration (cm/yr):	5.5E+001
Z = Soil Depth From Which Leaching Removal Occurs (see below):	
Tilled Soil (cm):	2.0E+001
Untilled Soil (cm):	1.0E+000
theta sw= Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-Water Partition Coefficient (cm3/g or ml/g):	CS*
BD = Soil Bulk Density (g soil/cm3 soil)	1.5E+000
Ke = Equilibrium Coefficient (s/yr-cm):	CS*
UC1 = Units Conversion (sec/yr):	3.2E+007
H = Henry's Law Constant (atm-m3/mol):	CS*
Koc = Organic Carbon Partition Coefficient (mL/g):	See Note**
foc = Fraction of Organic Carbon in Soil (unitless):	See Note**
R = Ideal Gas Constant (atm-m3/mol-K):	8.2E-005
T = Temperature (K):	298
Kt = Gas Phase Mass Transfer Coefficient (cm/s):	CS*
Da = Diffusion Coefficient of Contaminant in Air (cm2/s):	CS*
theta v = Soil Void Fraction (cm3/cm3):	2.4E-001
ps = Solids Particle Density (g/cm3):	2.7E+000
IR = Infiltration Rate (cm/yr):	2.2E+001

**Note: Koc * foc = Kds (cm3/g)

CALCULATION OF SOIL LOSS CONSTANT

Contaminant	ks Tilled (yr-1)	ks Untilled (yr-1)	ksg (yr-1)	ksl Tilled (yr-1)	ksl Untilled (yr-1)	ksr Tilled (yr-1)	ksr Untilled (yr-1)	ksv Tilled (yr-1)	ksv Untilled (yr-1)	Kds
Inorganics										
Arsenic	5.7E-002	1.1E+000	NA	2.5E-002	5.0E-001	3.1E-002	6.3E-001	NA	NA	2.9E+001

CONTAMINANT CONCENTRATION IN ABOVE GROUND VEGETATION
SUBSISTENCE FARMER

Parameters

Pd =(UC1 * [Dydp + (FW * Dywp)] * Rp * [1 - exp(-kp*Tp)]) / Yp * kp
Pv = ((Cyv * Bvag * VGag) / pa)
Pr abvgrd = Sc * Br ag

Where:

Values Specific to Contaminant:	CS*
Pd = Aboveground Produce Concentration Due to Direct Exposure (mg/kg) :	CS*
Pv = Aboveground Produce Concentration Due to Air-to-Plant Transfer(ug/g) :	CS*
Pr abvgrd = Exposed and Protected Aboveground Produce Concentration Due to Root Uptake (mg/kg) :	CS*
UC1 = Units Conversion Factor (mg/g):	1000
Cyv = Yearly Average Air Concentration From Vapor Phase (ug/m3):	NA
Dydp = Yearly Average Dry Deposition From Particle Phase (g/m2-yr):	7.090E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (g/m2-yr):	5.937E-004
FW = Fraction of COC Wet Deposition That Adheres to Plant Surfaces (--):	CS*
Bvag = Air-to-Plant Biotransfer Factor (--):	CS*
VGag = Above Ground Vegetable Correction Factor (--):	CS*
Rp = Interception Factor For Above Ground Vegetation (--):	3.9E-001
kp = Plant Surface Loss Coefficient (yr-1):	1.8E+001
Tp = Length of Growing Season For Above Ground Vegetation (yr):	1.64E-001
Yp = Vegetation Yield For Above Ground Vegetation (kg DW/m2):	2.24E+000
pa = Air Density (g/m3):	1.2E+003
Sc = Average Soil Concentration Over Exposure Duration (mg/kg) :	CS*
Br ag= Plant Soil Bioconcentration Factor For Produce (--):	CS*

CONTAMINANT CONCENTRATION IN ABOVE GROUND VEGETATION
SUBSISTENCE FARMER

Contaminant	Pd	Pv	Pr abvgrd exposed	Pr abvgrd protected	Sc Tilled (20 cm)	Fv	Fw	Bvag	VG ag	Br ag
Inorganics										
Arsenic	3.4E-003	NA	1.2E-004	1.2E-004	1.8E-002	0.0E+000	6.0E-001	NA	NA	6.3E-003

CONTAMINANT CONCENTRATION IN BELOW GROUND VEGETATION
SUBSISTENCE FARMER SCENARIO

Parameters

Pr bg = Sc * Br rv * VG rv

Where:

Values Specific to Contaminant:	CS*
Pr bg = Total Contaminant Level In Below Ground Vegetation (mg/kg):	CS*
Sc = Soil Concentration (tilled) (mg/kg):	CS*
Br rv = Plant-Soil Bioconcentration Factor For Below Ground Vegetables:	CS*
VGrv = Below Ground Vegetable Correction Factor:	CS*

CONTAMINANT CONCENTRATION IN BELOW GROUND VEGETATION
SUBSISTENCE FARMER SCENARIO

Contaminant	Pr bg	Sc Tilled (20 cm)	Br rv	VGrv
Inorganics				
Arsenic	1.5E-004	1.8E-002	8.0E-003	1.0E+000

CONTAMINANT CONCENTRATION IN FORAGE
SUBSISTENCE FARMER SCENARIO

Parameters

$$\mathrm{Pd} = (\mathrm{UC1} * [\mathrm{Dydp} + (\mathrm{FW} * \mathrm{Dywp})] * \mathrm{Rp} * [1 - \exp(-\mathrm{kp} * \mathrm{Tp})]) / \mathrm{Yp} * \mathrm{kp}$$

$$\mathrm{Pv} = ((\mathrm{Cyv} * \mathrm{Bvforage} * \mathrm{VGag}) / \mathrm{pa})$$

$$\mathrm{Pr} = \mathrm{Sc} * \mathrm{Br\ forage}$$

Where:

Values Specific to Contaminant:	CS*
Pd = Aboveground Produce Concentration Due to Direct Exposure (mg/kg) :	CS*
Pv = Aboveground Produce Concentration Due to Air-to-Plant Transfer (ug/g) :	CS*
Pr = Forage Concentration Due to Root Uptake (mg/kg) :	CS*
Cyv = Yearly Average Air Concentration From Vapor Phase (ug-s/g-m3):	NA
Fv = Fraction of Air Concentration in Vapor Phase (--):	CS*
1-Fv = Fraction of Air Concentration in Particulate Phase (--):	CS*
UC1 = Units Conversion Factor (mg/g):	1000
Dydp = Yearly Average Dry Deposition From Particle Phase (s/m2-yr):	7.09E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (s/m2-yr):	5.9E-004
FW = Fraction of COC Wet Deposition That Adheres to Plant Surfaces (--):	CS*
Bvag = Air-to-Plant Biotransfer Factor (--):	CS*
VGag = Above Ground Vegetable Correction Factor - Forage (--):	1.0E+000
Rp = Interception Factor For Above Ground Vegetation (--):	5.0E-001
kp = Plant Surface Loss Coefficient (yr-1):	1.8E+001
Tp = Length of Growing Season For Above Ground Vegetation (yr):	1.20E-001
Yp = Vegetation Yield For Above Ground Vegetation (kg DW/m2):	2.40E-001
pa = Air Density (g/m3):	1.2E+003
Sc = Average Soil Concentration Over Exposure Duration (mg/kg) :	CS*
Br = Plant Soil Bioconcentration Factor For Produce (--):	CS*

CONTAMINANT CONCENTRATION IN FORAGE
SUBSISTENCE FARMER SCENARIO

Contaminant	Pd	Pv	Pr forage	Sc Tilled (20 cm)	Fv	Fw	Bv forage	Br forage
Inorganics								
Arsenic	6.2E-002	NA	6.6E-004	1.8E-002	0.0E+000	6.0E-001	NA	3.6E-002

CONTAMINANT CONCENTRATION IN SILAGE
SUBSISTENCE FARMER SCENARIO

Parameters

$$Pd = (UC1 * [Dydp + (FW * Dywp)] * Rp * [1 - \exp(-kp*Tp)]) / Yp * kp$$

$$Pv = ((Cyv * Bvforage * VGag) / pa)$$

$$Pr\ silage = Sc * Br\ forage$$

Where:

Values Specific to Contaminant:	CS*
Pd = Aboveground Produce Concentration Due to Direct Exposure (mg/kg) :	CS*
Pv = Aboveground Produce Concentration Due to Air-to-Plant Transfer(ug/g) :	CS*
Pr silage = Silage Concentration Due to Root Uptake (mg/kg) :	CS*
Cyv = Yearly Average Air Concentration From Vapor Phase (ug-s/g-m3):	NA
Fv = Fraction of Air Concentration in Vapor Phase (--):	CS*
1-Fv = Fraction of Air Concentration in Particulate Phase (--):	CS*
UC1 = Units Conversion Factor (mg/g):	1000
Dydp = Yearly Average Dry Deposition From Particle Phase (s/m2-yr):	7.09E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (s/m2-yr):	5.9E-004
FW = Fraction of COC Wet Deposition That Adheres to Plant Surfaces (--):	CS*
Bv forage = Air-to-Plant Biotransfer Factor (--):	CS*
VGag = Above Ground Vegetable Correction Factor - Forage (--):	5.0E-001
Rp = Interception Factor For Above Ground Vegetation (--):	4.6E-001
kp = Plant Surface Loss Coefficient (yr-1):	1.8E+001
Tp = Length of Growing Season For Above Ground Vegetation (yr):	1.60E-001
Yp = Vegetation Yield For Above Ground Vegetation (kg DW/m2):	8.00E-001
pa = Air Density (g/m3):	1.2E+003
Sc = Average Soil Concentration Over Exposure Duration (mg/kg) :	CS*
Br = Plant Soil Bioconcentration Factor For Produce (--):	CS*

CONTAMINANT CONCENTRATION IN SILAGE
SUBSISTENCE FARMER SCENARIO

Contaminant	Pd	Pv	Pr silage	Sc Tilled (20 cm)	Fv	Fw	Bv forage	Br forage
Inorganics								
Arsenic	1.1E-002	NA	6.6E-004	1.8E-002	0.0E+000	6.0E-001	NA	3.6E-002

CONTAMINANT CONCENTRATION IN GRAIN
SUBSISTENCE FARMER SCENARIO

Parameter

Pr grain = Sc * Br grain

Where:

Values Specific to Contaminant: CS*

Pr grain = Grain Concentration Due to Root Uptake (mg/kg) : CS*

Sc = Average Soil Concentration Over Exposure Duration (mg/kg) : CS*

Br = Plant Soil Bioconcentration Factor For Produce (--): CS*

CONTAMINANT CONCENTRATION IN GRAIN
SUBSISTENCE FARMER SCENARIO

Contaminant	Pr abvgrd protected	Sc Tilled (20 cm)	Br ag
Inorganics			
Arsenic	7.3E-005	1.8E-002	4.0E-003

CONTAMINANT CONCENTRATION IN BEEF AND MILK
SUBSISTENCE FARMER SCENARIO

Parameters

Abeef = (Sum of (Fi * Qpi * Pi) + Qs * SC * Bs) * Ba beef * MF
Amilk = (Sum of (Fi * Qpi * Pi) + Qs * SC * Bs) * Ba milk * MF
and:

Pi = Pdi + Pvi + Pri

Where:

Abeef = Concentration of COC in Beef (mg/kg):	CS*
Amilk = Concentration of COC in Milk (mg/kg):	CS*
Fi = Fraction of Plant type i Grown on Contaminated Soil (--):	1.0E+000
Qpi = Quantity of Plant Type i Eaten By Beef Cattle per day (kg/d):	See Below
Forage:	8.8E+000
Silage:	2.5E+000
Grain:	4.7E-001
Qpi = Quantity of Plant Type i Eaten By Dairy Cattle per day (kg/d):	See Below
Forage:	1.3E+001
Silage:	4.1E+000
Grain:	3.0E+000
Pi = Concentration of COC in Each Plant Type i (mg/kg):	CS*
Pd = Aboveground Produce Concentration of Plant Type i Due to Direct Exposure (mg/kg) :	CS*
Pv = Aboveground Produce Concentration of Plant Type i Due to Air-to-Plant Transfer (ug/g) :	CS*
Pr abvgrd = Exposed and Protected Aboveground Produce Concentration Due to Root Uptake (mg/kg) :	CS*
Qs = Quantity of Soil Eaten Each Day (kg/d):	See Below:
Beef Cattle:	5.0E-001
Dairy Cattle:	4.0E-001
Sc = Average Soil Concentration Over Exposure Duration (mg/kg) :	CS*
Bs = Soil Bioavailability Factor (--):	1.0E+000
Ba beef = COC Biotransfer Factor for Beef (d/kg):	CS*
Ba milk = COC Biotransfer Factor for Milk (d/kg):	CS*
MF = Metabolism Factor (--):	1.0E+000

CONTAMINANT CONCENTRATION IN BEEF AND MILK
SUBSISTENCE FARMER SCENARIO

Contaminant	A beef	A milk	P for	P sil	P gr	Sc Untilled (1 cm)	Babeef	Bamilk
Inorganics								
Arsenic	1.2E-003	5.3E-005	6.3E-002	1.2E-002	7.3E-005	3.4E-002	2.0E-003	6.0E-005

WATERSHED SOIL CONTAMINANT CONCENTRATION DUE TO DEPOSITION
RESIDENTIAL DRINKING WATER SCENARIO - HUDSON RIVER

Contaminant	Sc Surface (1 cm)	Ds (1cm)	ks (yr-1)	ksl (yr-1)	ksr (yr-1)	kse (yr-1)	ksv (yr-1)	ksg (yr-1)	Kds
Inorganics									
Arsenic	3.5E-002	4.0E-002	1.1E+000	5.0E-001	6.3E-001	6.1E-003	NA	NA	2.9E+001

CALCULATION OF TOTAL WATERBODY LOAD
RESIDENTIAL DRINKING WATER SCENARIO - HUDSON RIVER

Parameters

LT = LDif + LDep + LRI + LR + LE
Where:
LDep = Dytwp * WAw
LRI = Dytwp * WAi
LR = UC1 * RO * (WAL) * ((Sc * BD)/(theta sw + Kds * BD))
LE = Xe * (WAL) * SD * ER * (Sc * Kds * BD)/(theta sw + Kds * BD) * UC2
LDif = (Kv * Cywv * WAw * UC5)/(H/R*Twk)
Xe = RF * K * LS * C * PF * (UC3/UC4)
SD = a * (WAl)^-b
Kv = ([Kl^-1+(Kg*(H/R*T)^-1)]^-1)*theta^Twk-293)
Kl = SQRT((1 * 1E-04 * Dw * u)/dz) * UC6 (Flowing Streams or Rivers)

and:

Values Specific to Contaminant:	CS*
LT = Total Contaminant Load to the Water Body (g/yr):	CS*
LDep = Deposition of Particle Phase and Wet Vapor Phase Contaminant Load to the Water Body (g/yr):	CS*
LRI = Runoff Load From Impervious Surfaces (g/yr):	CS*
LR = Runoff Load From Pervious Surface (g/yr):	CS*
LE = Soil Erosion Load (g/yr):	CS*
Dytwp = Yearly Waterbody Average Total (Wet and Dry) Deposition From Particle Phase (g/m2*yr):	5.937E-004
Cyv = Yearly Average Air Concentration From Vapor Phase (ug/m3):	NA
WAw = Water Body Area (m2):	7.2E+007
WAi = Impervious Watershed Area Receiving Pollutant Deposition (m2):	4.00E+008
UC1 = Units Conversion Factor (kg-cm2/mg-m2):	1.0E-002
WAL = Total Watershed Area Receiving Pollutant Deposition (m2):	4.00E+008
RO = Average Annual Surface Runoff (cm/yr):	2.7E+001
Sc = Contaminant Level in Watershed Soil (mg/kg):	CS*
BD = Soil Bulk Density (g/cm3):	1.5E+000
theta sw = Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-water partition coefficient (cm3/g or ml/g):	CS*
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.05E-002
ER = Contaminant Enrichment Ratio (--):	1.0E+000
UC2 = Units Conversion Factor (g/mg):	1.0E-003
RF = "Erosivity" Factor (yr-1):	1.5E+002
K = "Erodibility" Factor (tons/acre):	3.6E-001
LS = "Topographic or Slope Length" Factor (--):	1.5E+000
C = "Cover Management" Factor (--):	1.0E-001
PF = "Supporting Practice" Factor (--):	1.0E+000
a = Empirical Intercept Coefficient:	6.0E-001
b = Empirical Slope Coefficient:	1.25E-001
UC3 = Units Conversion Factor (kg/ton):	9.1E+002
UC4 = Units Conversion Factor (m2/acre):	4.0E+003
Kv = Overall Transfer Rate Coefficient (m/yr):	CS*
H = Henry's Law Constant (atm-m3/mol):	CS*
R = Universal Gas Constant (atm-m3/mol-K):	8.2E-005
Twk = Water Body Temperature (K):	3.0E+002
theta = Temperature Correction Factor (--):	1.03E+000
Kl = Liquid Phase Transfer Coefficient (m/yr):	CS*
Dw = Diffusivity of COC in Water (cm3 s):	CS*
UC5 = Units Conversion Factor (g/ug):	1.00E-006
UC6 = Units Conversion Factor (s/yr):	3.2E+007
Kg = Gas Phase Transfer Coefficient For Flowing Rivers or Streams (m/yr):	3.7E+004
u = Current Velocity (m s):	5.0E-001
dz = Total Waterbody Depth (m):	7.6E+000

CALCULATION OF TOTAL WATERBODY LOAD
RESIDENTIAL DRINKING WATER SCENARIO - HUDSON RIVER

Contaminant	LT	LDiff	LDep	LRI	LR	LE	Kv	Kl
Inorganics								
Arsenic	4.1E+005	NA	4.3E+004	2.4E+005	1.3E+005	1.3E+003	NA	2.8E+002

CALCULATION OF WATER CONCENTRATION
RESIDENTIAL DRINKING WATER SCENARIO - HUDSON RIVER

Parameters

Cwtot = LT/Vfx * fwc + kwt * WAw * (dwc + dbs)
Cwt = fwc * Cwtot * (dwc + dbs/dwc)
Cdw = Cwt/1 + Kdsw * TSS * 10-6
Csb = fbs * Cwtot * (Kdbs / thetabs + Kdbs * Cbs) * (dwc + dbs/dbs)

Where:
fwc = (1 + Kdsw * TSS * 10-6) * (dwc/dz)/(1 + Kdsw * TSS * 10-6) * (dwc/dz) + (thetabs + Kdbs * Cbs) * (dbs/dz)
kwt = fwc * kv + fbs * kb
fbs = 1 - fwc
kv = Kv/(dz * (1 + Kdsw * TSS * 10-6)
kb = [(Xe * WAl * SD * 10+3 - Vfx * TSS)/(WAw *TSS)] * [(TSS * 10-6)/(Cbs * dbs)]

and:

Values Specific to Contaminant:	CS*
Cwtot = Total Water Body Concentration (mg/L):	CS*
Cwt = Total Concentration in Water Column (mg/L):	CS*
Cdw = Dissolved Phase Water Concentration (mg/L):	CS*
Csb = Concentration Sorbed to Bed Sediments (mg/L):	CS*
fwc = Fraction of Total Water Body Concentration That Occurs in the Water Column (--):	CS*
kwt = Total First Order Dissipation Rate Constant (yr-1):	CS*
fbs = Fraction of Total Water Body Concentration That Occurs in the Bed Sediment (--):	CS*
LT = Total Contaminant Load to the Water Body (mg/yr):	CS*
Vfx = Average Volumetric Flow Rate Through Water Body (m3/yr):	1.11E-011
dwc = Depth of Water Column (m):	7.6E-000
dbs = Depth of Upper Benthic Sediment Layer (m):	3.0E-002
dz = Total Waterbody Depth (m):	7.6E-000
WAw = Water Body Area (m2):	7.20E-007
UC1 = Units Conversion Factor (g//mg):	1.0E-003
Kdsw = Suspended Sediment/Surface Water Partition Coefficient (L/kg):	CS*
TSS = Total Suspended Solids (mg/L):	1.4E-002
thetabs = Bed Sediment Porosity (Lwater/L):	6.0E-001
Kdbs = Bed Sediment/Sediment Pore Water Partition Coefficient (L/kg):	CS*
Cbs = Bed Sediment Concentration (g/cm3):	1.0E-000
kb = Benthic Burial Rate Constant (yr-1):	0.0E-000
kv = Water Column Volatilization Rate Constant (yr-1):	CS*
Kv = Overall COC Transfer Rate Coefficient (m/yr):	CS*
Xe = Unit Soil Loss (kg/m2/yr):	1.8E-000
SD = Sediment Delivery Ratio (--):	5.0E-002
WAl = Total Watershed Area Recieving Pollutant Deposition (m2):	4.0E-008

CALCULATION OF WATER CONCENTRATION
RESIDENTIAL DRINKING WATER SCENARIO - HUDSON RIVER

Contaminant	Cwtot	Cwt	Cdw	Csb	fwc	fbs	kwt	kv	Kdsw	Kdbs
Inorganics										
Arsenic	4.1E-006	3.7E-006	3.7E-006	1.1E-004	9.0E-001	1.04E-001	NA	NA	2.9E+001	2.9E+001

CALCULATION OF CHEMICAL INTAKES
SUBSISTENCE FARMER: ADULT

Parameter		Contaminant	Itot	Isoil	Iag	Ibeef	Imilk	Idw
Itot = Isoil + Iag + Ibeef + Imilk + Idw								
Where:		**Inorganics**						
Isoil = Sc * CRsoil * Fsoil/BW		Arsenic	2.5E-006	4.9E-008	2.9E-007	1.7E-006	4.5E-007	7.4E-008
Iag = [((Pd+Pv+Pr)*CRag)+(Pr*CRpp)+(Prbg*CRbg)] * Fag								
Ibeef = Abeef * CRbeef * Fbeef								
Imilk = Amilk * CRmilk * Fmilk								
Idw = Cdw * CRdw * Fdw/BW								
Where:								
CS* = Values Specific to Contaminant:								
Itot = Total Daily Intake of Contaminant (mg/kg-d):	CS*							
Isoil = Daily Intake of Contaminant from Soil (mg/kg-d):	CS*							
Iag = Daily Intake of Contaminant from Produce (mg/kg-d):	CS*							
Pd=Above Ground Exposed Produce Concentration Due to Direct Deposition (mg/kg):	CS*							
v=Above Ground Exposed Produce Concentration Due to Air-to-Plant Transfer (mg/kg):	CS*							
Pr=Above Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*							
PRbg=Below Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*							
Ibeef = Daily Intake of Contaminant from Beef (mg/kg-d):	CS*							
Imilk = Daily Intake of Contaminant from Milk (mg/kg-d):	CS*							
Sc = Soil Concentration (untilled) (mg/kg):	CS*							
CRsoil = Adult Soil Consumption Rate (kg/d):	0.0001							
Fsoil = Fraction of Consumed Soil that is Contaminated:	1							
CRag = Adult Consumption Rate of Above Ground Produce (kg/kg-d DW):	0.0003							
CRpp=Adult Consumption Rate of Protected Aboveground Produce (kg/kg-d DW):	0.00057							
CRbg=Adult Consumption Rate of Below Ground Produce (kg/kg-d DW):	0.00014							
Fag = Fraction of Produce that is Contaminated:	1							
Abeef = Total Contaminant Concentration in Beef (mg/kg):	CS*							
CRbeef = Consumption Rate of Beef (kg/d FW):	0.0014							
Fbeef = Fraction of Beef that is Contaminated:	1							
Amilk = Total Contaminant Concentration in Milk (mg/kg):	CS*							
CRmilk = Consumption Rate of Milk (kg/d):	0.00842							
Fmilk = Fraction of Milk that is Contaminated:	1							
Idw = Daily Intake of Contaminant from Drinking Water (mg/kg-day):	CS*							
Cdw = Dissolved phase water concentration (mg/L):	CS*							
CRdw = Adult Consumption Rate of Drinking Water (L/day):	1.4							
Fdw = Fraction of Drinking Water that is Contaminated (--):	1							
BW = Body weight (adult) (kg):	70							

WATERSHED SOIL CONTAMINANT CONCENTRATION DUE TO DEPOSITION
RESIDENTIAL DRINKING WATER SCENARIO - HUDSON RIVER

Parameters

Carcinogens

Sc=Ds/ks*(tD-T1)*[(tD+exp*(-ks*tD)/ks)-(T1+exp(-ks*T1)/ks)]

where:

Ds = [UC1*(Dytp)/Zs*BD]

ks = ksl + ksg + ksr + kse + ksv
ksl = IR/ Z * (theta sw + Kds * BD)
ksr = RO/theta sw*Zs*(1/(1.0+(Kds*BD/theta sw)))
ksv = Ke*Kt
kse = (Xe * SD * ER * 0.1)/(BD * Z) * (Kds * BD)/(theta + (Kds * BD))

where:

Ke = (UC3 + H) /(Zs * Koc * foc * R * T * BD)
Kt = (Da * theta v)/ Zs
theta v = 1 - (BD/ps) - theta sw

and:

Values Specific to Contaminant:	CS*
Values Specific to Receptor:	RS*
Sc = Average Soil Concentration Over Exposure Duration (mg/kg soil):	CS*
Ds = Deposition Term (mg/kg soil/yr):	CS*
ks = COC Soil Loss Constant (yr-1):	CS*
ksl = COC Loss Constant Due to Leaching (yr-1):	CS*
ksr = COC Loss Constant Due to Runoff (yr-1):	CS*
kse = COC Loss Constant Due to Erosion (yr-1) (default):	0.0E+000
ksg = COC Loss Constant Due to Biotic and Abiotic Degradation (yr-1):	CS*
ksv = COC Loss Constant Due to Volitilization (yr-1) (default):	CS*
tD = Time Period Over Which Depositon Occurs (yr):	3.0E+001
Sc(tD) = Soil Concentration At Time tD (mg/kg):	CS*
Zs = Soil Mixing Depth (cm):	1.0E+000
T1 = Time Peroid At Beginning Of Combustion (yr):	0.0E+000
UC1 = Units Conversion Factor (mg-g-cm2/g-kg-m2):	1.0E+002
BD = Soil Bulk Density (g soil/cm3 soil)	1.5E+000
UC2 = Units Conversion Factor (m-g-s/cm-ug-yr):	3.2E-001
Dytwp = Yearly Average Total Deposition From Particle Phase (Watershed) (g/m2-yr):	5.937E-004
P = Average Annual Precipitation (cm/yr):	1.2E+002
I = Average Annual Irrigation (cm/yr):	0.0E+000
RO = Average Annual Surface Water Runoff	2.7E+001
Ev = Average Annual Evapotranspiration (cm/yr):	7.0E+001
theta sw = Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-Water Partition Coefficient (cm3/g or ml/g):	CS*
Ke = Equilibrium Coefficient (s/yr-cm):	CS*
UC3 = Units Conversion (sec/yr):	3.2E+007
H = Henry's Law Constant (atm-m3/mol):	CS*
Koc = Organic Carbon Partition Coefficient (mL/g):	See Note**
foc = Fraction of Organic Carbon in Soil (unitless):	See Note**
R = Ideal Gas Constant (atm-m3/mol-K):	8.2E-005
T = Temperature (K):	298
Kt = Gas Phase Mass Transfer Coefficient (cm/s):	CS*
Da = Diffusion Coefficient of Contaminant in Air (cm2/s):	CS*
theta v = Soil Void Fraction (cm3/cm3):	2.4E-001
ps = Solids Particle Density (g/cm3):	2.7E+000
IR = Soil Infiltration Rate (cm/yr):	2.2E+001
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.0E-002
ER = Contaminant Enrichment Ratio (--):	1.0E+000

**Note: Koc * foc = Kds (cm3/g)

CALCULATION OF CHEMICAL INTAKES
SUBSISTENCE FARMER: CHILD

Parameter		Contaminant	Itot	Isoil	Iag	Ibeef	Imilk	Idw
Itot = Isoil + Iag + Ibeef + Imilk + Idw		**Inorganics**						
Where:		Arsenic	2.6E-006	4.6E-007	4.0E-007	6.1E-007	9.9E-007	1.7E-007
Isoil = Sc * CRsoil * Fsoil/BW								
Iag = [((Pd+Pv+Pr)*CRag)+(Pr*CRpp)+(Prbg*CRbg)] * Fag								
Ibeef = Abeef * CRbeef * Fbeef								
Imilk = Amilk * CRmilk * Fmilk								
Idw = Cdw * CRdw * Fdw/BW								
Where:								
Values Specific to Contaminant:	CS*							
Itot = Total Daily Intake of Contaminant (mg/kg-d):	CS*							
Isoil = Daily Intake of Contaminant from Soil (mg/kg-d):	CS*							
Iag = Daily Intake of Contaminant from Produce (mg/kg-d):	CS*							
Pd=Above Ground Exposed Produce Concentration Due to Direct Deposition (mg/kg):	CS*							
v=Above Ground Exposed Produce Concentration Due to Air-to-Plant Transfer (mg/kg):	CS*							
Pr=Above Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*							
PRbg=Below Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*							
Ibeef = Daily Intake of Contaminant from Beef (mg/kg-d):	CS*							
Imilk = Daily Intake of Contaminant from Milk (mg/kg-d):	CS*							
Sc = Soil Concentration (untilled) (mg/kg):	CS*							
CRsoil = Child Soil Consumption Rate (kg/d):	0.0002							
Fsoil = Fraction of Consumed Soil that is Contaminated:	1							
CRag = Child Consumption Rate of Above Ground Produce (kg/kg-d DW):	0.00042							
CRpp=Child Consumption Rate of Protected Aboveground Produce (kg/kg-d DW):	0.00077							
CRbg=Child Consumption Rate of Below Ground Produce (kg/kg-d DW):	0.00022							
Fag = Fraction of Produce that is Contaminated:	1							
Abeef = Total Contaminant Concentration in Beef (mg/kg):	CS*							
CRbeef = Consumption Rate of Beef (kg/d FW):	0.00051							
Fbeef = Fraction of Beef that is Contaminated:	1							
Amilk = Total Contaminant Concentration in Milk (mg/kg):	CS*							
CRmilk = Consumption Rate of Milk (kg/d):	0.01857							
Fmilk = Fraction of Milk that is Contaminated:	1							
Idw = Daily Intake of Contaminant from Drinking Water (mg/kg-day):	CS*							
Cdw = Dissolved phase water concentration (mg/L):	CS*							
CRdw = Child Consumption Rate of Drinking Water (L/day):	0.67							
Fdw = Fraction of Drinking Water that is Contaminated (--):	1							
BW = Body weight (child) (kg):	15							

SUBSISTENCE FARMER SCENARIO
SUMMARY OF CANCER RISKS AND HAZARD INDICES (a)

Parameter	Contaminant	RfDo	SFo	HQo Adult	CRo Adult	HQo Child	CRo Child	Noncarcinogenic Critical Effects
CRo = Itot * ED * EF * SFo/ AT * UC HQo = Itot * ED * EF/ RfDo * AT * UC	**Inorganics**							
Where: CS* = Values Specific to Contaminant: CRo = Cancer Risk oral (--): CS* HQo = Ingestion Hazard Index (--): CS* Itot = Total Daily Intake of Contaminant (mg/d): CS* SFo = Ingestion Slope Factor ((mg/kg-d)-1): CS* RfDo = Ingestion Reference Dose (mg/kg-d): CS* ED = Exposure Duration (see below) (yr): adult: 40 child: 6 EF = Exposure Frequency (day/yr): 350 AT = Averaging Time (yr): See Below Cancer: 70 Noncancer: See Below adult: 40 child: 6 UC = Units Conversion (day/yr): 365	Arsenic	3.0E-004	1.5E+000	8.1E-003	2E-006	8.4E-003	3E-007	Hyperpigmentation, keratosis, possible vascular effects

(a) Exposures routes include soil ingestion, beef, milk, produce and drinking water consumption

	Adult	Child
Total Cancer Risk:	2E-006	3E-007
Critical Effect HIs:	8.1E-003	8.4E-003

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

CHRONIC INHALATION OF AMBIENT CONSTITUENTS
SUBSISTENCE FARMER

Parameter	Contaminant	Ca	RfDi	SFi	HQi Adult	CRi Adult	HQi Child	CRi Child	Noncarcinogenic Critical Effects
CRi = Ca * IR * ED * EF * ET * SFi * UC1/ BW * AT * UC2 HQi = Ca * IR * ED * EF * ET * UC1/ RfDi * AT * BW * UC2 And:	**Inorganics**								
	Arsenic	3.80E-005	NA	1.5E+001	NA	5E-008	NA	2E-008	

Where:

CS* = Values specific to Contaminant:
Values specific to Site: RS*
CRi = Cancer Risk inhalation (--): CS*
HQi = Inhalation Hazard Index (--): CS*
Ca = Air Concentration (ug/m3) 3.796E-005
SFi = Ingestion Slope Factor ((mg/kg-d)-1): CS*
RfDi = Ingestion Reference Dose (mg/kg-d): CS*

IR = Inhalation Rate (see below) (m3/hr):
adult: 0.63
child: 0.3
ED = Exposure Duration (see below) (yr):
adult: 30
child: 6
EF = Exposure Frequency (day/yr): 350
ET = Exposure Time (hrs/day): 24
UC1 = Units Conversion (mg/ug): 0.001
BW = Body Weight (see below) (kg):
adult: 70
child: 15
AT = Averaging Time (yr): See Below
Cancer: 70
Noncancer: See Below
adult: 30
child: 6
UC2 = Units Conversion (day/yr): 365

	Adult	Child
Total Cancer Risk:	5E-008	2E-008
Critical Effect HIs:	NA	NA

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

SUBSISTENCE FISHER SCENARIO

CONTAMINANT CONCENTRATION IN SOIL
SUBSISTENCE FISHER SCENARIO

Parameters

Carcinogens

Sc=[Ds/(ks*(tD-T1))]*[(tD+(exp(-ks*tD)/ks))-(T1+(exp(-ks*T1))/ks)]

where:
Ds = [UC1*(Dydp+Dywp)/Zs*BD]

and:

Values Specific to Contaminant:	CS*
Sc = Average Soil Concentration Over Exposure Duration (mg/kg soil):	CS*
Ds = Deposition Term (mg/kg soil/yr):	CS*
T1 = Time Peroid At Beginning Of Combustion (yr):	0
ks = COC Soil Loss Constant (yr-1):	CS*
tD = Time Period Over Which Depositon Occurs (yr):	30
Sc(tD) = Soil Concentration At Time tD (mg/kg):	CS*
Zs = Soil Mixing Depth (cm):	see below
Tilled Soil:	2.0E+001
Untilled Soil:	1.0E+000
UC1 = Units Conversion Factor (mg-g-cm2/g-kg-m2):	1.0E+002
BD = Soil Bulk Density (g soil/cm3 soil):	1.5E+000
Dydp = Yearly Average Dry Deposition From Particle Phase (g/m2-yr):	7.09E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (g/m2-yr):	5.937E-004

CONTAMINANT CONCENTRATION IN SOIL
SUBSISTENCE FISHER SCENARIO

Contaminant	Sc Tilled (20 cm)	Sc Untilled (1 cm)	Ds Tilled (20 cm)	Ds Untilled (1 cm)	ks Tilled (yr-1)	ks Untilled (yr-1)
Inorganics						
Arsenic	1.8E-002	3.4E-002	2.0E-003	4.0E-002	5.65E-002	1.13E+000

CALCULATION OF SOIL LOSS CONSTANT

Parameters

ks = ksl + ksg + ksr + kse + ksv

where:
ksl = IR/ Z * (theta sw + Kds * BD)
ksr = (RO/*theta sw*Zs)*(1/(1.0+(Kds*BD/theta sw)))
ksv = Ke*Kt

where:
Ke = (UC1 * H) /(Zs * Koc * foc * R * T * BD)
Kt = (Da * theta v)/ Zs
theta v = 1 - (BD/ps) - theta sw

and:

Values Specific to Contaminant:	CS*
ks = COC Soil Loss Constant (yr-1):	CS*
ksl = COC Loss Constant Due to Leaching (yr-1):	CS*
ksr = COC Loss Constant Due to Runoff (yr-1):	CS*
kse = COC Loss Constant Due to Erosion (yr-1) (default):	0
ksg = COC Loss Constant Due to Biotic and Abiotic Degradation (yr-1):	CS*
ksv = COC Loss Constant Due to Volitilization (yr-1) (default):	CS*
P = Average Annual Precipitation (cm/yr):	8.1E+001
I = Average Annual Irrigation (cm/yr):	0.0E+000
RO = Average Annual Surface Water Runoff (cm/yr):	2.7E+001
Ev = Average Annual Evapotranspiration (cm/yr):	5.5E+001
Z = Soil Depth From Which Leaching Removal Occurs (see below):	
Tilled Soil (cm):	2.0E+001
Untilled Soil (cm):	1.0E+000
theta sw= Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-Water Partition Coefficient (cm3/g or ml/g):	CS*
BD = Soil Bulk Density (g soil/cm3 soil)	1.5E+000
Ke = Equilibrium Coefficient (s/yr-cm):	CS*
UC1 = Units Conversion (sec/yr):	3.2E+007
H = Henry's Law Constant (atm-m3/mol):	CS*
Koc = Organic Carbon Partition Coefficient (mL/g):	See Note**
foc = Fraction of Organic Carbon in Soil (unitless):	See Note**
R = Ideal Gas Constant (atm-m3/mol-K):	8.2E-005
T = Temperature (K):	298
Kt = Gas Phase Mass Transfer Coefficient (cm/s):	CS*
Da = Diffusion Coefficient of Contaminant in Air (cm2/s):	CS*
theta v = Soil Void Fraction (cm3/cm3):	2.4E-001
ps = Solids Particle Density (g/cm3):	2.7E+000
IR = Infiltration Rate (cm/yr):	2.2E+001

**Note: Koc * foc = Kds (cm3/g)

CALCULATION OF SOIL LOSS CONSTANT

Contaminant	ks Tilled (yr-1)	ks Untilled (yr-1)	ksg (yr-1)	ksl Tilled (yr-1)	ksl Untilled (yr-1)	ksr Tilled (yr-1)	ksr Untilled (yr-1)	ksv Tilled (yr-1)	ksv Untilled (yr-1)	Kds
Inorganics										
Arsenic	5.7E-002	1.1E+000	NA	2.5E-002	5.0E-001	3.1E-002	6.3E-001	NA	NA	2.9E+001

CONTAMINANT CONCENTRATION IN ABOVE GROUND VEGETATION
SUBSISTENCE FISHER SCENARIO

Parameters

$$Pd = (UC1 * [Dydp + (FW * Dywp)] * Rp * [1 - \exp(-kp * Tp)]) / Yp * kp$$

$$Pv = ((Cyv * Bvag * VGag) / pa)$$

$$Pr\ abvgrd = Sc * Br\ ag$$

Where:

Values Specific to Contaminant: CS*
Pd = Aboveground Produce Concentration Due to Direct Exposure (mg/kg) : CS*
Pv = Aboveground Produce Concentration Due to Air-to-Plant Transfer(ug/g) : CS*
Pr abvgrd = Exposed and Protected Aboveground Produce Concentration Due to Root Uptake (mg/kg) : CS*
UC1 = Units Conversion Factor (mg/g): 1000
Cyv = Yearly Average Air Concentration From Vapor Phase (ug/m3): NA
Dydp = Yearly Average Dry Deposition From Particle Phase (g/m2-yr): 7.090E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (g/m2-yr): 5.937E-004
FW = Fraction of COC Wet Deposition That Adheres to Plant Surfaces (--): CS*
Bvag = Air-to-Plant Biotransfer Factor (--): CS*
VGag = Above Ground Vegetable Correction Factor (--): CS*
Rp = Interception Factor For Above Ground Vegetation (--): 3.9E-001
kp = Plant Surface Loss Coefficient (yr-1): 1.8E+001
Tp = Length of Growing Season For Above Ground Vegetation (yr): 1.64E-001
Yp = Vegetation Yield For Above Ground Vegetation (kg DW/m2): 2.24E+000
pa = Air Density (g/m3): 1.2E+003
Sc = Average Soil Concentration Over Exposure Duration (mg/kg) : CS*
Br ag= Plant Soil Bioconcentration Factor For Produce (--): CS*

CONTAMINANT CONCENTRATION IN ABOVE GROUND VEGETATION
SUBSISTENCE FISHER SCENARIO

Contaminant	Pd	Pv	Pr abvgrd exposed	Pr abvgrd protected	Sc Tilled (20 cm)	Fv	Fw	Bvag	VG ag	Br ag
Inorganics										
Arsenic	3.4E-003	NA	1.2E-004	1.2E-004	1.8E-002	0.0E+000	6.0E-001	NA	NA	6.3E-003

CONTAMINANT CONCENTRATION IN BELOW GROUND VEGETATION
SUBSISTENCE FISHER SCENARIO

Parameters

$Pr\ bg = Sc * Br\ rv * VG\ rv$

Where:

Values Specific to Contaminant:	CS*
Pr bg = Total Contaminant Level In Below Ground Vegetation (mg/kg):	CS*
Sc = Soil Concentration (tilled) (mg/kg):	CS*
Br rv = Plant-Soil Bioconcentration Factor For Below Ground Vegetables:	CS*
VGrv = Below Ground Vegetable Correction Factor:	CS*

CONTAMINANT CONCENTRATION IN BELOW GROUND VEGETATION
SUBSISTENCE FISHER SCENARIO

Contaminant	Pr bg	Sc Tilled (20 cm)	Br rv	VGrv
Inorganics				
Arsenic	1.5E-004	1.8E-002	8.0E-003	1.0E+000

WATERSHED SOIL CONTAMINANT CONCENTRATION DUE TO DEPOSITION
DRINKING WATER AND SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Parameters

Carcinogens

Sc=Ds/ks*(tD-T1)*[(tD+exp*(-ks*tD)/ks)-(T1+exp(-ks*T1)/ks)]

where:
Ds = [UC1*(Dytp)/Zs*BD]

ks = ksl + ksg + ksr + kse + ksv
ksl = IR/ Z * (theta sw + Kds * BD)
ksr = RO/theta sw*Zs*(1/(1.0+(Kds*BD/theta sw)))
ksv = Ke*Kt
kse = (Xe * SD * ER * 0.1)/(BD * Z) * (Kds * BD)/(theta + (Kds * BD))

where:
Ke = (UC3 + H) /(Zs * Koc * foc * R * T * BD)
Kt = (Da * theta v)/ Zs
theta v = 1 - (BD/ps) - theta sw

and:

Values Specific to Contaminant:	CS*
Values Specific to Receptor:	RS*
Sc = Average Soil Concentration Over Exposure Duration (mg/kg soil):	CS*
Ds = Deposition Term (mg/kg soil/yr):	CS*
ks = COC Soil Loss Constant (yr-1):	CS*
ksl = COC Loss Constant Due to Leaching (yr-1):	CS*
ksr = COC Loss Constant Due to Runoff (yr-1):	CS*
kse = COC Loss Constant Due to Erosion (yr-1) (default):	0.0E+000
ksg = COC Loss Constant Due to Biotic and Abiotic Degradation (yr-1):	CS*
ksv = COC Loss Constant Due to Volitilization (yr-1) (default):	CS*
tD = Time Period Over Which Depositon Occurs (yr):	3.0E+001
Sc(tD) = Soil Concentration At Time tD (mg/kg):	CS*
Zs = Soil Mixing Depth (cm):	1.0E+000
T1 = Time Peroid At Beginning Of Combustion (yr):	0.0E+000
UC1 = Units Conversion Factor (mg-g-cm2/g-kg-m2):	1.0E+002
BD = Soil Bulk Density (g soil/cm3 soil)	1.5E+000
UC2 = Units Conversion Factor (m-g-s/cm-ug-yr):	3.2E-001
Dytwp = Yearly Average Total Deposition From Particle Phase (Watershed) (g/m2-yr):	5.937E-004
P = Average Annual Precipitation (cm/yr):	1.2E+002
I = Average Annual Irrigation (cm/yr):	0.0E+000
RO = Average Annual Surface Water Runoff	2.7E+001
Ev = Average Annual Evapotranspiration (cm/yr):	7.0E+001
theta sw = Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-Water Partition Coefficient (cm3/g or ml/g):	CS*
Ke = Equilibrium Coefficient (s/yr-cm):	CS*
UC3 = Units Conversion (sec/yr):	3.2E+007
H = Henry's Law Constant (atm-m3/mol):	CS*
Koc = Organic Carbon Partition Coefficient (mL/g):	See Note**
foc = Fraction of Organic Carbon in Soil (unitless):	See Note**
R = Ideal Gas Constant (atm-m3/mol-K):	8.2E-005
T = Temperature (K):	298
Kt = Gas Phase Mass Transfer Coefficient (cm/s):	CS*
Da = Diffusion Coefficient of Contaminant in Air (cm2/s):	CS*
theta v = Soil Void Fraction (cm3/cm3):	2.4E-001
ps = Solids Particle Density (g/cm3):	2.7E+000
IR = Soil Infiltration Rate (cm/yr):	2.2E+001
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.0E-002
ER = Contaminant Enrichment Ratio (--):	1.0E+000

**Note: Koc * foc = Kds (cm3/g)

WATERSHED SOIL CONTAMINANT CONCENTRATION DUE TO DEPOSITION
DRINKING WATER AND SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Contaminant	Sc Surface (1 cm)	Ds (1cm)	ks (yr-1)	ksl (yr-1)	ksr (yr-1)	kse (yr-1)	ksv (yr-1)	ksg (yr-1)	Kds
Inorganics									
Arsenic	3.5E-002	4.0E-002	1.1E+000	5.0E-001	6.3E-001	6.1E-003	NA	NA	2.9E+001

CALCULATION OF TOTAL WATERBODY LOAD
DRINKING WATER AND SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Parameters

LT = LDif + LDep + LRI + LR + LE
Where:
LDep = Dytwp * WAw
LRI = Dytwp * WAi
LR = UC1 * RO * (WAL) * ((Sc * BD)/(theta sw + Kds * BD))
LE = Xe * (WAL) * SD * ER * (Sc * Kds * BD)/(theta sw + Kds * BD) * UC2
LDif = (Kv * Cywv * WAw * UC5)/(H/R*Twk)
Xe = RF * K * LS * C * PF * (UC3/UC4)
SD = a * (WAl)^-b
Kv = ([Kl^-1+(Kg*(H/R*T)^-1)]^-1)*theta^Twk-293)
Kl = SQRT((1 * 1E-04 * Dw * u)/dz) * UC6 (Flowing Streams or Rivers)

and:

Values Specific to Contaminant:	CS*
LT = Total Contaminant Load to the Water Body (g/yr):	CS*
LDep = Deposition of Particle Phase and Wet Vapor Phase Contaminant Load to the Water Body (g/yr):	CS*
LRI = Runoff Load From Impervious Surfaces (g/yr):	CS*
LR = Runoff Load From Pervious Surface (g/yr):	CS*
LE = Soil Erosion Load (g/yr):	CS*
Dytwp = Yearly Waterbody Average Total (Wet and Dry) Deposition From Particle Phase (g/m2*yr):	5.937E-004
Cyv = Yearly Average Air Concentration From Vapor Phase (ug/m3):	NA
WAw = Water Body Area (m2):	7.2E+007
WAi = Impervious Watershed Area Receiving Pollutant Deposition (m2):	4.00E+008
UC1 = Units Conversion Factor (kg-cm2/mg-m2):	1.0E-002
WAL = Total Watershed Area Receiving Pollutant Deposition (m2):	4.00E+008
RO = Average Annual Surface Runoff (cm/yr):	2.7E+001
Sc = Contaminant Level in Watershed Soil (mg/kg):	CS*
BD = Soil Bulk Density (g/cm3):	1.5E+000
theta sw = Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-water partition coefficient (cm3/g or ml/g):	CS*
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.05E-002
ER = Contaminant Enrichment Ratio (--):	1.0E+000
UC2 = Units Conversion Factor (g/mg):	1.0E-003
RF = "Erosivity" Factor (yr-1):	1.5E+002
K = "Erodibility" Factor (tons/acre):	3.6E-001
LS = "Topographic or Slope Length" Factor (--):	1.5E+000
C = "Cover Management" Factor (--):	1.0E-001
PF = "Supporting Practice" Factor (--):	1.0E+000
a = Empirical Intercept Coefficient:	6.0E-001
b = Empirical Slope Coefficient:	1.25E-001
UC3 = Units Conversion Factor (kg/ton):	9.1E+002
UC4 = Units Conversion Factor (m2/acre):	4.0E+003
Kv = Overall Transfer Rate Coefficient (m/yr):	CS*
H = Henry's Law Constant (atm-m3/mol):	CS*
R = Universal Gas Constant (atm-m3/mol-K):	8.2E-005
Twk = Water Body Temperature (K):	3.0E+002
theta = Temperature Correction Factor (--):	1.03E+000
Kl = Liquid Phase Transfer Coefficient (m/yr):	CS*
Dw = Diffusivity of COC in Water (cm3/s):	CS*
UC5 = Units Conversion Factor (g/ug):	1.00E-006
UC6 = Units Conversion Factor (s/yr):	3.2E+007
Kg = Gas Phase Transfer Coefficient For Flowing Rivers or Streams (m/yr):	3.7E+004
u = Current Velocity (m/s):	5.0E-001
dz = Total Waterbody Depth (m):	7.6E+000

CALCULATION OF TOTAL WATERBODY LOAD
DRINKING WATER AND SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Contaminant	LT	LDiff	LDep	LRI	LR	LE	Kv	Kl
Inorganics								
Arsenic	4.1E+005	NA	4.3E+004	2.4E+005	1.3E+005	1.3E+003	NA	2.8E+002

CALCULATION OF WATER CONCENTRATION
DRINKING WATER AND SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Parameters

Cwtot = LT/Vfx * fwc + kwt * WAw * (dwc + dbs)
Cwt = fwc * Cwtot * (dwc + dbs/dwc)
Cdw = Cwt/1 + Kdsw * TSS * 10-6
Csb = fbs * Cwtot * (Kdbs / thetabs + Kdbs * Cbs) * (dwc + dbs/dbs)

Where:
fwc = (1 + Kdsw * TSS * 10-6) * (dwc/dz)/(1 + Kdsw * TSS * 10-6) * (dwc/dz) + (thetabs + Kdbs * Cbs) * (dbs/dz)
kwt = fwc * kv + fbs * kb
fbs = 1 - fwc
kv = Kv/(dz * (1 + Kdsw * TSS * 10-6)
kb = [(Xe * WAl * SD * 10+3 - Vfx * TSS)/(WAw *TSS)] * [(TSS * 10-6)/(Cbs * dbs)]

and:

Values Specific to Contaminant:	CS*
Cwtot = Total Water Body Concentration (mg/L):	CS*
Cwt = Total Concentration in Water Column (mg/L):	CS*
Cdw = Dissolved Phase Water Concentration (mg/L):	CS*
Csb = Concentration Sorbed to Bed Sediments (mg/L):	CS*
fwc = Fraction of Total Water Body Concentration That Occurs in the Water Column (--):	CS*
kwt = Total First Order Dissipation Rate Constant (yr-1):	CS*
fbs = Fraction of Total Water Body Concentration That Occurs in the Bed Sediment (--):	CS*
LT = Total Contaminant Load to the Water Body (mg/yr):	CS*
Vfx = Average Volumetric Flow Rate Through Water Body (m3/yr):	1.11E+011
dwc = Depth of Water Column (m):	7.6E+000
dbs = Depth of Upper Benthic Sediment Layer (m):	3.0E-002
dz = Total Waterbody Depth (m):	7.6E+000
WAw = Water Body Area (m2):	7.20E+007
UC1 = Units Conversion Factor (g//mg):	1.0E+003
Kdsw = Suspended Sediment/Surface Water Partition Coefficient (L/kg):	CS*
TSS = Total Suspended Solids (mg/L):	1.4E+002
thetabs = Bed Sediment Porosity (Lwater/L):	6.0E-001
Kdbs = Bed Sediment/Sediment Pore Water Partition Coefficient (L/kg):	CS*
Cbs = Bed Sediment Concentration (g/cm3):	1.0E+000
kb = Benthic Burial Rate Constant (yr-1):	0.0E+000
kv = Water Column Volatilization Rate Constant (yr-1):	CS*
Kv = Overall COC Transfer Rate Coefficient (m/yr):	CS*
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.0E-002
WAl = Total Watershed Area Recieving Pollutant Deposition (m2):	4.0E+008

CALCULATION OF WATER CONCENTRATION
DRINKING WATER AND SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Contaminant	Cwtot	Cwt	Cdw	Csb	fwc	fbs	kwt	kv	Kdsw	Kdbs
Inorganics										
Arsenic	4.1E-006	3.7E-006	3.7E-006	1.1E-004	9.0E-001	1.04E-001	NA	NA	2.9E+001	2.9E+001

CALCULATION OF FISH CONTAMINANT CONCENTRATION
SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Parameters

Cfishdw = Cdw * BCFfish or
Cfishdw = Cdw * BAFfish or
Cfishsb = Csb * flipid * BSAF/ OCsed

Where:

Values Specific to Contaminant:	CS*
Cfish = Contaminant Concentration In Fish (mg/kg):	CS*
Cfishdw = Fish Concentration from Dissolved Water Concentration (mg/kg):	CS*
Cfishsb = Fish Concentration from Bed Sediments (mg/kg):	CS*
Cdw = Dissolved Water Concentration (mg/L):	CS*
Cwt = Total Water Column Concentration (mg/L):	CS*
Csb = Concentration of Contaminant Sorbed to Bed Sediment (mg/kg):	CS*
BCFfish = Fish Bioconcentration Factor (L/kg):	CS*
BAFfish = Fish Bioaccumulation Factor (L/kg):	CS*
BSAF = Biota to Sediment Accumulation Factor (--):	CS*
flipid = Fish Lipid Content:	7.0E-002
OCsed = Fraction Organic Carbon in Bottom Sediment:	4.0E-002

CALCULATION OF FISH CONTAMINANT CONCENTRATION
SUBSISTENCE FISHER SCENARIO - HUDSON RIVER

Contaminant	Cfish	Cfishdw_BCF	BCF	Cfishdw_BAF	BAF	Cfishsb	BSAF
Inorganics							
Arsenic	7.4E-005	7.4E-005	2.0E+001	NA	NA	NA	NA

CALCULATION OF CHEMICAL INTAKES
SUSISTENCE FISHER: ADULT

Parameter		Contaminant	Itot	Isoil	Iag	Ifish	Idw
Itot = Isoil + Iag + Ifish + Idw		**Inorganics**					
Where:		Arsenic	5.0E-007	4.9E-008	2.9E-007	8.7E-008	7.4E-008
Isoil = Sc * CRsoil * Fsoil/BW							
Iag = [((Pd+Pv+Pr)*CRag)+(Pr*CRpp)+(Prbg*CRbg)] * Fag							
Ifish = Cfish * CRfish * Ffish							
Idw = Cdw * CRdw * Fdw/BW							
Where:							
CS* = Values Specific to Contaminant:							
Itot = Total Daily Intake of Contaminant (mg/kg-d):	CS*						
Isoil = Daily Intake of Contaminant from Soil (mg/kg-d):	CS*						
Iag = Daily Intake of Contaminant from Produce (mg/kg-d):	CS*						
Pd=Above Ground Exposed Produce Concentration Due to Direct Deposition (mg/kg):	CS*						
Pv=Above Ground Exposed Produce Concentration Due to Air-to-Plant Transfer (mg/kg):	CS*						
Pr=Above Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*						
PRbg=Below Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*						
Ifish = Daily Intake of Contaminant from Fish (mg/kg-d):	CS*						
Sc = Soil Concentration (untilled) (mg/kg):	CS*						
CRsoil = Adult Soil Consumption Rate (kg/d):	0.00005						
Fsoil = Fraction of Consumed Soil that is Contaminated:	1						
CRag = Adult Consumption Rate of Above Ground Produce (kg/kg-d DW):	0.0003						
CRpp=Adult Consumption Rate of Protected Aboveground Produce (kg/kg-d DW):	0.00057						
CRbg=Adult Consumption Rate of Below Ground Produce (kg/kg-d DW):	0.00014						
Fag = Fraction of Above Ground Vegetables that are Contaminated:	0.25						
Cfish = Total Contaminant Concentration in Fish (mg/kg):	CS*						
CRfish = Consumption Rate of Fish (kg/kg-d FW):	0.00117						
Ffish = Fraction of Fish that is Contaminated:	1						
Idw = Daily Intake of Contaminant from Drinking Water (mg/kg-day):	CS*						
Cdw = Dissolved phase water concentration (mg/L):	CS*						
CRdw = Adult Consumption Rate of Drinking Water (L/day):	1.4						
Fdw = Fraction of Drinking Water that is Contaminated (--):	1						
BW = Body weight (adult) (kg):	70						

CALCULATION OF CHEMICAL INTAKES
SUBSISTENCE FISHER: CHILD

Parameter	Contaminant	Itot	Isoil	Iag	Ifish	Idw
Itot = Isoil + Iag + Ifish + Idw	**Inorganics**					
Where: Isoil = Sc * CRsoil * Fsoil/BW Iag = [((Pd+Pv+Pr)*CRag)+(Pr*CRpp)+(Prbg*CRbg)] * Fag Ifish = Cfish * CRfish * Ffish Idw = Cdw * CRdw * Fdw/BW	Arsenic	1.1E-006	4.6E-007	4.0E-007	5.6E-008	1.7E-007

Where:

CS* = Values Specific to Contaminant:	
Itot = Total Daily Intake of Contaminant (mg/kg-d):	CS*
Isoil = Daily Intake of Contaminant from Soil (mg/kg-d):	CS*
Iag = Daily Intake of Contaminant from Produce (mg/kg-d):	CS*
Pd=Above Ground Exposed Produce Concentration Due to Direct Deposition (mg/kg):	CS*
Pv=Above Ground Exposed Produce Concentration Due to Air-to-Plant Transfer (mg/kg):	CS*
Pr=Above Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*
PRbg=Below Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*
Ifish = Daily Intake of Contaminant from Fish (mg/kg-d):	CS*
Sc = Soil Concentration (untilled) (mg/kg):	CS*
CRsoil = Child Soil Consumption Rate (kg/d):	0.0002
Fsoil = Fraction of Consumed Soil that is Contaminated:	1
CRag = Child Consumption Rate of Above Ground Produce (kg/kg-d DW):	0.00042
CRpp=Child Consumption Rate of Protected Aboveground Produce (kg/kg-d DW):	0.00077
CRbg=Child Consumption Rate of Below Ground Produce (kg/kg-d DW):	0.00022
Fag = Fraction of Produce that is Contaminated:	0.25
Cfish = Total Contaminant Concentration in Fish (mg/kg):	CS*
CRfish = Child Consumption Rate of Fish (kg/kg-d FW):	0.000759
Ffish = Fraction of Fish that is Contaminated:	1
Idw = Daily Intake of Contaminant from Drinking Water (mg/kg-day):	CS*
Cdw = Dissolved phase water concentration (mg/L):	CS*
CRdw = Child Consumption Rate of Drinking Water (L/day):	0.67
Fdw = Fraction of Drinking Water that is Contaminated (--):	1
BW = Body weight (child) (kg):	15

SUBSISTENCE FISHER SCENARIO - HUDSON RIVER
SUMMARY OF CANCER RISKS AND HAZARD INDICES (a)

Parameter	Contaminant	RfDo	SFo	HQo Adult	CRo Adult	HQo Child	CRo Child	Noncarcinogenic Critical Effects
CRo = Itot * ED * EF * SFo/AT * UC HQo = Itot * ED * EF/ RfDo * AT * UC	**Inorganics**							
	Arsenic	3.0E-004	1.5E+000	1.6E-003	3E-007	3.5E-003	1E-007	Hyperpigmentation, keratosis, possible vascular effects
Where: CS* = Values specific to Contaminant: CRo = Cancer Risk oral (--): CS* HQo = Ingestion Hazard Index (--): CS* Itot = Total Daily Intake of Contaminant (mg/d): CS* SFo = Ingestion Slope Factor ((mg/kg-d)-1): CS* RfDo = Ingestion Reference Dose (mg/kg-d): CS* ED = Exposure Duration (see below) (yr): adult: 30 child: 6 EF = Exposure Frequency (day/yr): 350 AT = Averaging Time (yr): See Below Cancer: 70 Noncancer: See Below adult: 30 child: 6 UC = Units Conversion (day/yr): 365								

(a) Exposures routes include soil ingestion, fish, produce and drinking water consumption

	Adult	Child
Total Cancer Risk:	3E-007	1E-007
Critical Effect HIs:	1.6E-003	3.5E-003

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

CHRONIC INHALATION OF AMBIENT CONSTITUENTS
SUBSISTENCE FISHER SCENARIO

Parameter	Contaminant	Ca	RfDi	SFi	HQi Adult	CRi Adult	HQi Child	CRi Child	Noncarcinogenic Critical Effects
CRi = Ca * IR * ED * EF * ET * SFi * UC1/ BW * AT * UC2 HQi = Ca * IR * ED * EF * ET * UC1/ RfDi * AT * BW * UC2 And:	**Inorganics**								
	Arsenic	3.80E-005	NA	1.5E+001	NA	5E-008	NA	2E-008	
Where: CS* = Values specific to Contaminant: Values specific to Site: RS* CRi = Cancer Risk inhalation (--): CS* HQi = Inhalation Hazard Index (--): CS* Ca = Air Concentration (ug/m3) 3.796E-005 SFi = Ingestion Slope Factor ((mg/kg-d)-1): CS* RfDi = Ingestion Reference Dose (mg/kg-d): CS*									
IR = Inhalation Rate (see below) (m3/hr): adult: 0.63 child: 0.3 ED = Exposure Duration (see below) (yr): adult: 30 child: 6 EF = Exposure Frequency (day/yr): 350 ET = Exposure Time (hrs/day): 24 UC1 = Units Conversion (mg/ug): 0.001 BW = Body Weight (see below) (kg): adult: 70 child: 15 AT = Averaging Time (yr): See Below Cancer: 70 Noncancer: See Below adult: 30 child: 6 UC2 = Units Conversion (day/yr): 365									

	Adult	Child
Total Cancer Risk:	5E-008	2E-008
Critical Effect HIs:	NA	NA

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

SUBSISTENCE FARMER SCENARIO

CONTAMINANT CONCENTRATION IN SOIL
RESIDENTIAL SCENARIO

Parameters

Carcinogens

Sc=[Ds/(ks*(tD-T1))]*[(tD+(exp(-ks*tD)/ks))-(T1+(exp(-ks*T1))/ks)]

where:
Ds = [UC1*(Dydp+Dywp)/Zs*BD]

and:

Values Specific to Contaminant:	CS*
Sc = Average Soil Concentration Over Exposure Duration (mg/kg soil):	CS*
Ds = Deposition Term (mg/kg soil/yr):	CS*
T1 = Time Peroid At Beginning Of Combustion (yr):	0
ks = COC Soil Loss Constant (yr-1):	CS*
tD = Time Period Over Which Depositon Occurs (yr):	30
Sc(tD) = Soil Concentration At Time tD (mg/kg):	CS*
Zs = Soil Mixing Depth (cm):	see below
Tilled Soil:	2.0E+001
Untilled Soil:	1.0E+000
UC1 = Units Conversion Factor (mg-g-cm2/g-kg-m2):	1.0E+002
BD = Soil Bulk Density (g soil/cm3 soil):	1.5E+000
Dydp = Yearly Average Dry Deposition From Particle Phase (g/m2-yr):	7.09E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (g/m2-yr):	5.937E-004

CONTAMINANT CONCENTRATION IN SOIL
RESIDENTIAL SCENARIO

Contaminant	Sc Tilled (20 cm)	Sc Untilled (1 cm)	Ds Tilled (20 cm)	Ds Untilled (1 cm)	ks Tilled (yr-1)	ks Untilled (yr-1)
Inorganics						
Arsenic	1.8E-002	3.4E-002	2.0E-003	4.0E-002	5.65E-002	1.13E+000

CALCULATION OF SOIL LOSS CONSTANT

Parameters

ks = ksl + ksg + ksr + kse + ksv

where:
ksl = IR/ Z * (theta sw + Kds * BD)
ksr = (RO/*theta sw*Zs)*(1/(1.0+(Kds*BD/theta sw)))
ksv = Ke*Kt

where:
Ke = (UC1 * H) /(Zs * Koc * foc * R * T * BD)
Kt = (Da * theta v)/ Zs
theta v = 1 - (BD/ps) - theta sw

and:

Values Specific to Contaminant:	CS*
ks = COC Soil Loss Constant (yr-1):	CS*
ksl = COC Loss Constant Due to Leaching (yr-1):	CS*
ksr = COC Loss Constant Due to Runoff (yr-1):	CS*
kse = COC Loss Constant Due to Erosion (yr-1) (default):	0
ksg = COC Loss Constant Due to Biotic and Abiotic Degradation (yr-1):	CS*
ksv = COC Loss Constant Due to Volitilization (yr-1) (default):	CS*
P = Average Annual Precipitation (cm/yr):	8.1E+001
I = Average Annual Irrigation (cm/yr):	0.0E+000
RO = Average Annual Surface Water Runoff (cm/yr):	2.7E+001
Ev = Average Annual Evapotranspiration (cm/yr):	5.5E+001
Z = Soil Depth From Which Leaching Removal Occurs (see below):	
Tilled Soil (cm):	2.0E+001
Untilled Soil (cm):	1.0E+000
theta sw= Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-Water Partition Coefficient (cm3/g or ml/g):	CS*
BD = Soil Bulk Density (g soil/cm3 soil)	1.5E+000
Ke = Equilibrium Coefficient (s/yr-cm):	CS*
UC1 = Units Conversion (sec/yr):	3.2E+007
H = Henry's Law Constant (atm-m3/mol):	CS*
Koc = Organic Carbon Partition Coefficient (mL/g):	See Note**
foc = Fraction of Organic Carbon in Soil (unitless):	See Note**
R = Ideal Gas Constant (atm-m3/mol-K):	8.2E-005
T = Temperature (K):	298
Kt = Gas Phase Mass Transfer Coefficient (cm/s):	CS*
Da = Diffusion Coefficient of Contaminant in Air (cm2/s):	CS*
theta v = Soil Void Fraction (cm3/cm3):	2.4E-001
ps = Solids Particle Density (g/cm3):	2.7E+000
IR = Infiltration Rate (cm/yr):	2.2E+001

**Note: Koc * foc = Kds (cm3/g)

CALCULATION OF SOIL LOSS CONSTANT

Contaminant	ks Tilled (yr-1)	ks Untilled (yr-1)	ksg (yr-1)	ksl Tilled (yr-1)	ksl Untilled (yr-1)	ksr Tilled (yr-1)	ksr Untilled (yr-1)	ksv Tilled (yr-1)	ksv Untilled (yr-1)	Kds
Inorganics										
Arsenic	5.7E-002	1.1E+000	NA	2.5E-002	5.0E-001	3.1E-002	6.3E-001	NA	NA	2.9E+001

CONTAMINANT CONCENTRATION IN ABOVE GROUND VEGETATION
RESIDENTIAL SCENARIO

Parameters

$Pd = (UC1 * [Dydp + (FW * Dywp)] * Rp * [1 - \exp(-kp*Tp)]) / Yp * kp$

$Pv = ((Cyv * Bvag * VGag) / pa)$

$Pr\ abvgrd = Sc * Br\ ag$

Where:

Values Specific to Contaminant: CS*
Pd = Aboveground Produce Concentration Due to Direct Exposure (mg/kg) : CS*
Pv = Aboveground Produce Concentration Due to Air-to-Plant Transfer(ug/g) : CS*
Pr abvgrd = Exposed and Protected Aboveground Produce Concentration Due to Root Uptake (mg/kg) : CS*
UC1 = Units Conversion Factor (mg/g): 1000
Cyv = Yearly Average Air Concentration From Vapor Phase (ug/m3): NA
Dydp = Yearly Average Dry Deposition From Particle Phase (g/m2-yr): 7.090E-006
Dywp = Yearly Average Wet Deposition From Particle Phase (g/m2-yr): 5.937E-004
FW = Fraction of COC Wet Deposition That Adheres to Plant Surfaces (--): CS*
Bvag = Air-to-Plant Biotransfer Factor (--): CS*
VGag = Above Ground Vegetable Correction Factor (--): CS*
Rp = Interception Factor For Above Ground Vegetation (--): 3.9E-001
kp = Plant Surface Loss Coefficient (yr-1): 1.8E+001
Tp = Length of Growing Season For Above Ground Vegetation (yr): 1.64E-001
Yp = Vegetation Yield For Above Ground Vegetation (kg DW/m2): 2.24E+000
pa = Air Density (g/m3): 1.2E+003
Sc = Average Soil Concentration Over Exposure Duration (mg/kg) : CS*
Br ag= Plant Soil Bioconcentration Factor For Produce (--): CS*

CONTAMINANT CONCENTRATION IN ABOVE GROUND VEGETATION
RESIDENTIAL SCENARIO

Contaminant	Pd	Pv	Pr abvgrd exposed	Pr abvgrd protected	Sc Tilled (20 cm)	Fv	Fw	Bvag	VG ag	Br ag
Inorganics										
Arsenic	3.4E-003	NA	1.2E-004	1.2E-004	1.8E-002	0.0E+000	6.0E-001	NA	NA	6.3E-003

CONTAMINANT CONCENTRATION IN BELOW GROUND VEGETATION
RESIDENTIAL SCENARIO

Parameters

Pr bg = Sc * Br rv * VG rv

Where:

Values Specific to Contaminant:	CS*
Pr bg = Total Contaminant Level In Below Ground Vegetation (mg/kg):	CS*
Sc = Soil Concentration (tilled) (mg/kg):	CS*
Br rv = Plant-Soil Bioconcentration Factor For Below Ground Vegetables:	CS*
VGrv = Below Ground Vegetable Correction Factor:	CS*

CONTAMINANT CONCENTRATION IN BELOW GROUND VEGETATION
RESIDENTIAL SCENARIO

Contaminant	Pr bg	Sc Tilled (20 cm)	Br rv	VGrv
Inorganics				
Arsenic	1.5E-004	1.8E-002	8.0E-003	1.0E+000

WATERSHED SOIL CONTAMINANT CONCENTRATION DUE TO DEPOSITION
SUBSISTENCE FARMER DRINKING WATER SCENARIO - HUDSON RIVER

Parameters

Carcinogens

Sc=Ds/ks*(tD-T1)*[(tD+exp*(-ks*tD)/ks)-(T1+exp(-ks*T1)/ks)]

where:

Ds = [UC1*(Dytp)/Zs*BD]

ks = ksl + ksg + ksr + kse + ksv
ksl = IR/ Z * (theta sw + Kds * BD)
ksr = RO/theta sw*Zs*(1/(1.0+(Kds*BD/theta sw)))
ksv = Ke*Kt
kse = (Xe * SD * ER * 0.1)/(BD * Z) * (Kds * BD)/(theta + (Kds * BD))

where:

Ke = (UC3 + H) /(Zs * Koc * foc * R * T * BD)
Kt = (Da * theta v)/ Zs
theta v = 1 - (BD/ps) - theta sw

and:

Values Specific to Contaminant:	CS*
Values Specific to Receptor:	RS*
Sc = Average Soil Concentration Over Exposure Duration (mg/kg soil):	CS*
Ds = Deposition Term (mg/kg soil/yr):	CS*
ks = COC Soil Loss Constant (yr-1):	CS*
ksl = COC Loss Constant Due to Leaching (yr-1):	CS*
ksr = COC Loss Constant Due to Runoff (yr-1):	CS*
kse = COC Loss Constant Due to Erosion (yr-1) (default):	0.0E+000
ksg = COC Loss Constant Due to Biotic and Abiotic Degradation (yr-1):	CS*
ksv = COC Loss Constant Due to Volitilization (yr-1) (default):	CS*
tD = Time Period Over Which Depositon Occurs (yr):	3.0E+001
Sc(tD) = Soil Concentration At Time tD (mg/kg):	CS*
Zs = Soil Mixing Depth (cm):	1.0E+000
T1 = Time Peroid At Beginning Of Combustion (yr):	0.0E+000
UC1 = Units Conversion Factor (mg-g-cm2 g-kg-m2):	1.0E+002
BD = Soil Bulk Density (g soil cm3 soil)	1.5E+000
UC2 = Units Conversion Factor (m-g-s cm-ug-yr):	3.2E-001
Dytwp = Yearly Average Total Deposition From Particle Phase (Watershed) (g/m2-yr):	5.937E-004
P = Average Annual Precipitation (cm/yr):	1.2E+002
I = Average Annual Irrigation (cm/yr):	0.0E+000
RO = Average Annual Surface Water Runoff	2.7E+001
Ev = Average Annual Evapotranspiration (cm/yr):	7.0E+001
theta sw = Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-Water Partition Coefficient (cm3/g or ml/g):	CS*
Ke = Equilibrium Coefficient (s/yr-cm):	CS*
UC3 = Units Conversion (sec/yr):	3.2E+007
H = Henry's Law Constant (atm-m3/mol):	CS*
Koc = Organic Carbon Partition Coefficient (mL/g):	See Note**
foc = Fraction of Organic Carbon in Soil (unitless):	See Note**
R = Ideal Gas Constant (atm-m3 mol-K):	8.2E-005
T = Temperature (K):	298
Kt = Gas Phase Mass Transfer Coefficient (cm/s):	CS*
Da = Diffusion Coefficient of Contaminant in Air (cm2/s):	CS*
theta v = Soil Void Fraction (cm3/cm3):	2.4E-001
ps = Solids Particle Density (g/cm3):	2.7E+000
IR = Soil Infiltration Rate (cm/yr):	2.2E+001
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.0E-002
ER = Contaminant Enrichment Ratio (--):	1.0E+000

**Note: Koc * foc = Kds (cm3/g)

WATERSHED SOIL CONTAMINANT CONCENTRATION DUE TO DEPOSITION
SUBSISTENCE FARMER DRINKING WATER SCENARIO - HUDSON RIVER

Contaminant	Sc Surface (1 cm)	Ds (1cm)	ks (yr-1)	ksl (yr-1)	ksr (yr-1)	kse (yr-1)	ksv (yr-1)	ksg (yr-1)	Kds
Inorganics									
Arsenic	3.5E-002	4.0E-002	1.1E+000	5.0E-001	6.3E-001	6.1E-003	NA	NA	2.9E+001

CALCULATION OF TOTAL WATERBODY LOAD
SUBSISTENCE FARMER DRINKING WATER SCENARIO - HUDSON RIVER

Parameters

LT = LDif + LDep + LRI + LR + LE
Where:
LDep = Dytwp * WAw
LRI = Dytwp * WAi
LR = UC1 * RO * (WAL) * ((Sc * BD)/(theta sw + Kds * BD))
LE = Xe * (WAL) * SD * ER * (Sc * Kds * BD)/(theta sw + Kds * BD) * UC2
LDif = (Kv * Cywv * WAw * UC5)/(H/R*Twk)
Xe = RF * K * LS * C * PF * (UC3/UC4)
SD = a * (WAl)^-b
Kv = ([Kl^-1+(Kg*(H/R*T)^-1)]^-1)*theta^Twk-293)
Kl = SQRT((1 * 1E-04 * Dw * u)/dz) * UC6 (Flowing Streams or Rivers)

and:

Values Specific to Contaminant:	CS*
LT = Total Contaminant Load to the Water Body (g/yr):	CS*
LDep = Deposition of Particle Phase and Wet Vapor Phase Contaminant Load to the Water Body (g/yr):	CS*
LRI = Runoff Load From Impervious Surfaces (g/yr):	CS*
LR = Runoff Load From Pervious Surface (g/yr):	CS*
LE = Soil Erosion Load (g/yr):	CS*
Dytwp = Yearly Waterbody Average Total (Wet and Dry) Deposition From Particle Phase (g/m2*yr):	5.937E-004
Cyv = Yearly Average Air Concentration From Vapor Phase (ug/m3):	NA
WAw = Water Body Area (m2):	7.2E+007
WAi = Impervious Watershed Area Receiving Pollutant Deposition (m2):	4.00E+008
UC1 = Units Conversion Factor (kg-cm2/mg-m2):	1.0E-002
WAL = Total Watershed Area Receiving Pollutant Deposition (m2):	4.00E+008
RO = Average Annual Surface Runoff (cm/yr):	2.7E+001
Sc = Contaminant Level in Watershed Soil (mg/kg):	CS*
BD = Soil Bulk Density (g/cm3):	1.5E+000
theta sw = Volumetric Water Content (cm3/cm3):	2.0E-001
Kds = Soil-water partition coefficient (cm3/g or ml/g):	CS*
Xe = Unit Soil Loss (kg/m2/yr):	1.8E+000
SD = Sediment Delivery Ratio (--):	5.05E-002
ER = Contaminant Enrichment Ratio (--):	1.0E+000
UC2 = Units Conversion Factor (g/mg):	1.0E-003
RF = "Erosivity" Factor (yr-1):	1.5E+002
K = "Erodibility" Factor (tons/acre):	3.6E-001
LS = "Topographic or Slope Length" Factor (--):	1.5E+000
C = "Cover Management" Factor (--):	1.0E-001
PF = "Supporting Practice" Factor (--):	1.0E+000
a = Empirical Intercept Coefficient:	6.0E-001
b = Empirical Slope Coefficient:	1.25E-001
UC3 = Units Conversion Factor (kg/ton):	9.1E+002
UC4 = Units Conversion Factor (m2/acre):	4.0E+003
Kv = Overall Transfer Rate Coefficient (m/yr):	CS*
H = Henry's Law Constant (atm-m3/mol):	CS*
R = Universal Gas Constant (atm-m3/mol-K):	8.2E-005
Twk = Water Body Temperature (K):	3.0E+002
theta = Temperature Correction Factor (--):	1.03E+000
Kl = Liquid Phase Transfer Coefficient (m/yr):	CS*
Dw = Diffusivity of COC in Water (cm3/s):	CS*
UC5 = Units Conversion Factor (g/ug):	1.00E-006
UC6 = Units Conversion Factor (s/yr):	3.2E+007
Kg = Gas Phase Transfer Coefficient For Flowing Rivers or Streams (m/yr):	3.7E+004
u = Current Velocity (m/s):	5.0E-001
dz = Total Waterbody Depth (m):	7.6E+000

CALCULATION OF TOTAL WATERBODY LOAD
SUBSISTENCE FARMER DRINKING WATER SCENARIO - HUDSON RIVER

Contaminant	LT	LDiff	LDep	LRI	LR	LE	Kv	Kl
Inorganics								
Arsenic	4.1E+005	NA	4.3E+004	2.4E+005	1.3E+005	1.3E+003	NA	2.8E+002

CALCULATION OF WATER CONCENTRATION
SUBSISTENCE FARMER DRINKING WATER SCENARIO - HUDSON RIVER

Parameters

Cwtot = LT/Vfx * fwc + kwt * WAw * (dwc + dbs)
Cwt = fwc * Cwtot * (dwc + dbs/dwc)
Cdw = Cwt/1 + Kdsw * TSS * 10-6
Csb = fbs * Cwtot * (Kdbs / thetabs + Kdbs * Cbs) * (dwc + dbs/dbs)

Where:
fwc = (1 + Kdsw * TSS * 10-6) * (dwc/dz)/(1 + Kdsw * TSS * 10-6) * (dwc/dz) + (thetabs + Kdbs * Cbs) * (dbs/dz)
kwt = fwc * kv + fbs * kb
fbs = 1 - fwc
kv = Kv/(dz * (1 + Kdsw * TSS * 10-6)
kb = [(Xe * WAl * SD * 10+3 - Vfx * TSS)/(WAw *TSS)] * [(TSS * 10-6)/(Cbs * dbs)]

and:

Values Specific to Contaminant:	CS*
Cwtot = Total Water Body Concentration (mg/L):	CS*
Cwt = Total Concentration in Water Column (mg/L):	CS*
Cdw = Dissolved Phase Water Concentration (mg/L):	CS*
Csb = Concentration Sorbed to Bed Sediments (mg/L):	CS*
fwc = Fraction of Total Water Body Concentration That Occurs in the Water Column (--):	CS*
kwt = Total First Order Dissipation Rate Constant (yr-1):	CS*
fbs = Fraction of Total Water Body Concentration That Occurs in the Bed Sediment (--):	CS*
LT = Total Contaminant Load to the Water Body (mg/yr):	CS*
Vfx = Average Volumetric Flow Rate Through Water Body (m3/yr):	1.11E-011
dwc = Depth of Water Column (m):	7.6E-000
dbs = Depth of Upper Benthic Sediment Layer (m):	3.0E-002
dz = Total Waterbody Depth (m):	7.6E-000
WAw = Water Body Area (m2):	7.20E-007
UC1 = Units Conversion Factor (g/mg):	1.0E-003
Kdsw = Suspended Sediment/Surface Water Partition Coefficient (L/kg):	CS*
TSS = Total Suspended Solids (mg/L):	1.4E-002
thetabs = Bed Sediment Porosity (Lwater/L):	6.0E-001
Kdbs = Bed Sediment/Sediment Pore Water Partition Coefficient (L/kg):	CS*
Cbs = Bed Sediment Concentration (g/cm3):	1.0E-000
kb = Benthic Burial Rate Constant (yr-1):	0.0E-000
kv = Water Column Volatilization Rate Constant (yr-1):	CS*
Kv = Overall COC Transfer Rate Coefficient (m/yr):	CS*
Xe = Unit Soil Loss (kg/m2/yr):	1.8E-000
SD = Sediment Delivery Ratio (--):	5.0E-002
WAl = Total Watershed Area Recieving Pollutant Deposition (m2):	4.0E-008

CALCULATION OF WATER CONCENTRATION
SUBSISTENCE FARMER DRINKING WATER SCENARIO - HUDSON RIVER

Contaminant	Cwtot	Cwt	Cdw	Csb	fwc	fbs	kwt	kv	Kdsw	Kdbs
Inorganics										
Arsenic	4.1E-006	3.7E-006	3.7E-006	1.1E-004	9.0E-001	1.04E-001	NA	NA	2.9E+001	2.9E+001

CALCULATION OF CHEMICAL INTAKES
RESIDENTIAL SCENARIO: ADULT

Parameter		Contaminant	Itot	Isoil	Iag	Idw
Itot = Isoil + Iag + Idw		**Inorganics**				
		Arsenic	4.1E-007	4.9E-008	2.9E-007	7.4E-008
Where: Isoil = Sc * CRsoil * Fsoil/BW Iag = [((Pd+Pv+Pr)*CRag)+(Pr*CRpp)+(Prbg*CRbg)] * Fag Idw = (Cdw * CRdw * Fdw)/BW						
Where:						
CS* = Values Specific to Contaminant:						
Itot = Total Daily Intake of Contaminant (mg/kg-d):	CS*					
Isoil = Daily Intake of Contaminant from Soil (mg/kg-d):	CS*					
Sc = Soil Concentration (untilled) (mg/kg):	CS*					
CRsoil = Adult Soil Consumption Rate (kg/d):	0.0001					
Fsoil = Fraction of Consumed Soil that is Contaminated:	1					
Iag = Daily Intake of Contaminant from Produce (mg/kg-d):	CS*					
Pd=Above Ground Exposed Produce Concentration Due to Direct Deposition (mg/kg):	CS*					
Pv=Above Ground Exposed Produce Concentration Due to Air-to-Plant Transfer (mg/kg):	CS*					
Pr=Exposed and Protected Aboveground Produce Concentration Due to Root Uptake (mg/kg) :	CS*					
PRbg=Below Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*					
CRag = Adult Consumption Rate of Above Ground Produce (kg/kg-d DW):	0.0003					
CRpp=Adult Consumption Rate of Protected Aboveground Produce (kg/kg-d DW):	0.00057					
CRbg=Adult Consumption Rate of Below Ground Produce (kg/kg-d DW):	0.00014					
Fag = Fraction of Produce that is Contaminated:	0.25					
Idw = Daily Intake of Contaminant from Drinking Water (mg/kg-day):	CS*					
Cdw = Dissolved phase water concentration (mg/L):	CS*					
CRdw = Adult Consumption Rate of Drinking Water (L/day):	1.4					
Fdw = Fraction of Drinking Water that is Contaminated (--):	1					
BW = Body weight (adult) (kg):	70					

CALCULATION OF CHEMICAL INTAKES
RESIDENTIAL SCENARIO: CHILD

Parameter		Contaminant	Itot	Isoil	Iag	Idw
Itot = Isoil + Iag + dw		**Inorganics**				
Where: Isoil = Sc * CRsoil * Fsoil/BW Iag = [((Pd+Pv+Pr)*CRag)+(Pr*CRpp)+(Prbg*CRbg)] * Fag Idw = (Cdw * CRdw * Fdw)/BW		Arsenic	1.0E-006	4.6E-007	4.0E-007	1.7E-007
Where:						
CS* = Values Specific to Contaminant:						
Itot = Total Daily Intake of Contaminant (mg/kg-d):	CS*					
Isoil = Daily Intake of Contaminant from Soil (mg/kg-d):	CS*					
Sc = Soil Concentration (untilled) (mg/kg):	CS*					
CRsoil = Child Soil Consumption Rate (kg/d):	0.0002					
Fsoil = Fraction of Consumed Soil that is Contaminated:	1					
Iag = Daily Intake of Contaminant from Produce (mg/kg-d):	CS*					
Pd=Above Ground Exposed Produce Concentration Due to Direct Deposition (mg/kg):	CS*					
Pv=Above Ground Exposed Produce Concentration Due to Air-to-Plant Transfer (mg/kg):	CS*					
Pr=Above Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*					
PRbg=Below Ground Produce Concentration Due to Root Uptake (mg/kg):	CS*					
CRag = Child Consumption Rate of Above Ground Produce (kg/kg-d DW):	0.00042					
CRpp=Child Consumption Rate of Protected Aboveground Produce (kg/kg-d DW):	0.00077					
CRbg=Child Consumption Rate of Below Ground Produce (kg/kg-d DW):	0.00022					
Fag = Fraction of Produce that is Contaminated:	0.25					
Idw = Daily Intake of Contaminant from Drinking Water (mg/kg-day):	CS*					
Cdw = Dissolved phase water concentration (mg/L):	CS*					
CRdw = Child Consumption Rate of Drinking Water (L/day):	0.67					
Fdw = Fraction of Drinking Water that is Contaminated (--):	1					
BW = Body weight (child) (kg):	15					

RESIDENTIAL SCENARIO
SUMMARY OF CANCER RISKS AND HAZARD INDICES (a)

Parameter	Contaminant	RfDo	SFo	HQo Adult	CRo Adult	HQo Child	CRo Child	Noncarcinogenic Target Organ/Critical Effects
CRo = Itot * ED * EF * SFo/AT * UC HQo = Itot * ED * EF/ RfDo * AT * UC	**Inorganics**							
	Arsenic	3.0E-004	1.5E+000	1.3E-003	3E-007	3.3E-003	1E-007	Hyperpigmentation, keratosis, possible vascular effects
Where: CS* = Values Specific to Contaminant: CRo = Cancer Risk oral (--): CS* HQo = Ingestion Hazard Index (--): CS* Itot = Total Daily Intake of Contaminant (mg/d): CS* SFo = Ingestion Slope Factor ((mg/kg-d)-1): CS* RfDo = Ingestion Reference Dose (mg/kg-d): CS* ED = Exposure Duration (see below) (yr): adult: 30 child: 6 EF = Exposure Frequency (day/yr): 350 AT = Averaging Time (yr): See Below Cancer: 70 Noncancer: See Below adult: 30 child: 6 UC = Units Conversion (day/yr): 365								

(a) Exposures routes include soil ingestion, produce consumption and drinking water consumption

	Adult	Child
Total Cancer Risk:	3E-007	1E-007
Critical Effect HIs:	1.3E-003	3.3E-003

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

CHRONIC INHALATION OF AMBIENT CONSTITUENTS
RESIDENTIAL SCENARIO

Parameter	Contaminant	Ca	RfDi	SFi	HQi Adult	CRi Adult	HQi Child	CRi Child	Noncarcinogenic Critical Effects
CRi = Ca * IR * ED * EF * ET * SFi * UC1/ BW * AT * UC2	**Inorganics**								
HQi = Ca * IR * ED * EF * ET * UC1/ RfDi * AT * BW * UC2									
And:	Arsenic	3.80E-005	NA	1.5E+001	NA	5E-008	NA	2E-008	
Where:									
CS* = Values specific to Contaminant:									
Values specific to Site: RS*									
CRi = Cancer Risk inhalation (--): CS*									
HQi = Inhalation Hazard Index (--): CS*									
Ca = Air Concentration (ug/m3): 3.796E-005									
SFi = Ingestion Slope Factor ((mg/kg-d)-1): CS*									
RfDi = Ingestion Reference Dose (mg/kg-d): CS*									
IR = Inhalation Rate (see below) (m3/hr):									
adult: 0.63									
child: 0.3									
ED = Exposure Duration (see below) (yr):									
adult: 30									
child: 6									
EF = Exposure Frequency (day/yr): 350									
ET = Exposure Time (hrs/day): 24									
UC1 = Units Conversion (mg/ug): 0.001									
BW = Body Weight (see below) (kg):									
adult: 70									
child: 15									
AT = Averaging Time (yr): See Below									
Cancer: 70									
Noncancer: See Below									
adult: 30									
child: 6									
UC2 = Units Conversion (day/yr): 365									

	Adult	Child
Total Cancer Risk:	5E-008	2E-008
Critical Effect HIs:	NA	NA

☐ = Cancer Risk > 1E-05 or HI >2.5E-01

APPENDIX C

BOWLINE RISK ASSESSMENT

RESIDENTIAL SCENARIO

SUBSISTENCE FISHER SCENARIO

SUBSISTENCE FARMER SCENARIO

Site Assessment of Electric and Magnetic Fields (EMF):

CASE 00-T-0409 - Application of Southern Energy Bowline, L.L.C. for a Certificate of Environmental Compatibility and Public Need for the Construction of a 345-kV Underground Electric Transmission Line, approximately 1.7 miles in length, located in the Town of Haverstraw, Rockland County, New York.

Prepared for

Southern Energy Bowline, L.L.C.
400 Rella Boulevard
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Submitted by

Exponent
420 Lexington Avenue, Suite 408
New York, NY 10170

April 2000

1.0 INTRODUCTION AND SUMMARY

This report evaluates power frequency electric and magnetic fields (EMF) associated with the operation of a 345-kV underground electric transmission line ("electric transmission line") from the Bowline Point Generating Station property owned by Southern Energy Bowline, L.L.C.("Southern Energy") in the Town of Haverstraw, New York, to the West Haverstraw substation, owned by Orange and Rockland Utilities, Inc., located in the Village of West Haverstraw, New York. The issues to be addressed are potential changes in EMF levels and EMF effects on co-located electric transmission lines and natural gas pipelines. This report assesses: 1) whether the electric transmission line will cause magnetic fields at the edges of existing or new rights-of-way to exceed limits established by the New York State Public Service Commission ("Commission"), and 2) whether the electrostatic and electromagnetic fields generated by the electric transmission line cable system will affect existing underground electric transmission cable systems and existing and new underground natural gas lines.

Based on measurements of existing EMF levels at the Bowline Point Generating Station Property and along the right-of-way of the existing electric transmission lines and gas pipeline and modeled calculations of EMF levels for the new electric transmission line, the Project and the new electric transmission line will comply with the Commission's Statement of Interim Policy on Magnetic Fields of Major Electric Transmission Facilities, issued September 11, 1990 and Commission Opinion No. 78-13, issued June 19, 1978. Specifically, the Project and the new electric transmission line: (1) will be designed, constructed and operated such that magnetic fields, at the edge of the right-of-way (measured one meter above ground level) will not exceed 200 milligauss where the circuit phase currents are equal to the winter-normal conductor rating; and (2) the electric field strength, at the edge of the right of way, measured one meter above ground level, with the line at rated voltage, will not exceed 1.6 kV/m.

2.0 ELECTRIC AND MAGNETIC FIELDS (EMF): DEFINITION, SOURCES AND OCCURRENCE

Electric and magnetic fields that are associated with the transport and use of electricity are often termed EMF. These fields oscillate at the power frequency of 60 cycles per second, or 60 hertz (Hz). Transmission and distribution lines are sources of these fields. Other sources of these fields are household appliances, power tools, office machines, building wiring and any other types of electrical equipment. A less common source is current flowing on water pipes or grounding systems. Electromagnetic fields at radio frequencies from radio, television, microwave, and cellular telephone antennas, are generally referred to as RF. This radio frequency energy is sometimes also called EMF but, being different from power frequency, it is not produced by the electric transmission line and is not addresses in this report.

Power frequency electric fields are the result of voltages applied to electrical conductors and equipment; the electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter kV/m (a kilovolt per meter is equal to 1000 V/m). Electric fields are easily shielded by most objects including fences, shrubbery, and buildings. This prevents outside sources, such as power lines, from contributing significantly to electric field exposures indoors where people spend most of their time. In the existing transmission cable systems and in the new electric transmission line, the pipe enclosure and the ground layer between the line and the surface will block electric fields.

Magnetic fields are produced by the flow of electric currents but, unlike electric fields, are not readily shielded by most materials. This has focused interest on magnetic fields from power lines as potential contributors to exposures indoors. The strength of 60-Hz magnetic fields is commonly expressed as magnetic flux density in units called milligauss (mG). The strength of the magnetic field at any point depends on characteristics of the source, including the arrangement of conductors, the amount of current flow through the source, and the distance from the source. The intensity of both electric and magnetic fields diminishes with increasing distance from the source.

The location of all existing utility lines along the right-of-way, as well as the new electric transmission line and the new 24" gas pipeline, is shown on Drawings G499-102-022 through 024 attached to Southern Energy's Article VII Application ("Application"), filed in Case 00-T-0409, as Exhibit 12.

3.0 DESCRIPTION OF THE PROJECT

Southern Energy proposes to construct approximately 1.7 miles of 345-kV underground (UG) electric transmission line to transmit power from the proposed nominal 750-megawatt (MW) Bowline Unit 3 generating station ("Project") to the West Haverstraw substation owned by Orange and Rockland Utilities, Inc. The UG transmission line will consist of two 8.625" outer diameter, high-pressure fluid -filled cable systems. Each 8.625-inch pipe will contain three phase conductors (insulated cables). The location of the electric transmission line and the gas pipeline will be in an existing Right of Way (ROW) that currently includes the following:

- two (2) 345-kV UG transmission cable systems
- one (1) 16" UG natural gas line
- two (2) 138-kV UG transmission cable systems (for sections of the route)

The final configuration of the ROW will consist of all UG transmission cable systems and UG natural gas lines in parallel for most, but not all, of the ROW as detailed below:

- four (4) 345-kV UG transmission cable systems (The new electric transmission line will consist of 2 cable systems). (See Figure 5a.)

- one (1) 24" UG natural gas line
- one (1) 16" UG natural gas line
- two (2) 138-kV UG transmission cable systems (for sections of the run)

All of these are configured in parallel for about one-third of the distance from the switchyard; this would constitute the maximum exposure scenario for calculating the expected magnetic field levels (see Section 5.2). Further along, near the CSX railroad bridge crossing over Minisceongo Creek, the 138-kV cable systems veer off to the Minisceongo Switch. The gas lines veer off near Bridge Street, closer to the West Haverstraw substation. Thus, the last portion of the ROW includes only the 345-kV UG cable systems.

The ROW runs through a variety of terrain including wooded, industrial and residential areas. No schools or hospitals were identified in the area. Figure 1 shows the path of the new 345-kV underground (UG) line, from the Switchyard at the Bowline Point Generation Station Property to the West Haverstraw substation.

4.0 SOURCES OF EMF ON THE SITE

The property owned by Southern Energy and the components of the Bowline Project to be constructed includes several existing sources of electric and magnetic fields. These include the existing generating plant, the Orange and Rockland West Haverstraw substation and the existing 138-kV and 345-kV UG cable systems. Along the ROW, overhead 138-kV lines connect to the UG risers. Near the ROW, along the streets of Haverstraw, sources of EMF include overhead distribution lines.

5.0 ASSESSMENT OF EMF LEVELS AT THE SITE

The magnetic fields produced by the existing UG cable systems along the route of the new electric transmission line were characterized by measurements at a specific time. The effect of the additional 345-kV transmission line on field levels in conjunction with the maximum field levels produced by existing transmission cable systems was examined by modeling.

5.1 Field Measurements

5.1.1 Methods

Power frequency magnetic fields produced by known and other sources were measured during a site visit on April 7, 2000. The magnetic field was measured in units of milligauss (mG) in x, y and z-axes by orthogonally mounted sensing coils whose output was logged by a digital recording meter (Dexsil Corp.). This instrument meets the Institute of Electrical and Electronics Engineers (IEEE) instrumentation standard for obtaining valid and accurate field measurements at power line frequencies (IEEE Std. 1308-1994). The meter was calibrated by the manufacturers by methods described in IEEE Std. 644-1994.

A number of measurements were taken at a height of one meter (~40 inches) above ground in accordance with the industry standard protocol for taking measurements near power lines (IEEE Std. 644-1994). Magnetic fields were expressed as the total field computed as the resultant of field vectors measured in the x, y, and z-axes. Magnetic field measurements were taken at three foot intervals along a transect perpendicular to the cables and three foot intervals along the ROW. In addition, magnetic fields were measured along the streets in the Town of Haverstraw from the substation near Route 202 to the Bowline Point Generating Station Property.

5.1.2 Magnetic Field Profile Across the Right-of-Way

A magnetic field profile was measured going from north to south over, i.e., perpendicular to, over the existing 345-kV and 138-kV UG transmission cable systems (Figure 2). The load on the existing 345-kV line during the measurements was approximately 122 MVA. The path of the profile is approximately from point A to point B on Figure 1. The peak magnetic field along the profile was 1.24 mG, and occurs over the existing 345-kV transmission cable systems.

5.1.3 Magnetic Field Area Perimeter Measurements (Along the Right-of-Way)

The magnetic field levels along the ROW were measured from the fence at the edge of the Bowline Point Generating Station switchyard to the Orange and Rockland substation in West Haverstraw at Route 202. The longitudinal profile followed the path of the UG 138-kVand 345-kV cable systems by following the highest measured magnetic field in the ROW. As can be seen in Figure 3, the maximum magnetic field is 14 mG, under the overhead 138-kV risers near the Minisceongo Switch. Under the distribution line the magnetic field measured 11 mG. Other peaks, each less than 10 mG, are probably attributable to water or sewer lines and to the edge of the substation. The median field along this profile was 1.1 mG. Over 95% of the measurements were below 5 mG, and 75% were below 1.5 mG.

5.1.4 Magnetic Field Measurements Along Streets in the Town of Haverstraw

The path of the profile in Haverstraw included sidewalks and streets from the substation near Route 202 to the Bowline Point Generating Station Property. The route followed Route 202 to Bridge Street, then to Railroad

Street to the edge of the pond in Bowline Park, and then to the edge of the switchyard. As Figure 4 shows, the maximum field was 22.6 mG, measured at the location of the overhead lines and the edge of the substation. The median field value was 1.2 mG. In a few spots, magnetic field levels were 5 or 10 mG, but 95% of the profile was below 4.5 mG.

5.2 Calculated Magnetic Fields

5.2.1 Calculation Methods

Each of the new 345-kV circuits will consist of three insulated copper power cables contained in an 8.625-inch steel pipe. Magnetic fields are produced by the current flowing in the cables. Outside the pipe, the field is reduced due to the properties of steel. In fact, magnetic fields at 3.28 feet (1 meter) above pipe-type cable systems are reduced considerably from fields under overhead lines carrying comparable currents. [ESEERCO, 1989] The reduction is due to the much closer spacing of the conductors in cable systems and the field attenuation introduced by the steel pipe.

Magnetic fields from the new and existing cable systems along the corridor were modeled by calculating the fields from the cables without the steel pipe present and then applying an attenuation factor to account for the steel pipe. The modeling program, developed by the Bonneville Power Administration, an agency of the U.S. Department of Energy, is a standard program used by the electric utility industry to estimate EMF levels (BPA, undated). Based upon data regarding voltage, current flow, and physical dimensions of the existing and new transmission circuits, magnetic field levels were calculated along a profile perpendicular to and above the existing cables.

The currents for the existing cables were based on the cable design capabilities and winter-normal conductor ratings provided by Southern Energy, Inc.: 777 MVA for existing 345-kV cables and 304 MVA for existing 138-kV cables. The new cables were assumed to be dedicated to the Project with each cable carrying one-half the maximum output of the Project, or 415 MVA. Maximum currents were assumed to occur simultaneously on all cables. Balanced currents were assumed for all cables. Physical dimensions for the existing and new cable systems were derived from manufacturer's specifications provided by Southern Energy.

There are two important uncertainties in constructing a magnetic field model of the corridor. First, because the cables are buried, their exact location cannot be ascertained. The lateral locations of the cables relative to each other and to the edge of the right-of-way were determined from detailed plot plans of the corridor provided by Southern Energy. The cables were assumed to be parallel. Two locations were selected for modeling: a) where the new cables are closest to the existing 345-kV and 138-kV cables, as shown in Figure 5a, and b) where the new line is closest to the edge of the existing right-of-way, as shown in Figure 5b. The depth of the existing cables was assumed to be 3 feet: the minimum depth specified. The depth of the new cables was assumed to be 5 feet.

Second, the field attenuation factors for steel pipes depend on the thickness and diameter of the pipe and on whether the pipe is grounded at one point or at multiple points [Xu, 1997]. Information on the attenuation of specific pipes is not available. When a pipe is grounded at two or more points, currents are induced in the pipe. These currents produce higher fields in the vicinity of the cable than occur in the case of single-point grounding. For purposes of modeling, double-point grounding was assumed for the steel pipes containing the power cables. The estimated attenuation for double-point grounding was taken as 0.17 based on measurements on pipes similar to ones used in the existing and new systems [Xu, 1997]. If single point grounding is present the attenuation factor would be about 0.005 and much lower fields would be present above the cables than with double-point grounding.

The assumptions of minimum depth for the existing cables, simultaneous maximum currents, and double-point grounding on all cables represent a compounding of worst-case (highest field) conditions that are very unlikely to occur.

5.2.2 Magnetic Field Profiles

The calculated fields at a height of 3.28 feet at specific locations on the corridor with the existing and new cable systems are given in Table 1. Lateral profiles for the magnetic field at a height of 3.28 feet at the two corridor locations are given in Figure 6a and 6b.

Table 1: Magnetic field levels on Bowline corridor in milligauss for double-point grounding.

Right-of-way configuration	a) Closest to existing cables		b) Closest to ROW edge	
	New	Existing	New	Existing
Maximum above new cable, mG	13	-	16	-
Maximum above existing cables, mG	22	18	21	18
Edge of ROW, mG	5	4	5	4

Table 1 Shows that the magnetic filed at the edge of the ROW, with the new electric transmission line and all existing utility lines, will be far below the 200 mG standard established by the Commission. Moreover, based on the shielding of the electric fields, and the design of the UG line and its enclosure in a pipe type cable, no impact is expected from the new 345-kV UG transmission cable systems on field levels outside the site.

6.0 INDUCED CURRENT AND VOLTAGE

One consequence of co-locating power and gas pipelines is induced voltages and currents on the pipelines, which must be kept to permissible values where the pipelines leave the ROW. The steel pipe of the electric transmission line will be grounded in accordance with all applicable regulations. With an adequate ground, the steel pipe will be at zero potential and electric field coupling will not occur.

Induced voltages can be produced by magnetic-field coupling. Magnetic fields from the transmission cables can arise from current unbalance and/or phase shifting. The final design of the electric transmission line will address the mitigation of inductive coupling in accordance with applicable regulations.

7.0 GROUNDING AND CORROSION CONTROL

Adequate system grounding is required for mitigation of corrosion of the metallic pipes as well as mitigation of electromagnetic field effects, power quality, and fault current protection, and other safety issues. The new electric transmission line will be grounded in accordance with applicable standards and regulations.

Metallic structures and components buried underground are subject to corrosion. An accepted practice for mitigating corrosion is the use of cathodic protection. The cathodic protection design is based on material specifications, system voltage, full load current, fault current, and configuration of power lines, among other data. The existing cable systems have a cathodic protection system. The final design of the new electric transmission line will account for and address all of the underground power cable transmission lines and underground natural gas lines along the route, as well as any other system interactions. (See Section E-3.5 of the Application) The final design of the corrosion control cathodic protection system will be in accordance with applicable regulations.

The pipeline burial depth of all newly constructed underground cable systems will be in accordance with The Lineman's and Cableman's Handbook, which states that the recommended burial depths of cables at 40 kV and above should be 42 inches minimum. Greater depths are recommended at areas subjected to higher force (under roadways) and erosion.

8.0 ASSESSING THE IMPACT OF THE PROJECT

The power generated by Bowline Unit 3 will be transmitted from the Bowline Point Generation Station switchyard in UG 345-kV transmission cable systems encased in steel pipes to the Orange and Rockland West Haverstraw substation. The pipe enclosure and the earth layer between the line and the surface essentially block electric fields in the existing transmission cable systems and the new electric transmission line.

The 60-Hz magnetic fields from the Project and electric transmission line to the West Haverstraw substation were assessed by measurements and by modeling. Measurements of the magnetic fields in this vicinity at a point in time characterized the fields from the existing lines both across the cable systems and along the ROW. Measurements also show the levels of existing magnetic fields in the Town of Haverstraw. Calculations were performed to predict the levels expected to occur after the completion of the Project and the new electric transmission line. The assumptions of minimum depth for the existing cables, simultaneous maximum currents, and double-point grounding on all cables represent a compounding of worst-case (highest field) conditions that are very unlikely to occur. Under these worst case conditions, the calculations show that the levels of measured magnetic fields produced by existing sources will be changed only minimally by the Project and new electric transmission line, pursuant to the calculations. Therefore, the Project and electric transmission line will not have any significant effect on EMF levels along the existing rights-of-way.

The operation of the Project and the electric transmission line will not increase existing EMF levels above the limits set by the Commission for new transmission line rights-of-way. Magnetic field levels along the electric transmission line corridor after construction of the new transmission line, at a winter normal conductor loading, at the edge of the ROW, are well below the limit of 200 mG. In addition, electric field levels are expected to be well below the electric field strength stand of 1.6 kV/m as established by the Commission. Accordingly, the Project and the new electric transmission line comply with: (a) the Commission's applicable electric field strength standards, as set forth in Opinion 78-13, and (b) the applicable provisions of the Commission's Interim Statement on Magnetic Fields, dated September 11, 1990.

Moreover, the magnetic field levels associated with the Project and the new and existing transmission cable systems are well below guidance levels to protect against acute effects of induced current and voltages (Bailey et al, 1997).

9.0 REFERENCES

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IEEE. IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters - 10 Hz to 3 kHz. ANSI/IEEE Std 1308-1994, The Institute of Electrical and Electronics Engineers, New York, NY, 1994

New York Public Service Commission (NYPSC). Cases 26529 and 26559 et al., Order Continuing Interim Transmission Line Electric Field Standard, Directing that an Interim Transmission Line Magnetic Field Standard be Developed and Directing Utilities to Undertake Studies, (Issued and Effective, April 12, 1988. (and Opinion 78-13).

New York Public Service Commission (NYPSC). Statement of Interim Policy on Magnetic Fields of Major Electric Transmission Facilities. September 11, 1990.

Xu, XB. Computing the Magnetic Fields of High Pressure Fluid-Filled Cables. Electric Power Research Institute, Palo Alto, CA. EPRI Report TR-108269, 1997

Figure 2

Magnetic Field Measurements Across ROW
Haverstraw and West Haverstraw, New York

1245-1250 April 7, 2000

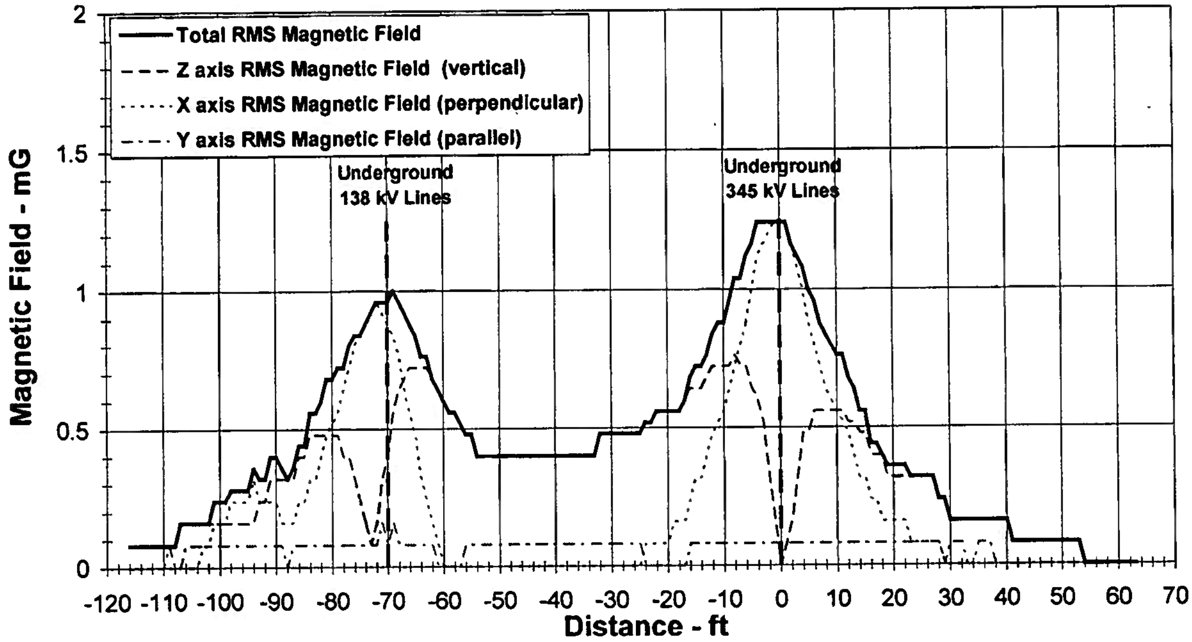


Figure 3

Magnetic Field Measurements Along ROW
Haverstraw and West Haverstraw, NY

1450-1650 April 7, 2000

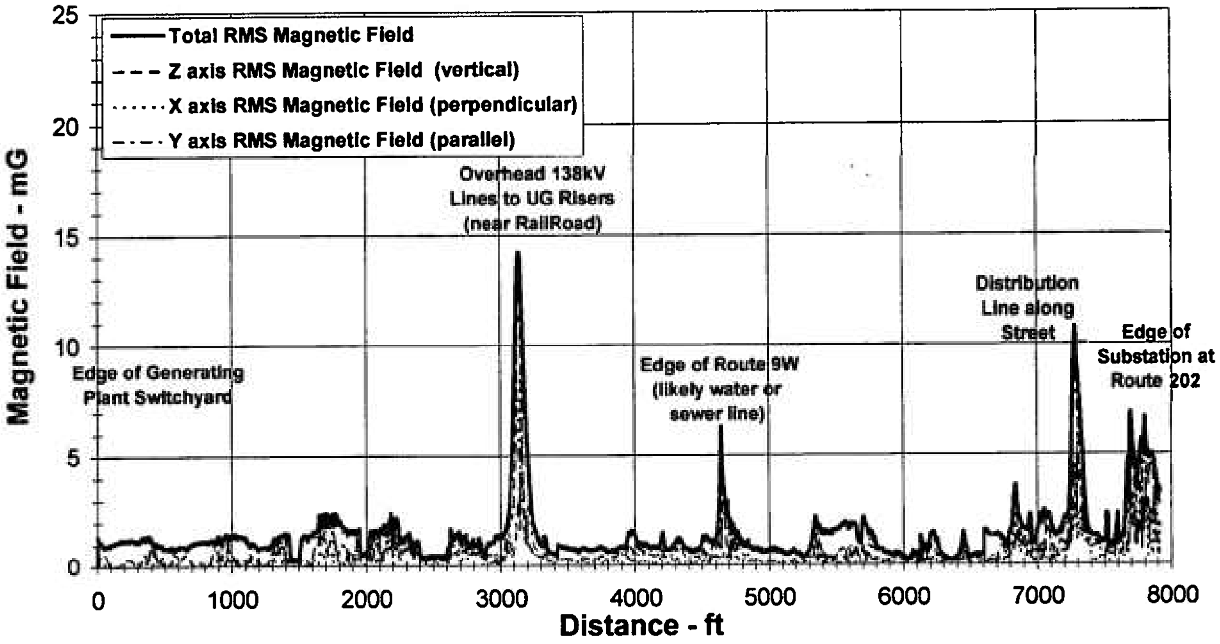
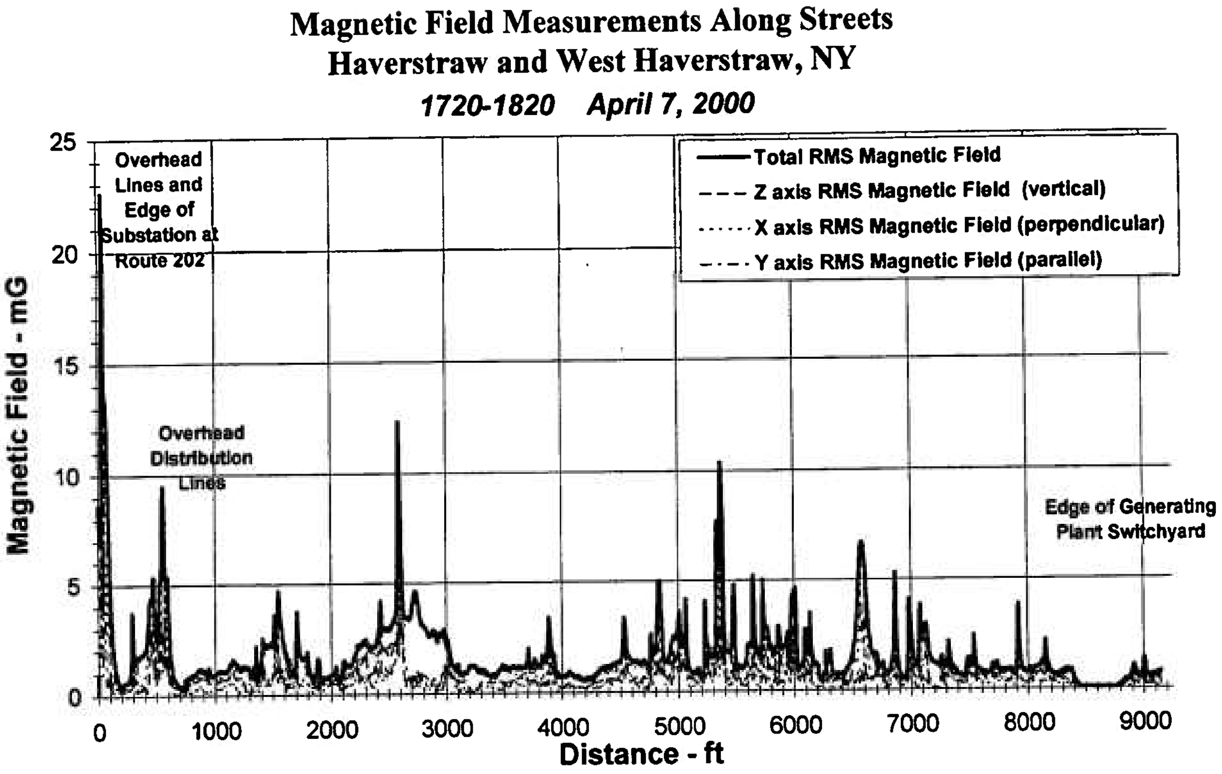
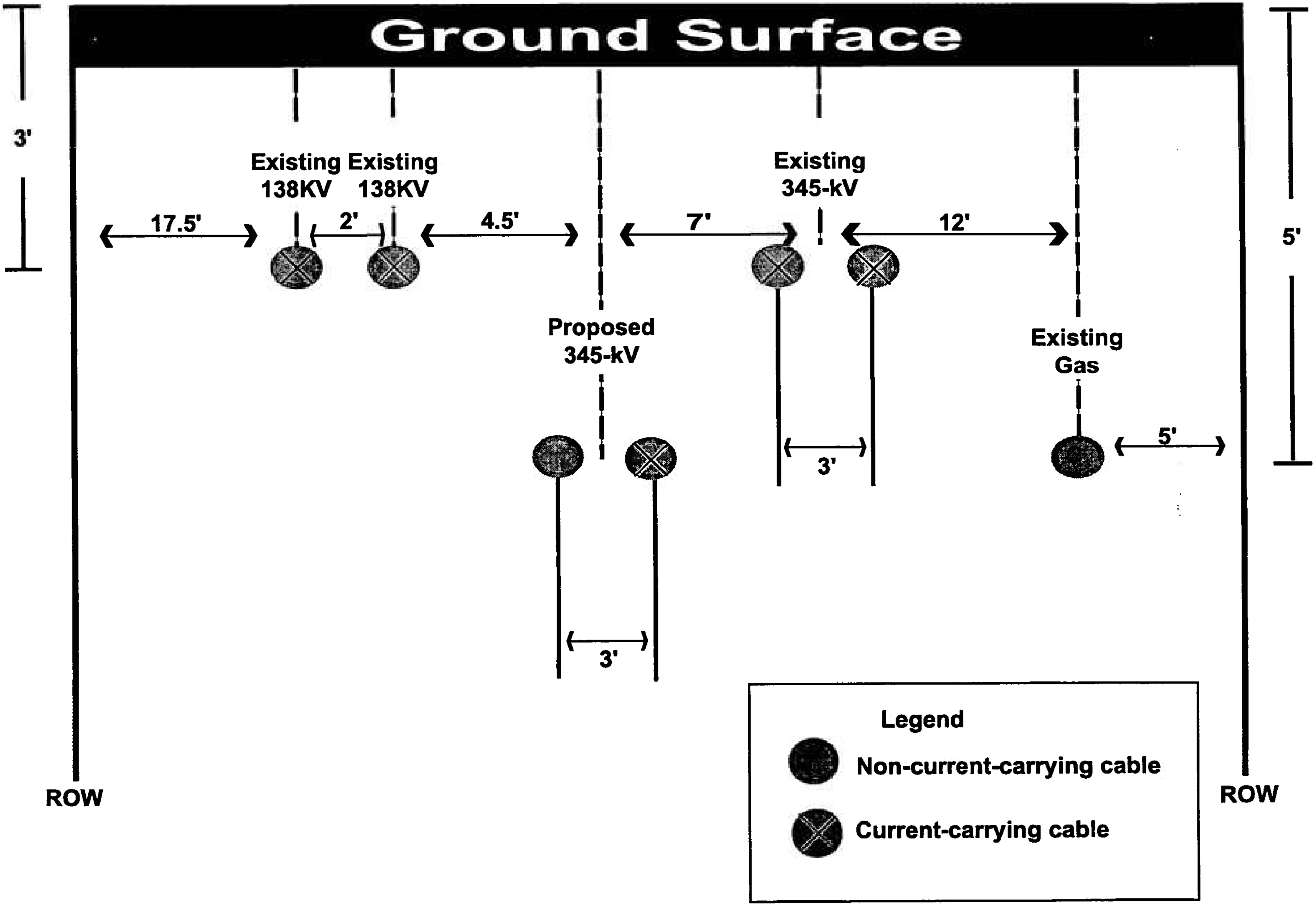


Figure 4


Magnetic Field Measurements Along Streets
Haverstraw and West Haverstraw, NY
1720-1820 April 7, 2000
Total RMS Magnetic Field
Z axis RMS Magnetic Field (vertical)
X axis RMS Magnetic Field (perpendicular)
Y axis RMS Magnetic Field (parallel)
Overhead Lines and Edge of Substation at Route 202
Overhead Distribution Lines
Edge of Generating Plant Switchyard
Magnetic Field - mG
0
5
10
15
20
25
Distance - ft
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

5a. Location where proposed 345-kV line is closest to existing 345-kV, 138-kV, and gas lines (not to scale)



5b. Location where proposed 345-KV line is closest to edge of Right of Way (ROW) (not to scale)

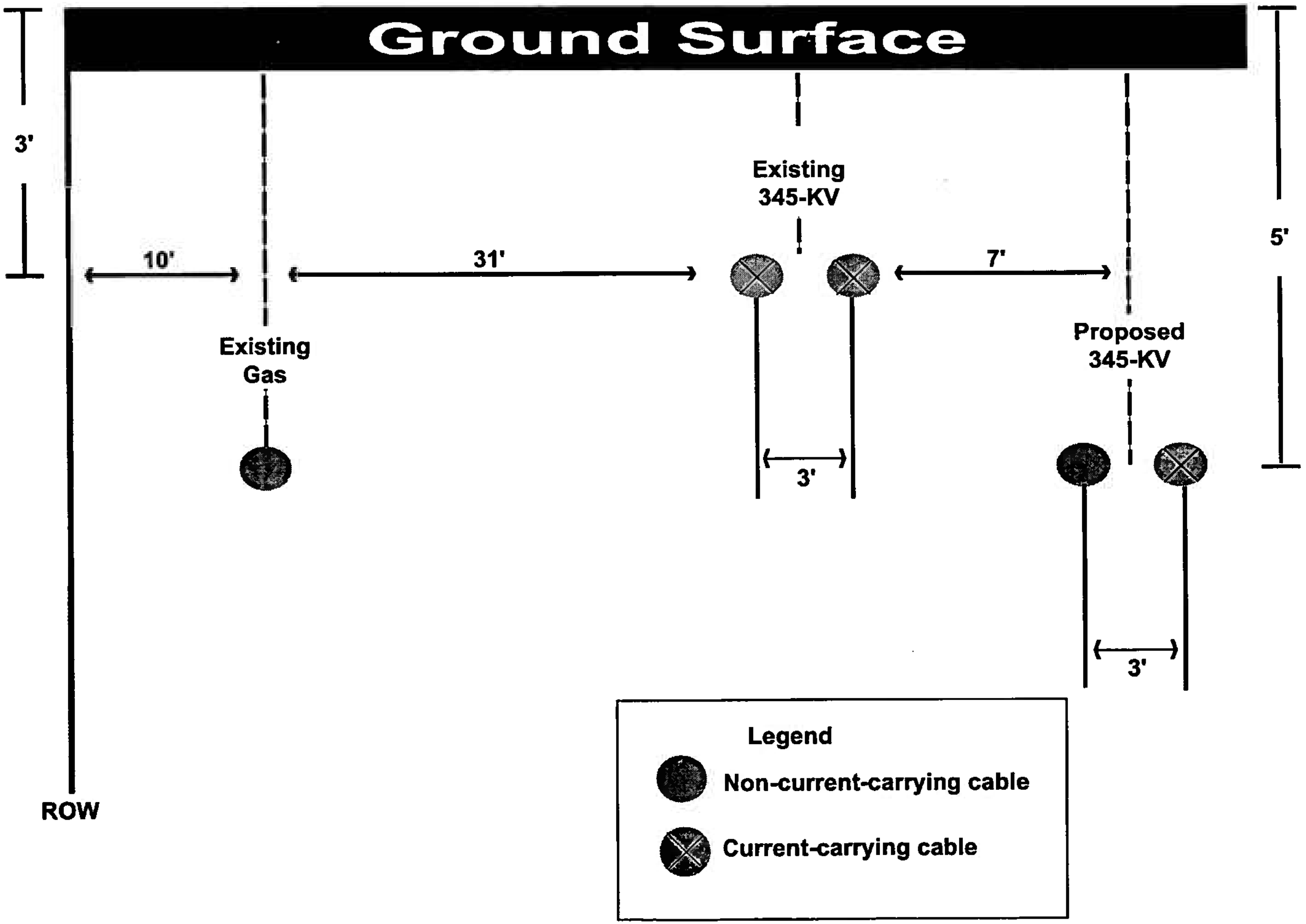


Figure 6a

Calculated Magnetic Field Lateral Profiles for Proposed and Existing Lines

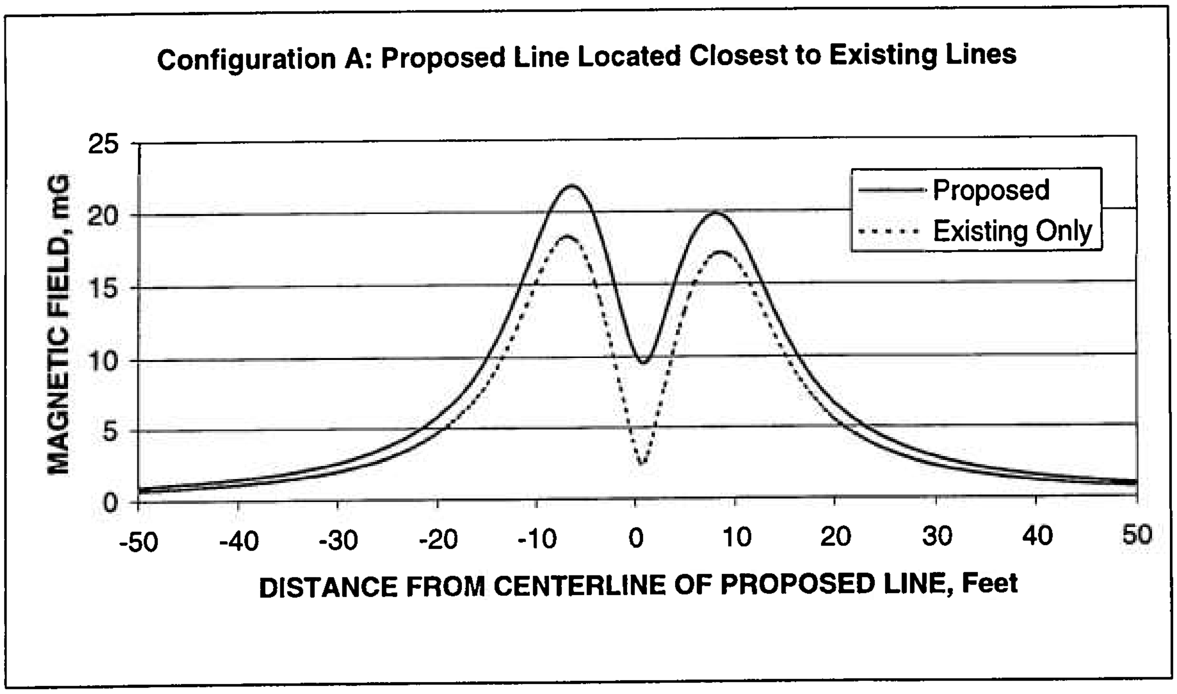
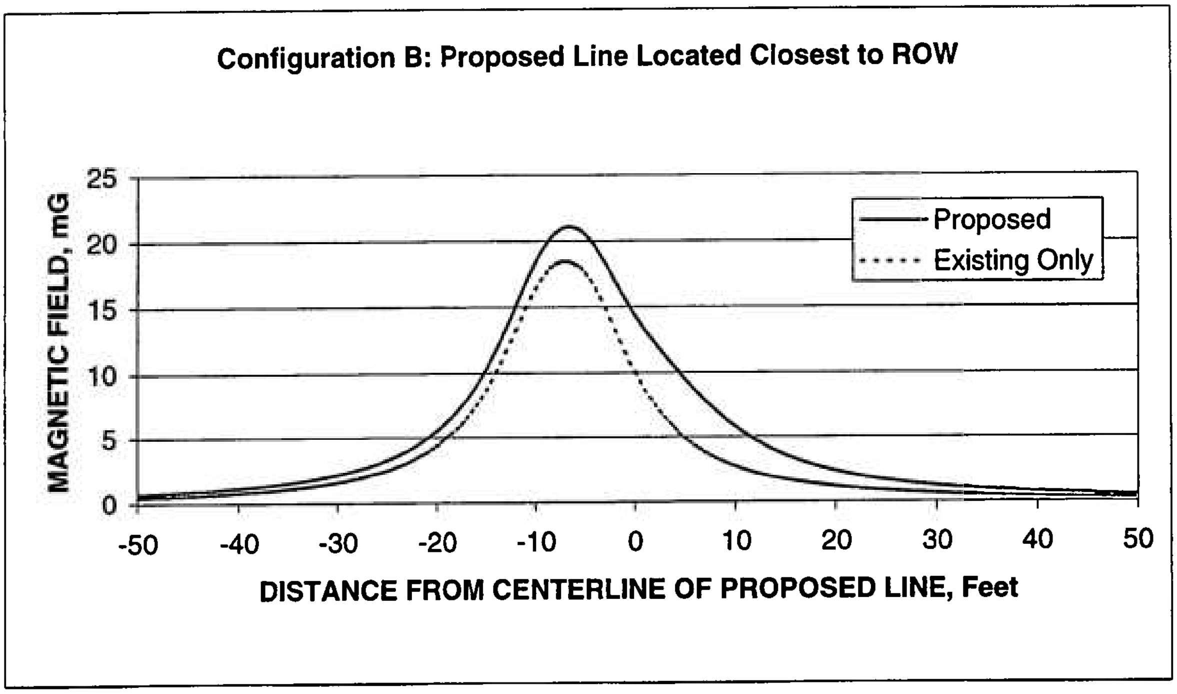


Figure 6b
Calculated Magnetic Field Lateral Profiles for Proposed and Existing Lines


Configuration B: Proposed Line Located Closest to ROW

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION

Configuration (a) Input Data

Transmission Line	Conductor Number and Type	Subconductor Diameter (in)	Number of subconductors	Position (ft)		Phase Angle (degrees)	Conductor Rating Current (amperes)*
				x	y		
138 kV (existing)	PH-A1	1.82	1	-6.7	2.2	0	0.212
	PH-B1	1.82	1	-6.5	2.5	120	0.212
	PH-C1	1.82	1	-6.3	2.2	240	0.212
	PH-A2	1.82	1	-4.7	2.2	0	0.212
	PH-B2	1.82	1	-4.5	2.5	120	0.212
	PH-C2	1.82	1	-4.3	2.2	240	0.212
345 kV (new)	PH-A3	1.74	1	-1.5	0.2	0	0.116
	PH-B3	1.74	1	-1.3	0.1	120	0.116
	PH-C3	1.74	1	-1.0	0.2	240	0.116
	PH-A4	1.74	1	1.0	0.2	0	0.116
	PH-B4	1.74	1	1.3	0.1	120	0.116
	PH-C4	1.74	1	1.5	0.2	240	0.116
345 kV (existing)	PH-A5	1.82	1	5.3	2.2	0	0.217
	PH-B5	1.82	1	5.5	2.5	120	0.217
	PH-C5	1.82	1	5.7	2.2	240	0.217
	PH-A6	1.82	1	8.3	2.2	0	0.217
	PH-B6	1.82	1	8.5	2.5	120	0.217
	PH-C6	1.82	1	8.7	2.2	240	0.217

* Load current divided by 6 for attenuation of steel pipe

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION
Configuration(b) Input Data

Transmission Line	Conductor Number and Type	Subconductor Diameter (in)	Number of subconductors	Position (ft)		Phase Angle (degrees)	Conductor Rating Current (amperes)*
				x	y		
345 kV (existing)	PH-A1	1.82	1	-8.7	2.2	0	0.217
	PH-B1	1.82	1	-8.5	2.5	120	0.217
	PH-C1	1.82	1	-8.3	2.2	240	0.217
	PH-A2	1.82	1	-5.7	2.2	0	0.217
	PH-B2	1.82	1	-5.5	2.5	120	0.217
	PH-C2	1.82	1	-5.3	2.2	240	0.217
345 kV (new)	PH-A3	1.74	1	-1.3	0.2	0	0.116
	PH-B3	1.74	1	-1.0	0.1	120	0.116
	PH-C3	1.74	1	-1.0	0.2	240	0.116
	PH-A4	1.74	1	1.0	0.2	0	0.116
	PH-B4	1.74	1	1.3	0.1	120	0.116
	PH-C4	1.74	1	1.5	0.2	240	0.116

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* Load current divided by 6 for attenuation of steel pipe

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR EXISTING CONFIGURATION
Configuration a: Output data

Field point location (ft)	Magnetic field (Milligauss)
-50.0	0.705
-49.5	0.719
-49.0	0.734
-48.5	0.750
-48.0	0.765
-47.5	0.782
-47.0	0.799
-46.5	0.816
-46.0	0.834
-45.5	0.853
-45.0	0.873
-44.5	0.893
-44.0	0.913
-43.5	0.935
-43.0	0.957
-42.5	0.980
-42.0	1.004
-41.5	1.029
-41.0	1.054
-40.5	1.081
-40.0	1.109
-39.5	1.138
-39.0	1.168
-38.5	1.199
-38.0	1.231
-37.5	1.265
-37.0	1.300
-36.5	1.337
-36.0	1.376
-35.5	1.416
-35.0	1.457
-34.5	1.501
-34.0	1.547
-33.5	1.594
-33.0	1.644
-32.5	1.697
-32.0	1.752
-31.5	1.810
-31.0	1.870
-30.5	1.934
-30.0	2.001
-29.5	2.072
-29.0	2.146
-28.5	2.225
-28.0	2.308
-27.5	2.395
-27.0	2.488
-26.5	2.586
-26.0	2.690
-25.5	2.801
-25.0	2.918
-24.5	3.043
-24.0	3.176
-23.5	3.317
-23.0	3.468
-22.5	3.629
-22.0	3.802
-21.5	3.987
-21.0	4.185
-20.5	4.397
-20.0	4.626
-19.5	4.872
-19.0	5.137
-18.5	5.422
-18.0	5.731
-17.5	6.064
-17.0	6.423
-16.5	6.812

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR EXISTING CONFIGURATION
Configuration a: Output data

Field point location (ft)	Magnetic field (Milligauss)
-16.0	7.233
-15.5	7.688
-15.0	8.180
-14.5	8.710
-14.0	9.282
-13.5	9.895
-13.0	10.551
-12.5	11.249
-12.0	11.985
-11.5	12.754
-11.0	13.547
-10.5	14.351
-10.0	15.149
-9.5	15.918
-9.0	16.631
-8.5	17.258
-8.0	17.765
-7.5	18.122
-7.0	18.300
-6.5	18.277
-6.0	18.040
-5.5	17.582
-5.0	16.906
-4.5	16.025
-4.0	14.955
-3.5	13.722
-3.0	12.356
-2.5	10.890
-2.0	9.356
-1.5	7.790
-1.0	6.225
-0.5	4.713
0.0	3.359
0.5	2.484
1.0	2.667
1.5	3.724
2.0	5.092
2.5	6.545
3.0	8.003
3.5	9.423
4.0	10.774
4.5	12.028
5.0	13.165
5.5	14.169
6.0	15.031
6.5	15.749
7.0	16.321
7.5	16.747
8.0	17.025
8.5	17.151
9.0	17.123
9.5	16.942
10.0	16.619
10.5	16.168
11.0	15.611
11.5	14.974
12.0	14.282
12.5	13.559
13.0	12.826
13.5	12.098
14.0	11.389
14.5	10.708
15.0	10.060
15.5	9.448
16.0	8.875
16.5	8.339
17.0	7.841
17.5	7.378

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR EXISTING CONFIGURATION
Configuration a: Output data

Field point location (ft)	Magnetic field (Milligauss)
18.0	6.949
18.5	6.551
19.0	6.183
19.5	5.842
20.0	5.526
20.5	5.233
21.0	4.962
21.5	4.709
22.0	4.475
22.5	4.257
23.0	4.054
23.5	3.865
24.0	3.688
24.5	3.523
25.0	3.368
25.5	3.223
26.0	3.087
26.5	2.960
27.0	2.840
27.5	2.727
28.0	2.621
28.5	2.521
29.0	2.426
29.5	2.337
30.0	2.252
30.5	2.172
31.0	2.096
31.5	2.024
32.0	1.956
32.5	1.891
33.0	1.829
33.5	1.771
34.0	1.715
34.5	1.661
35.0	1.610
35.5	1.562
36.0	1.516
36.5	1.471
37.0	1.429
37.5	1.388
38.0	1.349
38.5	1.312
39.0	1.276
39.5	1.242
40.0	1.209
40.5	1.178
41.0	1.147
41.5	1.118
42.0	1.090
42.5	1.063
43.0	1.037
43.5	1.012
44.0	0.987
44.5	0.964
45.0	0.942
45.5	0.920
46.0	0.899
46.5	0.879
47.0	0.859
47.5	0.840
48.0	0.822
48.5	0.804
49.0	0.787
49.5	0.770
50.0	0.754

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION
Configuration a: Output data

Field point location (ft)	Magnetic field (Milligauss)
-50.0	0.924
-49.5	0.943
-49.0	0.963
-48.5	0.982
-48.0	1.003
-47.5	1.024
-47.0	1.046
-46.5	1.069
-46.0	1.092
-45.5	1.117
-45.0	1.142
-44.5	1.167
-44.0	1.194
-43.5	1.222
-43.0	1.250
-42.5	1.280
-42.0	1.311
-41.5	1.343
-41.0	1.376
-40.5	1.410
-40.0	1.446
-39.5	1.483
-39.0	1.521
-38.5	1.561
-38.0	1.602
-37.5	1.645
-37.0	1.690
-36.5	1.737
-36.0	1.786
-35.5	1.837
-35.0	1.890
-34.5	1.945
-34.0	2.003
-33.5	2.064
-33.0	2.127
-32.5	2.193
-32.0	2.263
-31.5	2.335
-31.0	2.412
-30.5	2.492
-30.0	2.576
-29.5	2.664
-29.0	2.757
-28.5	2.855
-28.0	2.958
-27.5	3.067
-27.0	3.182
-26.5	3.304
-26.0	3.432
-25.5	3.568
-25.0	3.712
-24.5	3.865
-24.0	4.028
-23.5	4.200
-23.0	4.384
-22.5	4.580
-22.0	4.789
-21.5	5.012
-21.0	5.250
-20.5	5.505
-20.0	5.778
-19.5	6.071
-19.0	6.385
-18.5	6.722
-18.0	7.085
-17.5	7.475
-17.0	7.895
-16.5	8.347
-16.0	8.834

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION
Configuration a: Output data

Field point location (ft)	Magnetic field (Milligauss)
-15.5	9.357
-15.0	9.920
-14.5	10.525
-14.0	11.173
-13.5	11.865
-13.0	12.601
-12.5	13.381
-12.0	14.201
-11.5	15.054
-11.0	15.934
-10.5	16.826
-10.0	17.716
-9.5	18.583
-9.0	19.403
-8.5	20.148
-8.0	20.789
-7.5	21.296
-7.0	21.640
-6.5	21.799
-6.0	21.754
-5.5	21.498
-5.0	21.029
-4.5	20.356
-4.0	19.496
-3.5	18.474
-3.0	17.323
-2.5	16.079
-2.0	14.786
-1.5	13.488
-1.0	12.241
-0.5	11.115
0.0	10.210
0.5	9.653
1.0	9.555
1.5	9.927
2.0	10.666
2.5	11.637
3.0	12.726
3.5	13.853
4.0	14.958
4.5	15.997
5.0	16.938
5.5	17.760
6.0	18.449
6.5	18.999
7.0	19.410
7.5	19.678
8.0	19.803
8.5	19.781
9.0	19.613
9.5	19.304
10.0	18.865
10.5	18.313
11.0	17.670
11.5	16.959
12.0	16.204
12.5	15.423
13.0	14.636
13.5	13.857
14.0	13.097
14.5	12.365
15.0	11.665
15.5	11.002
16.0	10.377
16.5	9.790
17.0	9.241
17.5	8.729
18.0	8.251
18.5	7.807

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION
Configuration a: Output data

Field point location (ft)	Magnetic field (Milligauss)
19.0	7.393
19.5	7.008
20.0	6.650
20.5	6.316
21.0	6.006
21.5	5.716
22.0	5.446
22.5	5.193
23.0	4.958
23.5	4.737
24.0	4.530
24.5	4.336
25.0	4.155
25.5	3.984
26.0	3.823
26.5	3.672
27.0	3.529
27.5	3.394
28.0	3.267
28.5	3.147
29.0	3.034
29.5	2.926
30.0	2.824
30.5	2.727
31.0	2.635
31.5	2.548
32.0	2.465
32.5	2.386
33.0	2.310
33.5	2.238
34.0	2.170
34.5	2.104
35.0	2.042
35.5	1.982
36.0	1.925
36.5	1.870
37.0	1.818
37.5	1.768
38.0	1.719
38.5	1.673
39.0	1.629
39.5	1.586
40.0	1.545
40.5	1.506
41.0	1.468
41.5	1.431
42.0	1.396
42.5	1.362
43.0	1.330
43.5	1.298
44.0	1.268
44.5	1.239
45.0	1.210
45.5	1.183
46.0	1.157
46.5	1.131
47.0	1.106
47.5	1.082
48.0	1.059
48.5	1.037
49.0	1.015
49.5	0.994
50.0	0.974

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR EXISTING CONFIGURATION
Configuration b: Output data

Field point location (ft)	Magnetic field (Milligauss)
-50.0	0.475
-49.5	0.486
-49.0	0.497
-48.5	0.509
-48.0	0.521
-47.5	0.534
-47.0	0.547
-46.5	0.561
-46.0	0.575
-45.5	0.590
-45.0	0.605
-44.5	0.621
-44.0	0.637
-43.5	0.655
-43.0	0.672
-42.5	0.691
-42.0	0.710
-41.5	0.731
-41.0	0.752
-40.5	0.774
-40.0	0.796
-39.5	0.820
-39.0	0.845
-38.5	0.872
-38.0	0.899
-37.5	0.928
-37.0	0.958
-36.5	0.989
-36.0	1.022
-35.5	1.057
-35.0	1.093
-34.5	1.132
-34.0	1.172
-33.5	1.215
-33.0	1.260
-32.5	1.307
-32.0	1.357
-31.5	1.410
-31.0	1.466
-30.5	1.525
-30.0	1.588
-29.5	1.655
-29.0	1.726
-28.5	1.801
-28.0	1.881
-27.5	1.967
-27.0	2.058
-26.5	2.156
-26.0	2.260
-25.5	2.372
-25.0	2.492
-24.5	2.621
-24.0	2.760
-23.5	2.909
-23.0	3.070
-22.5	3.244
-22.0	3.432
-21.5	3.636
-21.0	3.856
-20.5	4.096
-20.0	4.357
-19.5	4.640
-19.0	4.949
-18.5	5.285
-18.0	5.653
-17.5	6.053
-17.0	6.490
-16.5	6.965
-16.0	7.483

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR EXISTING CONFIGURATION
Configuration b: Output data

Field point location (ft)	Magnetic field (Milligauss)
-15.5	8.046
-15.0	8.655
-14.5	9.312
-14.0	10.015
-13.5	10.764
-13.0	11.551
-12.5	12.370
-12.0	13.206
-11.5	14.045
-11.0	14.866
-10.5	15.646
-10.0	16.361
-9.5	16.991
-9.0	17.517
-8.5	17.928
-8.0	18.221
-7.5	18.396
-7.0	18.453
-6.5	18.396
-6.0	18.221
-5.5	17.928
-5.0	17.517
-4.5	16.991
-4.0	16.361
-3.5	15.646
-3.0	14.866
-2.5	14.045
-2.0	13.206
-1.5	12.370
-1.0	11.551
-0.5	10.764
0.0	10.015
0.5	9.312
1.0	8.655
1.5	8.046
2.0	7.483
2.5	6.965
3.0	6.490
3.5	6.053
4.0	5.653
4.5	5.285
5.0	4.949
5.5	4.640
6.0	4.357
6.5	4.096
7.0	3.856
7.5	3.636
8.0	3.432
8.5	3.244
9.0	3.070
9.5	2.909
10.0	2.760
10.5	2.621
11.0	2.492
11.5	2.372
12.0	2.260
12.5	2.156
13.0	2.058
13.5	1.967
14.0	1.881
14.5	1.801
15.0	1.726
15.5	1.655
16.0	1.588
16.5	1.525
17.0	1.466
17.5	1.410
18.0	1.357
18.5	1.307

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR EXISTING CONFIGURATION
Configuration b: Output data

Field point location (ft)	Magnetic field (Milligauss)
19.0	1.260
19.5	1.215
20.0	1.172
20.5	1.132
21.0	1.093
21.5	1.057
22.0	1.022
22.5	0.989
23.0	0.958
23.5	0.928
24.0	0.899
24.5	0.872
25.0	0.845
25.5	0.820
26.0	0.796
26.5	0.774
27.0	0.752
27.5	0.731
28.0	0.710
28.5	0.691
29.0	0.672
29.5	0.655
30.0	0.637
30.5	0.621
31.0	0.605
31.5	0.590
32.0	0.575
32.5	0.561
33.0	0.547
33.5	0.534
34.0	0.521
34.5	0.509
35.0	0.497
35.5	0.486
36.0	0.475
36.5	0.464
37.0	0.454
37.5	0.444
38.0	0.434
38.5	0.425
39.0	0.416
39.5	0.407
40.0	0.399
40.5	0.390
41.0	0.382
41.5	0.375
42.0	0.367
42.5	0.360
43.0	0.353
43.5	0.346
44.0	0.339
44.5	0.333
45.0	0.326
45.5	0.320
46.0	0.314
46.5	0.309
47.0	0.303
47.5	0.297
48.0	0.292
48.5	0.287
49.0	0.282
49.5	0.277
50.0	0.272

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION

Configuration b: Output data

Field point location (ft)	Magnetic field (Milligauss)
-50.0	0.695
-49.5	0.710
-49.0	0.726
-48.5	0.742
-48.0	0.759
-47.5	0.777
-47.0	0.795
-46.5	0.814
-46.0	0.833
-45.5	0.854
-45.0	0.874
-44.5	0.896
-44.0	0.919
-43.5	0.942
-43.0	0.966
-42.5	0.992
-42.0	1.018
-41.5	1.045
-41.0	1.073
-40.5	1.103
-40.0	1.134
-39.5	1.166
-39.0	1.199
-38.5	1.234
-38.0	1.270
-37.5	1.308
-37.0	1.348
-36.5	1.390
-36.0	1.433
-35.5	1.479
-35.0	1.526
-34.5	1.577
-34.0	1.629
-33.5	1.684
-33.0	1.742
-32.5	1.803
-32.0	1.868
-31.5	1.935
-31.0	2.007
-30.5	2.082
-30.0	2.162
-29.5	2.246
-29.0	2.335
-28.5	2.430
-28.0	2.530
-27.5	2.637
-27.0	2.750
-26.5	2.870
-26.0	2.998
-25.5	3.135
-25.0	3.281
-24.5	3.437
-24.0	3.604
-23.5	3.783
-23.0	3.975
-22.5	4.182
-22.0	4.404
-21.5	4.643
-21.0	4.900
-20.5	5.178
-20.0	5.478
-19.5	5.803
-19.0	6.154
-18.5	6.535
-18.0	6.946
-17.5	7.392
-17.0	7.875
-16.5	8.398
-16.0	8.962

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION
Configuration b: Output data

Field point location (ft)	Magnetic field (Milligauss)
-15.5	9.570
-15.0	10.223
-14.5	10.922
-14.0	11.666
-13.5	12.452
-13.0	13.276
-12.5	14.130
-12.0	15.003
-11.5	15.882
-11.0	16.748
-10.5	17.583
-10.0	18.364
-9.5	19.069
-9.0	19.681
-8.5	20.186
-8.0	20.577
-7.5	20.852
-7.0	21.011
-6.5	21.055
-6.0	20.983
-5.5	20.795
-5.0	20.491
-4.5	20.077
-4.0	19.563
-3.5	18.970
-3.0	18.319
-2.5	17.635
-2.0	16.941
-1.5	16.256
-1.0	15.594
-0.5	14.963
0.0	14.367
0.5	13.804
1.0	13.272
1.5	12.765
2.0	12.276
2.5	11.801
3.0	11.336
3.5	10.877
4.0	10.424
4.5	9.976
5.0	9.535
5.5	9.101
6.0	8.676
6.5	8.263
7.0	7.863
7.5	7.477
8.0	7.107
8.5	6.753
9.0	6.416
9.5	6.096
10.0	5.793
10.5	5.506
11.0	5.236
11.5	4.981
12.0	4.741
12.5	4.515
13.0	4.303
13.5	4.103
14.0	3.915
14.5	3.738
15.0	3.572
15.5	3.416
16.0	3.268
16.5	3.130
17.0	2.999
17.5	2.876
18.0	2.759
18.5	2.649

BOWLINE PROJECT - HAVERSTRAW AND WEST HAVERSTRAW, NY

CALCULATED MAGNETIC FIELDS FOR NEW CONFIGURATION
Configuration b: Output data

Field point location (ft)	Magnetic field (Milligauss)
19.0	2.546
19.5	2.448
20.0	2.355
20.5	2.267
21.0	2.184
21.5	2.105
22.0	2.030
22.5	1.959
23.0	1.891
23.5	1.827
24.0	1.766
24.5	1.708
25.0	1.652
25.5	1.599
26.0	1.549
26.5	1.501
27.0	1.455
27.5	1.411
28.0	1.369
28.5	1.329
29.0	1.290
29.5	1.254
30.0	1.218
30.5	1.184
31.0	1.152
31.5	1.121
32.0	1.091
32.5	1.062
33.0	1.034
33.5	1.008
34.0	0.982
34.5	0.957
35.0	0.934
35.5	0.911
36.0	0.889
36.5	0.867
37.0	0.847
37.5	0.827
38.0	0.808
38.5	0.789
39.0	0.771
39.5	0.754
40.0	0.737
40.5	0.721
41.0	0.706
41.5	0.690
42.0	0.676
42.5	0.662
43.0	0.648
43.5	0.635
44.0	0.622
44.5	0.609
45.0	0.597
45.5	0.585
46.0	0.574
46.5	0.562
47.0	0.552
47.5	0.541
48.0	0.531
48.5	0.521
49.0	0.511
49.5	0.502
50.0	0.493

ANALYSIS IN ACCORDANCE WITH CLAUSE 5 OF STIPULATION NO. 5: GAS TRANSMISSION FACILITIES

In accordance with Clause 5 of Stipulation No. 5: Gas Transmission Facilities, this analysis demonstrates that with the construction of the facilities that are the subject of the Article VII Application that was filed at the New York State Public Service Commission on December 27, 1999, Case 99-T-1814: In the Matter of the Application of Southern Energy Bowline, L.L.C. Pursuant to Subpart 85-1.3 of the Public Service Commission's Rules of Procedure to Construct a Fuel Transmission Line Which is Less Than 10 Miles Long, there is sufficient gas supply and interstate and intrastate gas transmission capacity to support the requirements of Bowline Unit 3.

1. Natural Gas Requirements for Bowline Unit 3

As set forth in Southern Energy's Article X Application (see Section 3 at 3-22), the estimated peak day requirements for natural gas at Bowline Unit 3 will be approximately 124,800 MMBtu per day. The estimated peak hour requirements will be approximately 8,000 MMBtu per hour. The estimated seasonal requirements will be approximately 10,500,000 MMBtu (summer); 11,000,000 MMBtu (winter); 10,700,000 MMBtu (spring); and 10,700,000 MMBtu (fall). The estimated annual requirements for natural gas are approximately 43,000,000 MMbtu.

2. Adequate Intrastate and Interstate Pipeline Capacity Will be Available to Serve Bowline Unit 3

There are four pipelines that interconnect with the Orange & Rockland Utilities, Inc. (O&R) distribution system: Algonquin Gas Transmission Company (Algonquin), Columbia Gas (Columbia), Transco Energy Co. (Transco) and Tennessee Gas Company (Tennessee). Primary firm, secondary released capacity, and/or interruptible capacity is available from these pipelines or third party sellers in the area to meet the seasonal requirements of Bowline Unit 3. The interconnection that would serve the Bowline Point Generating Station Property is located downstream of one compressor station at Hanover, New Jersey and upstream of Algonquin's remaining five compressor stations, which are located in Stony Point and Southeast, New York; Cromwell and Chaplin, Connecticut; and Burrville, Rhode Island. The natural gas pipeline that will serve the Bowline Point Generating Station Property also will be near a number of upstream pipeline interconnections. These include Lambertville, New Jersey (Texas Eastern Gas Transmission Corporation); Hanover, New Jersey (Texas Eastern and Columbia); Centerville, New Jersey (Transcontinental Gas); and Mahwah, New Jersey (Tennessee).

Currently, Southern Energy has 25,000 mmbtu/day of OPT-60 firm annual transportation capacity to the O&R distribution system via the Columbia Gas system and this capacity has been made available for Southern Energy to utilize as a part of its overall transportation portfolio.

This delivery capacity is firm on Columbia's system with 60 days of potential annual interruption by Columbia. Actual delivery is made to the Algonquin Hanover interconnection and further transport to the O&R system is made via secondary firm capacity ("capacity release") on the Algonquin system or via interruptible transportation, as available from time to time on the Algonquin system. Southern Energy also is active in the secondary market, seeking capacity released from third parties to complement these arrangements, as well as interruptible forward haul and/or backhaul transportation on the Algonquin and Tennessee pipeline systems. These arrangements will provide adequate interstate pipeline capacity to meet the requirements of Bowline Unit 3, as well as the existing Bowline Units 1 and 2.

As set forth more fully in the "Application of Southern Energy Bowline, L.L.C. Pursuant to subpart 85-1.3 of the Public Service Commission's Rules of Procedure to Construct a Fuel Transmission Line Which is Less Than 10 Miles Long," which is annexed to Southern Energy's Article X Application, as Appendix 3C, the existing O&R gas distribution system is not capable of being operated in a manner sufficient to meet the existing full service loads at Bowline Units 1 and 2 and the Lovett Station. In order to provide adequate gas transportation capacity to these existing generating stations, a larger diameter gas pipeline is needed.

The additional capacity also is needed to enable Southern Energy to utilize natural gas at Bowline Unit 3. The existing O&R system is not capable of supplying any of the incremental gas needs of Bowline Unit 3. The 16-inch O&R pipeline is not sized to accommodate the level of increased load at Bowline Unit 3. In addition, the O&R system cannot supply gas to Bowline Point at the pressure required to operate Bowline Unit 3, which is a combined cycle combustion generator requiring gas at approximately a minimum, sustainable 425 psig.

The design of O&R gas distribution system constrains the gas transportation capability to Bowline Point. The new natural gas pipeline will remedy this situation and will provide Southern Energy with the necessary transportation capacity from the interstate pipeline system to Bowline Point.

3. Sufficient Gas Supply Will Be Available to Serve Bowline Unit 3

Southern Energy has examined available information on the status of gas supply availability for the nation and the Northeast. Reports show that adequate supplies of gas will be available to meet forecast demands that assume high, middle and low growth scenarios. For example, the 1998 New York State Energy Plan ("SEP") included a high demand growth case that assumed all new electric generation capacity needs within the planning horizon of the year 2016 would be met through new natural gas-fired generation units located in New York. The 1998 SEP states that natural gas supplies are expected to be adequate to meet this range of demand in the planning period. (See SEP and Final Environmental Impact Statement [November 1998] at 3-30 and Appendix at 6.1). Other studies also show that adequate gas supplies will be available to meet the nation's and Northeast's regional needs over the planning horizon. (See Potential Supply of Natural Gas in the United States, Report of the Colorado

Potential Gas Committee [March 1999]; United States Department of Energy Information Administration, Natural Gas Issues and Trends at 109-127 [April 1999].)

Because most of the gas to be consumed at Bowline Unit 3 is likely to enter from the Algonquin system, Southern Energy will seek gas supply from third parties for delivery into the Algonquin pipeline system from sellers on the Tennessee Gas, Texas Eastern, Transco, and Columbia Gas pipeline systems. These interconnections represent availability of over 2,500,000 mmbtu/day of potential supply access in the immediate vicinity of the Bowline Generating Station Property, except during the colder months of the winter season when much of this supply is routed instead by sellers to other firm markets. In such case, Bowline Unit 3 may be dispatched on oil, or Bowline Units 1 and 2 (which might not normally be dispatched in the winter time periods) can be dispatched utilizing oil.

As stated above, the Algonquin system connects to four interstate pipeline systems, Algonquin, Tennessee, Columbia Gas, and Transco in the immediate area. To the extent that third party sellers have gas they desire to deliver to Algonquin for the account of Southern Energy for redelivery to Bowline Unit 3, Southern Energy can implement these third party purchase transactions. These arrangements can be of a daily nature, a monthly nature, or a seasonal nature.

In addition, there are a variety of gas commodity products and services offered by third party sellers in today's marketplace. Such physical and financial positions are taken relative to, in the case of the Bowline 1 and 2 units, Texas Eastern's M 3 regional pricing index. Some of these are purely financial in nature, and settlement is at price only; others often involve physical delivery of gas at firm service terms and conditions. Many may involve liquidated damages for seller's non-performance or failure to deliver firm volumes. Because a liquid market for these types of products and services exists in the Bowline generating station property region most of the year, other types of products and services also are created by the marketplace. These products include pipeline interruptible storage and park-n-rides to put/call options on daily volumes, reverse tolling options (wherein gas is swapped for power at a designated heat rate and location) and backhauls on transportation capacity.

Southern Energy has entered into a 5-year arrangement with Southern Company Energy Marketing Company ("SCEM"), an affiliated company of Southern Energy, under which SCEM is responsible for the management of fuel supply to the existing Bowline Units 1 and 2 and the marketing of electric power generated at Bowline Units 1 and 2. Under this arrangement, SCEM's responsibilities are determining the choice of fuel used at Bowline Units 1 and 2 and any associated emissions allowances required. In the case of natural gas deliveries to the facilities, SCEM determines, among other things, the type of interstate gas transportation resources to use and the costs it is willing to pay for delivered gas supply to the O&R citygate for SCEM's account either by third party sellers or for its own account. O&R then transports that gas on an interruptible basis, and subject to system design constraints, to the Bowline and Lovett plants.

4. Proposed Pipeline Projects may Increase the Availability of Capacity and Gas Supply

There will be adequate gas supply and transmission capacity to serve Bowline Unit 3 if the Southern Energy proposed pipeline is constructed, even if no other proposed pipeline is constructed. Nevertheless, if any of the proposed pipelines are constructed, the availability of gas supply and capacity may increase. The proposed projects are:

Millennium Pipeline – This is a 424 mile pipeline from Lake Erie to Westchester County, New York. If Millennium is built, and the approved route is the initial route which had been proposed to route across the Bowline Generating Station Property enroute to the Hudson River, Southern Energy would propose to connect to the Millennium system and take advantage of its higher pressure and new throughput capacity into the region.

Market-Link – This proposal has a conditional FERC order to proceed on the project <u>if</u> it is able to demonstrate certain things, i.e., 35% of the capacity must be contracted to non-affiliates and it must resolve numerous landowner issues. Transco has elected to reduce the size and scope of the proposed project.

Spectrum– This is a proposed Texas Eastern Gas Transmission project, which would utilize some "turned-back" capacity (300,000 mcf/day) on its system, rather than build extensive facilities as proposed by Millennium and others. Texas Eastern maintains that it can serve the markets via current capacity with no new area buildout.

Iroquois– This pipeline has proposed a limited expansion of its system by 150,000 mcf/day that would provide additional gas capability into Con Edison's service territory in Manhattan.