BAE SYSTEMS

Multipathway Human Health Risk Assessment Report for the Open Burning Ground Operations

Radford Army Ammunition Plant

Radford, Virginia

Revised August 2020

Submitted to:

Virginia Department of Environmental Quality

August 2020

Revised March 2020

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ADD	average daily dose
ADI	average daily intake
AEGL	acute exposure guideline level
AHQ	acute hazard quotient
AIEC	acute inhalation exposure criteria
ALM	Adult Lead Exposure Model
AP-42	Compilation of Air Pollutant Emission Factors
BAE	BAE Systems, Ordnance Systems, Inc.
BW	body weight
CFR	Code of Federal Regulations
CO_2	carbon dioxide
COPC	constituent of potential concern
CSF	cancer slope factor
DOD	Department of Defense
DOE	Department of Energy
ERPG	emergency response planning guideline
EWI-CWP	explosive waste incinerator-contaminated waste processor
FOD	foreign object debris
HHRAP	Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic
LADD	lifetime average daily dose
MPRA	multipathway risk assessment
NEW	net explosive weight
NOAA	National Oceanic and Atmospheric Association
OBG	open burning ground
OBODM	Open Burn and Open Detonation Model
PAC	protective action criteria
PAH	polynuclear aromatic hydrocarbon
PCDD	polychlorinated dibenzo-p-dioxin

PCDF	polychlorinated dibenzofuran
PIC	product of incomplete combustion
RCRA	Resource Conservation and Recovery Act
RFAAP	Radford Army Ammunition Plant
RfC	reference concentration
RfD	reference dose
RME	reasonable maximum exposure
RSL	regional screening level
SO_2	sulfur dioxide
TCD	Tetrachlorodibenzo(p)dioxin
TEEL	temporary emergency exposure limit
TEF	toxicity equivalent factor
TEQ	toxic equivalent
TRV	toxicity reference value
UF	uncertainty factor
U.S.C.	United States Code
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator coordinate system
VDEQ	Virginia Department of Environmental Quality

1.0 INTRODUCTION

This multipathway risk assessment (MPRA) report is being submitted by BAE Systems, Ordnance Systems, Inc., (BAE) to fulfill a requirement of the Resource Conservation and Recovery Act (RCRA) permit application for the open burning ground (OBG) operated at the Radford Army Ammunition Plant (RFAAP). This report documents the methodologies by which BAE evaluated the risks to human health resulting from continued operation of the OBG.

This MPRA was required by the Virginia Department of Environmental Quality (VDEQ) under the authority of the RCRA Omnibus provision granted by Title 40 Code of Federal Regulations (CFR) Part 270.32(b)(2). While a prior MPRA was performed for the OBG at the RFAAP, VDEQ requested that a new assessment be performed due to changes in modeling guidance, meteorological data availability, and toxicity data.

1.1 BACKGROUND

Although there are no specific promulgated requirements for MPRAs in RCRA, previous permitting efforts in Virginia and throughout the United States have included this requirement as part of the permitting process for OBG operations and other hazardous waste thermal treatment sources. This policy was initiated by the United States Environmental Protection Agency (USEPA) as part of the Hazardous Waste Minimization and Combustion Strategy. Site-specific MPRAs were performed as part of the RCRA permitting process for many hazardous waste thermal treatment units to ensure protection of human health and the environment. Specifically, these site-specific MPRAs are intended to address potential concerns about hazardous constituents that may be found in the OBG emissions, including dioxins, furans, metals, and non-dioxin products of incomplete combustion (PICs). Although hazardous waste open burning grounds were not specifically included in this policy recommendation, VDEQ has determined that these waste combustion guidelines are appropriate for application to the OBG permit. As such, an MPRA was performed for the OBG as part of the application for the current RCRA permit and was required as a condition of the renewal of that permit.

The "omnibus" authority of Section 3005(c)(3) of RCRA, 42 United States Code (U.S.C.) 6925(c)(3), and 40 CFR § 270.32(b)(2) gives the Agency both the authority and the responsibility to establish permit conditions on a case-by-case basis as necessary to protect human health and the environment. Performance of a site-specific MPRA can provide the information necessary to determine what, if any, additional permit conditions are necessary to ensure that operation of the OBG is protective of human health and the environment. Under 40 CFR § 270.10(k), the Agency may require a permit applicant to submit additional information (*e.g.*, a site-specific MPRA) that is needed to establish permit conditions under the omnibus authority. The VDEQ requested that RFAAP perform this MPRA as part of the RCRA permit renewal for the OBG.

1.2 PURPOSE AND SCOPE

BAE is submitting this MPRA report in conjunction with the renewal application for the OBG RCRA permit. The MPRA was conducted in accordance with the methods described in USEPA's guidance document entitled, *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP) (USEPA, 1998c), USEPA's *Errata to the HHRAP* (USEPA, 1999), and the approved MPRA protocol entitled *Multipathway Risk Assessment Protocol for the Radford Army Ammunition Plant Open Burning Grounds* (RFAAP, 2019). The human health elements of the MPRA protocol were officially approved by VDEQ on February 20, 2019. The MPRA was site-specific with respect to the source and dispersion of emissions and the locations of potential receptors. Default variable values were used to represent the potential intake of the hypothetical receptors located throughout the surrounding community.

This MPRA report presents the following information:

- Constituents of potential concern (COPC) evaluated in the MPRA and the emission factors used for them;
- Site-specific exposure pathways and hypothetical receptors evaluated in the MPRA;
- Procedures used in the estimation of risk associated with potential direct and indirect exposures to OBG emissions;
- Calculated risk and hazard estimates for each exposure scenario; and
- As appropriate, recommendation of site-specific risk-based limitations for the OBG to ensure protection of human health in the surrounding community.

The goal of the MPRA described by this document was to demonstrate that emissions from the OBG meet the site-specific risk-based goals established by the VDEQ and determined by them to be sufficiently protective of the surrounding population.

1.3 FACILITY CHARACTERIZATION

BAE operates a munitions propellant manufacturing facility at the RFAAP in Radford, Virginia. The primary mission of the RFAAP is to supply solvent and solventless propellant and explosives to the United States Armed Forces. The RFAAP is a government-owned, contractor operated, military industrial installation under the jurisdiction of the United States Army. Manufacturing operations at the RFAAP commenced in 1941 and have been in continuous operation ever since. Currently, the RFAAP is recognized as the largest supplier of ammunition propellant to the United States Department of Defense (DOD) and as a major producer of medium caliber ammunition and commercial and military smokeless powder.

1.3.1 SURROUNDING AREA

The RFAAP is situated in hilly terrain in Pulaski and Montgomery Counties in southwest Virginia and is divided into two sections: the main plant, and the Horseshoe Area. The New River separates the two counties and these two portions of the facility. The OBG is located in the lower southeast portion of the

Horseshoe Area, as shown on Figure 1-1. Surrounding land use is primarily a combination of deciduous forest and pastureland, intermingled with small residential areas. The main developed areas are Blacksburg to the northwest, Christiansburg to the east, and Radford to the southwest. The location of these towns relative to the RFAAP is demonstrated on Figure 1-2.

With hilly terrain and numerous drainage areas, the area surrounding the RFAAP provides multiple streams and creeks for fishing. In addition, the New River itself, serves as a major resource for fishing, supporting populations of nearly every major freshwater game fish in the state, including: smallmouth bass, spotted bass, largemouth bass, rock bass, striped bass, white bass, hybrid striped bass, muskellunge, walleye, black crappie, channel catfish, flathead catfish, yellow perch, redbreast sunfish, and bluegill (VDGIF, 2018). In addition, the New River is utilized as a drinking water supply for nearby communities.

1.3.2 Open Burning Grounds

Various types of hazardous waste are generated as part of the RFAAP production operations. These wastes are managed via one of three mechanisms. The hazardous energetic wastes are treated onsite in either the hazardous waste incinerators or the OBG. Non-energetic hazardous wastes are generally sent offsite for disposal.

The OBG receives those wastes that cannot otherwise be treated in the hazardous waste incinerators. This includes wastes containing foreign object debris (FOD) such as screws, rocks, *etc*., that are collected in pits in the operating areas of the facility. In addition, wastes that are too large to process through the incinerators' waste preparation system are managed at the OBG. Combined, these wastes represent less than 40 percent of the total hazardous waste generated and managed onsite. Efforts are continuously underway to reduce this percentage through waste minimization efforts and the implementation of innovative production and waste treatment technologies.

In addition, RFAAP is currently in the process of completing the design of a new explosive waste incinerator and contaminated waste processing (EWI-CWP) complex. This facility, once permitted and designed, will be able to process many of the wastes currently going to the OBG. Both RCRA and air permit applications for the EWI-CWP have been submitted, and VDEQ expects to issue the draft Permit for the EWI-CWP later this year. Once both the RCRA and air permits are issued and vendor selection is complete, RFAAP can commence with the final design and construction efforts. Based on VDEQ estimates and expected funding awards, RFAAP expects to initiate these efforts in 2020.

2.0 COMPOUNDS OF POTENTIAL CONCERN

The MPRA protocol described the process that was used to identify COPCs. This section provides an overview of that process and documents the final COPCs included in the risk assessment and the emission factors utilized for them.

2.1 COPC SELECTION

COPCs for the MPRA were identified based on their potential to pose increased risk or hazard via one or more of the exposure pathways. This identification process focused on compounds that:

- are likely to be emitted, based on the presence of the compound or its precursors in the waste feed and emissions;
- are potentially toxic to humans; and/or
- have a propensity for bioaccumulating or bioconcentrating in food chains.

The previous MPRA performed for the OBG relied on a combination of data to generate the COPC list for the assessment, including "bang-box" data generated by the Department of Energy (DOE) at a test facility and emissions data collected from the onsite incinerators. Since that assessment, new emission factors for military ordnance were released by the USEPA in Chapter 15 of their *Compilation of Air Pollutant Emission Factors* (AP-42) (USEPA, 2009). Although these factors do not apply directly to RFAAP OBG operations, they do provide an approximation of emissions from ordnance items that contain RFAAP product and therefore, provide some degree of representation of treatment of these products at the OBG. In addition to the AP-42 factors, and in an effort to use even more site-specific data and provide the most realistic estimate of risk from RFAAP's OBG, RFAAP partnered with the USEPA to conduct first of its kind emissions sampling of the OBG operations. These sampling results were used in combination with the AP-42 emission factors and data on RFAAP product formulations to develop the COPC list for this MPRA.

2.1.1 SITE-SPECIFIC EMISSIONS TESTING

In an effort to obtain site-specific emissions data on the RFAAP OBG emissions, RFAAP partnered with the USEPA to conduct direct sampling and calculation of the OBG emissions. USEPA attached their gas and particle sensor system to a National Aeronautics and Space Agency, Ames Research Center (NASA Ames) hexacopter unmanned aerial vehicle (UAV) that was flown into the plumes from the OBG operations. While there are no USEPA approved methods for sampling emissions from any type of open burn, equipment calibrations and analytical methods followed EPA protocols. Over a 2-week period in September 2017, the NASA/ORD team sampled 33 plumes of dry propellant burns and skid burns. Those constituents for which USEPA was able to conduct site-specific emissions testing included:

- Dioxins and furans;

- Nitroaromatics;
- Semivolatile and volatile organic compounds;
- Metals; and
- Chlorate, hydrogen chloride, and perchlorate.

USEPA compared the measured emission factors to other recently sampled aerial emission data and found them to be consistent or, in some cases (for example, HCl) found to be considerably lower. (Aurell and Gullet, 2017) A complete copy of USEPA's report is provided in Appendix C. The test report provides information on the methodologies employed in collecting samples, as well as the emission factors obtained for each COPC that was measured. Results are reported in mass emitted per mass of energetic burned.

Those sampled constituents that were detected in one or more test run samples and did not meet any of the following exclusion criteria were included in the MPRA;

- Compounds reported as non-detect in all of the test run samples were excluded from the COPC list;
- Compounds present in test run samples that were also present in the method blank at greater than 50 percent of the test level were excluded from the COPC list; and
- Compounds without any chemical specific fate, transport, and/or toxicity data were excluded from the quantitative evaluation but are discussed qualitatively in the Section 7.2 of this report.

Table 2-1 summarizes the COPCs originating from the site-specific emissions testing, or flyer testing, and specifies whether a quantitative or qualitative assessment of the COPC was conducted. Note that none of the nitroaromatics for which USEPA conducted emissions testing were detected in any of the emissions samples. Therefore, the table below contains none of the nitroaromatic compounds.

TABLE 2-1
SUMMARY OF COPCS FROM SITE-SPECIFIC SAMPLING

COMPOUND	TYPE OF ASSESSMENT
Dioxins and Furans	
1,2,3,7,8-PeCDF	Quantitative
2,3,4,7,8-PeCDF	Quantitative
Semivolatile and Volatile Organics	
1,2,4-Trimethylbenzene	Quantitative
1,2-Dichloro-1,1,2,2-tetrafluoroethane	Qualitative
1,3,5-Trimethylbenzene	Quantitative
1,3-Butadiene	Quantitative
1,4-Dioxane	Quantitative
2,2,4-Trimethylpentane	Qualitative

Table 2-1 (continued)
Summary of COPCs from Site-Specific Sampling

Compound	Type of Assessment
Semivolatile and Volatile Organics (continued)	
2-Butanone	Quantitative
4-Methyl-2-pentanone	Quantitative
Acetone	Quantitative
Acetonitrile	Quantitative
Benzene	Quantitative
Carbon tetrachloride	Quantitative
Chloroethane	Quantitative
Chloroform	Quantitative
Chloromethane	Quantitative
Cumene	Quantitative
Dichlorodifluoromethane	Quantitative
Ethanol	Qualitative [1]
Ethylbenzene	Quantitative
m,p-Xylenes	Quantitative
Methylene chloride	Quantitative
Naphthalene	Quantitative
n-Heptane	Qualitative
n-Hexane	Quantitative
n-Octane	Qualitative
o-Xylene	Quantitative
Styrene	Quantitative
Tetrachloroethene	Quantitative
Tetrahydrofuran	Quantitative
Toluene	Quantitative
Trichlorofluoromethane	Quantitative
Trichlortrifluoroethane	Qualitative
Xylenes	Quantitative
Metals	
Aluminum	Quantitative
Antimony	Quantitative
Arsenic	Quantitative
Barium	Quantitative
Bromide	Qualitative
Cadmium	Quantitative

TABLE 2-1 (CONTINUED)
SUMMARY OF COPCS FROM SITE-SPECIFIC SAMPLING

COMPOUND	TYPE OF ASSESSMENT
Metals (continued)	
Calcium	Qualitative [1]
Chloride	Qualitative
Chromium	Quantitative
Copper	Quantitative
Gallium	Qualitative
Germanium	Qualitative
Hexavalent chromium	Quantitative
Indium	Qualitative
Iron	Qualitative
Lanthanum	Qualitative
Lead	Quantitative
Magnesium	Qualitative [1]
Manganese	Quantitative
Molybdenum	Quantitative
Palladium	Qualitative
Phosphorous	Quantitative
Potassium	Qualitative [1]
Rubidium	Qualitative
Silicon	Qualitative [1]
Silver	Quantitative
Sodium	Qualitative [1]
Strontium	Quantitative
Tin	Quantitative
Titanium	Qualitative [1]
Yttrium	Qualitative
Zinc	Quantitative
Other Inorganics	
Hydrogen chloride	Quantitative

[1] The MPRA protocol incorrectly noted this constituent has having available fate, transport, and/or toxicity data available. No such data is available via VDEQ-recommended sources. Therefore, a quantitative analysis of the risk from this COPC was not performed. The potential impact on the risk calculations due to this is discussed in the uncertainty section of this report.

2.1.2 AP-42 FACTORS

Those constituents for which USEPA was unable to conduct site-specific emissions testing but for which USEPA established an AP-42 emission factor for an item containing a RFAAP-product were included in the MPRA provided that:

- The referenced constituent was not included on the analyte list for the site-specific emissions testing;
- The referenced constituent could not be excluded based on the formulation of the RFAAP product within the item (*e.g.,* a metallic compound that is not found in the RFAAP product but is provided an emission factor because it is found in another component of the item); and
- The AP-42 factor is assigned an A, B, or C-rating (average to excellent level of confidence).

A preliminary review of these criteria was provided in the MPRA protocol based on the types of ammunition items into which RFAAP products are generally placed. As part of the MPRA effort, RFAAP conducted a detailed review of the military specification for each Department of Defense Identification Code (DODIC) and the associated AP-42 factors to confirm whether the item in fact has RFAAP-product within it and to verify if the selected emission factor meets the criteria specified above. Table 2-2 summarizes the COPCs originating from the AP-42 factor review and specifies whether a quantitative or qualitative assessment of the COPC was conducted.

TABLE 2-2
SUMMARY OF COPCS FROM AP-42

COMPOUND	TYPE OF ASSESSMENT
Polynuclear Aromatic Hydrocarbons	
Benzo(a)pyrene	Quantitative
Benz(a)anthracene	Quantitative
Benzo(b)fluoranthene	Quantitative
Benzo(e)pyrene	Qualitative
Benzo(g,h,i)perylene	Qualitative [1]
Benzo(k)fluoranthene	Quantitative
Chrysene	Quantitative
Dibenz(a,h)anthracene	Quantitative
Indeno(1,2,3-cd)pyrene	Quantitative
Nitroaromatics	
2-Nitrophenol	Quantitative
Pyridine	Quantitative

TABLE 2-2 (CONTINUED)
SUMMARY OF COPCS FROM AP-42

COMPOUND	TYPE OF ASSESSMENT
Phthalates	
Bis-2-Ethylhexyl phthalate	Quantitative
Butyl benzyl phthalate	Quantitative
Dibutyl phthalate	Quantitative
Semivolatile and Volatile Organics	
2-Methylnaphthalene	Quantitative
Acenaphthene	Quantitative
Acenaphthylene	Qualitative [1]
Acetaldehyde	Quantitative
Acrolein	Quantitative
Acrylonitrile	Quantitative
Anthracene	Quantitative
Crotonaldehyde	Quantitative
Ethyl acrylate	Quantitative
Ethylene	Qualitative [1]
Fluoranthene	Quantitative
Fluorene	Qualitative
Formaldehyde	Quantitative
Methane	Qualitative [1]
Methyl bromide	Quantitative
Methyl methacrylate	Qualitative
Octabenzone	Qualitative
Phenanthrene	Quantitative
Phenol	Quantitative
Propionaldehyde	Quantitative
Propylene	Qualitative
Pyrene	Quantitative
Metals and Metallic Compounds	
Beryllium	Quantitative

TABLE 2-2 (CONTINUED)
SUMMARY OF COPCS FROM AP-42

COMPOUND	TYPE OF ASSESSMENT
Other Inorganic Compounds	
Ammonia	Quantitative
Cyanide	Quantitative
Hydrogen cyanide	Quantitative
Hydrogen fluoride	Quantitative
Nitric acid	Qualitative [1]
Sulfuric acid (skid burn only) [2]	Quantitative

1 The MPRA protocol incorrectly noted this constituent has having available fate, transport, and/or toxicity data available. No such data is available via VDEQ-recommended sources. Therefore, a quantitative analysis of the risk from this COPC was not performed. The potential impact on the risk calculations due to this is discussed in the uncertainty section of this report.

2 The wastes processed in the propellant burns do not contain any sulfur. Therefore, it is not possible for sulfuric acid to form from the processing of propellant wastes at the OBG. Therefore, sulfuric acid is only included as a COPC for the skid burn scenarios.

4 The MPRA protocol erroneously identified 2,3,4,7,8-PCDD as a COPC for the MPRA based on an AP-42 emission factor. This was a typographical error. 2,3,4,7,8-PCDD is not one of the PCDD/PCDF congeners included in WHO's TEF groupings. The compound should have been specified as 2,3,4,7,8-PCDF. This compound was evaluated as part of the flyer testing and was specified as a COPC based on that test.

3 The MPRA protocol erroneously identified hexachlorobenzene and trichloroethylene as COPCs from an AP-42 emission factor for an ordnance item suspected to contain RFAAP product. This item was an M4A2 Floating Type HC Smoke Pot (DODIC K867). However, upon further review of the detailed military specification for the item in question, no RFAAP product is present in the item. No other DODIC containing RFAAP product provided an emission factor for hexachlorobenzene or trichloroethylene. Furthermore, RFAAP and VDEQ had specifically discussed hexachlorobenzene during review of the MPRA protocol and determined that it did not need to be included as a COPC in the risk assessment (reference *Response to the Third Notice of Deficiency Addressing the Technical Completeness of the Part A and Part B Permit Applications for the Renewal of the Subpart X Open Burning Ground* – Approval dated April 21, 2017). Therefore, neither hexachlorobenzene nor trichloroethylene were included in the MPRA.

4 The MPRA protocol erroneously identified benzyl chloride and methyl bromide as COPCs from an AP-42 emission factor for an ordnance item suspected to contain RFAAP product. This item was an M490 105-mm target practice tracer cartridge (DODIC C511). However, upon further review of the detailed military specification for the item in question, the only RFAAP product in the item is benite, which does not contain any chlorine or bromine, making the emission factors for benzyl chloride and methyl bromide inappropriate. No other DODIC containing RFAAP product provided an emission factor for benzyl chloride or methyl bromide. Therefore, neither benzyl chloride nor methyl bromide were included in the MPRA.

5 The MPRA protocol erroneously identified thallium as a COPC from an AP-42 emission factor for an ordnance item suspected to contain RFAAP product. This item was an M196 5.56-mm tracer cartridge (DODIC A068). However, upon further review of the detailed military specification for the item in question, no RFAAP product is present in the item. No other DODIC containing RFAAP product provided an emission factor for thallium. Therefore, thallium was not included in the MPRA.

2.1.3 RFAAP PRODUCTION CHEMICALS

In addition to evaluating the USEPA site-specific testing and the AP-42 factors, RFAAP considered other compounds that are known to be present in RFAAP formulations. The COPC list for the MPRA also included those compounds known to be present in RFAAP formulations or otherwise used onsite that were not represented in the flyer sampling or the AP-42 factors directly or indirectly via a chemically similar compound. Table 2-3 summarizes those compounds and the method in which they were evaluated. Note that most of these compounds were only able to be assessed qualitatively due to lack of a credible method for establishing an emission factor or due to the lack of credible fate, transport, and/or toxicity data.

TABLE 2-3
SUMMARY OF COPCS FROM RFAAP WASTES

COMPOUND	TYPE OF ASSESSMENT
Nitroaromatics	
3-Methyl-1,1-diphenylurea	Qualitative
Ethyl centralite	Qualitative
Methyl centralite	Qualitative
Rhodamine	Qualitative
Phthalates	
Diethyl phthalate	Quantitative
Dimethyl phthalate	Quantitative
Dioctyl phthalate	Quantitative
Other Semivolatile and Volatile Organics	
Acetylene black	Qualitative
Butyl acetate	Qualitative
Candelilla wax	Qualitative
Cellulose	Qualitative
Cellulose acetate	Qualitative
Diethylene glycol	Qualitative
Diethylene glycol dinitrate	Qualitative
Diethylene glycol monomethyl ether	Qualitative
Di-n-propyl adipate	Qualitative
Ethyl acetate	Qualitative
Ethyl cellulose	Qualitative
Glycollate	Qualitative
Lead carbonate	Qualitative
Lead resorcylate	Qualitative
Lead salicylate	Qualitative
Lead stearate	Qualitative
Magnesium stearate	Qualitative
Metriol trinitrate	Qualitative
n-Butyl stearate	Qualitative
Nitromethane	Qualitative
Rosolic acid	Qualitative
Triacetin	Qualitative
Triethylene glycol	Qualitative
Triethylene glycol dinitrate	Qualitative

TABLE 2-3 (CONTINUED)
SUMMARY OF COPCS FROM RFAAP WASTES

COMPOUND	TYPE OF ASSESSMENT
Metals and Metallic Compounds	
Antimony sulfide	Qualitative
Barium nitrate	Qualitative
Barium sulfate	Qualitative
Chromium nitrate	Qualitative
Cryolite	Qualitative
Magnesium oxide	Qualitative
Potassium cryolite	Qualitative
Potassium nitrate	Qualitative
Potassium perchlorate	Qualitative
Potassium sulfate	Qualitative
Zirconium carbide	Qualitative
Zirconium hydride	Qualitative
Zirconium silicate	Qualitative
Other Inorganics	
Ammonium nitrate	Qualitative
Ammonium perchlorate	Qualitative
Nitramine	Qualitative

2.2 SELECTED COPCS

For those COPCs that were evaluated quantitatively in the MPRA, it is necessary to identify the emission factors for each constituent and the toxicity data used in the assessment. The sections that follow provide a discussion on each of these items.

2.2.1 COPC EMISSION FACTORS

The emission factors for each COPC were determined from either the site-specific emissions testing or the AP-42 factors. Emission factors were specified on a pound emitted per pound of net explosive weight (NEW) burned. These emission factors were then used to calculate COPC emission rates by multiplying by the pound of NEW in each type of burn scenario as follows:

- Propellant burns - 8,000 pounds of NEW per burn
- Skid burns - 2,000 pounds of NEW per burn.

For the AP-42 based emission factors, the MPRA protocol provided a preliminary estimate of the appropriate emission factors based on an initial review of the AP-42 data and the types of ammunition items into which RFAAP products generally are placed. As part of the MPRA effort, RFAAP conducted a more detailed review of each of the AP-42 factors and the items from which those factors originated to confirm whether the item in fact has RFAAP-product within it. The highest emission factor from those items confirmed to contain RFAAP product was used in the MPRA unless a specific issue was noted with that factor. Table 2-4 presents the final emission factors and emission rates utilized for each COPC in the risk assessment. Any specific notations regarding the selected AP-42 factor for a given COPC are provided as footnotes to the table.

TABLE 2-4
COPC EMISSION FACTORS AND EMISSION RATES FOR THE MPRA

COPC	EMISSION FACTOR (LB/LB NEW)	SOURCE [1]	EMISSION RATE (G/S)	
			PROPELLANT BURN	SKID BURN
Dioxins and Furans				
1,2,3,7,8-PeCDF	4.26E-12	Flyer testing	4.29E-09	1.07E-09
2,3,4,7,8-PeCDF	4.26E-12	Flyer testing	4.29E-09	1.07E-09
Polynuclear Aromatic Hydrocarbons				
Benzo(a)pyrene	5.3E-07	AP-42 D540	5.34E-04	1.34E-04
Benz(a)anthracene	2.9E-07	AP-42 A363	2.92E-04	7.31E-05
Benzo(b)fluoranthene	3.4E-07	AP-42 D540	3.43E-04	8.57E-05
Benzo(k)fluoranthene	2.4E-07	AP-42 B642 [2]	2.42E-04	6.05E-05
Chrysene	3.0E-07	AP-42 A363 [2]	3.02E-04	7.56E-05
Dibenz(a,h)anthracene	3.9E-08	AP-42 A363 [2]	3.93E-05	9.83E-06
Indeno(1,2,3-cd)pyrene	5.8E-07	AP-42 D540	5.85E-04	1.46E-04
Nitroaromatics				
2-Nitrophenol	1.4E-06	AP-42 C870	1.41E-03	3.53E-04
Pyridine	1.0E-06	AP-42 B627	1.01E-03	2.52E-04
Phthalates				
Bis-2-Ethylhexyl phthalate	1.5E-05	AP-42 EF B542	1.51E-02	3.78E-03
Butyl benzyl phthalate	2.9E-06	AP-42 EF B571	2.92E-03	7.31E-04
Dibutyl phthalate	2.9E-05	AP-42 EF A403	2.92E-02	7.31E-03
Diethyl phthalate	2.9E-06	RFAAP Chemical	2.92E-03	7.31E-04
Dimethyl phthalate	2.9E-06	RFAAP Chemical	2.92E-03	7.31E-04
Dioctyl phthalate	2.9E-05	RFAAP Chemical	2.92E-02	7.31E-03

TABLE 2-4 (CONTINUED)
COPC EMISSION FACTORS AND EMISSION RATES FOR THE MPRA

COPC	EMISSION FACTOR (LB/LB NEW)	SOURCE [1]	EMISSION RATE (G/S)	
			PROPELLANT BURN	SKID BURN
Other Semivolatile and Volatile Organics				
1,2,4-Trimethylbenzene	2.72E-05	Flyer testing	2.74E-02	6.85E-03
1,3,5-Trimethylbenzene	7.28E-06	Flyer testing	7.33E-03	1.83E-03
1,3-Butadiene	1.97E-05	Flyer testing	1.99E-02	4.96E-03
1,4-Dioxane	6.93E-07	Flyer testing	6.99E-04	1.75E-04
2-Butanone	1.02E-05	Flyer testing	1.03E-02	2.57E-03
2-Methylnaphthalene	2.1E-06	AP-42 EF B535	2.12E-03	5.29E-04
4-Methyl-2-pentanone	1.47E-06	Flyer testing	1.48E-03	3.70E-04
Acenaphthene	5.2E-07	AP-42 EF D540	5.24E-04	1.31E-04
Acetaldehyde	1.3E-04	AP-42 EF A403 [2]	1.31E-01	3.28E-02
Acetone	4.47E-05	Flyer testing	4.51E-02	1.13E-02
Acetonitrile	2.69E-05	Flyer testing	2.71E-02	6.78E-03
Acrolein	1.0E-05	AP-42 EF A363	1.01E-02	2.52E-03
Acrylonitrile	1.3E-04	AP-42 EF D540	1.31E-01	3.28E-02
Anthracene	3.4E-07	AP-42 EF D540	3.43E-04	8.57E-05
Benzene	3.11E-04	Flyer testing	3.13E-01	7.84E-02
Carbon tetrachloride	1.09E-06	Flyer testing	1.10E-03	2.75E-04
Chloroethane	2.35E-06	Flyer testing	2.37E-03	5.92E-04
Chloroform	2.23E-07	Flyer testing	2.25E-04	5.62E-05
Chloromethane	7.58E-06	Flyer testing	7.64E-03	1.91E-03
Crotonaldehyde	7.2E-06	AP-42 EF B627	7.26E-03	1.81E-03
Cumene	3.75E-06	Flyer testing	3.78E-03	9.45E-04
Dichlorodifluoromethane	6.72E-06	Flyer testing	6.77E-03	1.69E-03
Ethyl acrylate	1.2E-08	AP-42 EF C511	1.21E-05	3.02E-06
Ethylbenzene	2.08E-05	Flyer testing	2.10E-02	5.24E-03

Table 2-4 (continued)
COPC Emission Factors and Emission Rates for the MPRA

COPC	Emission Factor (lb/lb NEW)	Source [1]	Emission Rate (g/s)	
			Propellant Burn	Skid Burn
Other Semivolatile and Volatile Organics (continued)				
Fluoranthene	1.0E-06	AP-42 EF D540	1.01E-03	2.52E-04
Formaldehyde	1.2E-03	AP-42 EF A403	1.21E+00	3.02E-01
n-Hexane	1.63E-05	Flyer testing	1.64E-02	4.11E-03
Methylene chloride	1.26E-04	Flyer testing	1.27E-01	3.18E-02
Naphthalene	1.45E-04	Flyer testing	1.46E-01	3.65E-02
Phenanthrene	2.3E-06	AP-42 EF D540 [2]	2.32E-03	5.80E-04
Phenol	1.2E-05	AP-42 EF D540	1.21E-02	3.02E-03
Propionaldehyde	8.9E-06	AP-42 EF B627	8.97E-03	2.24E-03
Pyrene	1.9E-06	AP-42 EF D540 [2]	1.92E-03	4.79E-04
Styrene	5.07E-05	Flyer testing	5.11E-02	1.28E-02
Tetrachloroethene	6.11E-07	Flyer testing	6.16E-04	1.54E-04
Tetrahydrofuran	7.30E-07	Flyer testing	7.36E-04	1.84E-04
Toluene	3.26E-04	Flyer testing	3.29E-01	8.22E-02
Trichlorofluoromethane	2.48E-06	Flyer testing	2.50E-03	6.25E-04
m-Xylene	4.11E-05	Flyer testing	4.14E-02	1.04E-02
o-Xylene	1.61E-05	Flyer testing	1.62E-02	4.06E-03
p-Xylene	4.11E-05	Flyer testing	4.14E-02	1.04E-02
Metals				
Aluminum	7.30E-06	Flyer testing	7.36E-03	1.84E-03
Antimony	2.32E-06	Flyer testing	2.34E-03	5.85E-04
Arsenic	2.08E-05	Flyer testing	2.10E-02	5.24E-03
Barium	6.36E-06	Flyer testing	6.41E-03	1.60E-03
Beryllium	3.2E-07	AP-42 EF B627	3.23E-04	8.06E-05
Cadmium	1.99E-06	Flyer testing	2.01E-03	5.01E-04
Chromium	1.40E-06	Flyer testing	1.41E-03	3.53E-04
Copper	3.07E-03	Flyer testing	3.09E+00	7.74E-01
Hexavalent chromium	3.95E-07	Flyer testing	3.98E-04	9.95E-05
Lead	1.02E-02	Flyer testing	1.03E+01	2.57E+00
Manganese	3.41E-07	Flyer testing	3.44E-04	8.59E-05
Molybdenum	8.50E-07	Flyer testing	8.57E-04	2.14E-04
Phosphorous	4.24E-06	Flyer testing	4.27E-03	1.07E-03
Silver	1.27E-06	Flyer testing	1.28E-03	3.20E-04

TABLE 2-4 (CONTINUED)
COPC EMISSION FACTORS AND EMISSION RATES FOR THE MPRA

COPC	Emission Factor (lb/lb NEW)	Source [1]	Emission Rate (g/s)	
			Propellant Burn	Skid Burn
Metals (continued)				
Strontium	1.51E-06	Flyer testing	1.52E-03	3.81E-04
Tin	9.13E-07	Flyer testing	9.20E-04	2.30E-04
Zinc	7.60E-06	Flyer testing	7.66E-03	1.92E-03
Other Inorganics				
Ammonia	1.0E-02	AP-42 EF D541	1.01E+01	2.52E+00
Cyanide	2.9E-04	AP-42 EF D541	2.92E-01	7.31E-02
Hydrogen chloride	4.59E-04	Flyer testing	4.63E-01	1.16E-01
Hydrogen cyanide	3.7E-03	AP-42 EF D541	3.73E+00	9.32E-01
Hydrogen fluoride	4.8E-05	AP-42 EF B642	4.84E-02	1.21E-02
Sulfuric acid (skid burn only)	5.2E-03	AP-42 EF A010	0.00E+00	1.31E+00

1 For all AP-42 emission factors from the M3 and M3A1 155-mm propelling charge (DODIC D540), while preparing the MPRA calculations, multiple errors were noted in the PDF emission factor summary on the USEPA AP-42 website. These appear to be transcription errors from the FP-5 source datasheets to the PDF document. All AP-42 D540 emission factors stated herein are based on the emission factor data presented in the FP-5 emission factor spreadsheet provided on the AP-42 website, which was specified in the PDF summary as the source of the emission factor data.

2 The MPRA protocol originally specified emission factors from DODIC A065 (M862 5.56-mm practice ball cartridge), DODIC A066 (M193 5.56-mm Ball Cartridge), DODIC A068 (M196 5.56-mm tracer cartridge), DODIC A080 (M200 5.56-mm blank cartridge), or DODIC H459 (2.75-inch Flechette, MK40 Mod 3 Motor) for this compound. However, upon examination of the military specification for these items, the items do not contain RFAAP product. Therefore, the AP-42 factors for these DODICs were not included in the assessment.

2.2.2 SELECTION OF TOXICITY FACTORS

Toxicity factors were used in the MPRA to calculate the total incremental risk and hazard to selected receptors. The chronic exposure toxicity factors for each COPC are identified in Table 2-5 and were obtained from the USEPA Region 3 regional screening level (RSL) tables as directed by VDEQ. Acute inhalation exposure criteria (AIEC) were obtained from the National Oceanic and Atmospheric Administration's (NOAA's) Protective Action Criteria (PACs), which is hierarchy-based system of the three common public exposure guideline systems: acute exposure guideline levels (AEGLs), emergency response planning guidelines (ERPGs), and temporary emergency exposure limits (TEELs). For determination of total incremental risk, data was collected on the cancer slope factors (CSFs) for ingestion and inhalation of each COPC. In some cases, separate data on an inhalation CSF was not available. In these cases, the CSF for ingestion was applied if the COPC is classified as a potential carcinogen via the inhalation pathway. For determination of total incremental hazard, data was collected on reference doses (RfDs) and reference concentrations (RfCs). The reference doses used were for ingestion of food and ingestion of drinking water. RfCs apply to hazard resulting from inhalation of COPCs.

TABLE 2-5
TOXICITY DATA FOR MPRA COPCS

COPC	CANCER SLOPE FACTORS [1]			REFERENCE DOSES/CONCENTRATIONS [2]			AIEC [3]
	INGESTION	INHALATION	D. WATER	INGESTION	INHALATION	D. WATER	
Dioxins and Furans							
1,2,3,7,8-PeCDF [4]	1.3E+05	1.8E+05	1.3E+05	0.0E+00	0.0E+00	0.0E+00	0.05
2,3,4,7,8-PeCDF [4]	1.3E+05	1.8E+05	1.3E+05	0.0E+00	0.0E+00	0.0E+00	0.005
Polynuclear Aromatic Hydrocarbons							
Benzo(a)pyrene	1.0E+00	2.1E+00	7.3E+00	3.0E-04	2.0E-06	3.0E-04	0.6
Benz(a)anthracene	1.0E-01	2.1E-01	1.0E-01	0.0E+00	0.0E+00	0.0E+00	0.6
Benzo(b)fluoranthene	1.0E-01	2.1E-01	1.0E-01	0.0E+00	0.0E+00	0.0E+00	0.6
Benzo(k)fluoranthene	1.0E-02	2.1E-02	1.0E-02	0.0E+00	0.0E+00	0.0E+00	0.6
Chrysene	1.0E-03	2.1E-03	1.0E-03	0.0E+00	0.0E+00	0.0E+00	0.6
Dibenz(a,h)anthracene	1.0E+00	2.1E+00	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.093
Indeno(1,2,3-cd)pyrene	1.0E-01	2.1E-01	1.0E-01	0.0E+00	0.0E+00	0.0E+00	1.2
Nitroaromatics							
2-Nitrophenol	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1
Pyridine	0.0E+00	0.0E+00	0.0E+00	1.0E-03	3.5E-03	1.0E-03	3
Phthalates							
Bis-2-Ethylhexyl phthalate	1.4E-02	8.4E-03	1.4E-02	2.0E-01	7.0E-01	2.0E-01	10
Butyl benzyl phthalate	1.9E-03	1.9E-03	1.9E-03	2.0E-01	7.0E-01	2.0E-01	15
Dibutyl phthalate	0.0E+00	0.0E+00	0.0E+00	1.0E-01	3.5E-01	1.0E-01	15
Diethyl phthalate	0.0E+00	0.0E+00	0.0E+00	8.0E-01	2.8E+00	8.0E-01	15
Dimethyl phthalate	0.0E+00	0.0E+00	0.0E+00	1.0E+01	3.5E+01	1.0E+01	15
Dioctyl phthalate	0.0E+00	0.0E+00	0.0E+00	1.0E-02	3.5E-02	1.0E-02	41
Other Semivolatile and Volatile Organics							
1,2,4-Trimethylbenzene	0.0E+00	0.0E+00	0.0E+00	1.0E-02	6.0E-02	1.0E-02	140
1,3,5-Trimethylbenzene	0.0E+00	0.0E+00	0.0E+00	1.0E-02	6.0E-02	1.0E-02	140
1,3-Butadiene	3.4E+00	1.1E-01	0.0E+00	5.7E-04	2.0E-03	5.7E-04	670
1,4-Dioxane	1.0E-01	1.8E-02	1.1E-02	3.0E-02	3.0E-02	3.0E-02	17
2-Butanone	0.0E+00	0.0E+00	0.0E+00	6.0E-01	5.0E+00	6.0E-01	200
2-Methylnaphthalene	0.0E+00	0.0E+00	0.0E+00	4.0E-03	1.4E-02	4.0E-03	9
4-Methyl-2-pentanone	0.0E+00	0.0E+00	0.0E+00	8.0E-02	3.0E+00	8.0E-02	75
Acenaphthene	0.0E+00	0.0E+00	0.0E+00	6.0E-02	2.1E-01	6.0E-02	3.6
Acetaldehyde	0.0E+00	7.7E-03	0.0E+00	4.0E-02	9.0E-03	4.0E-02	45
Acetone	0.0E+00	0.0E+00	0.0E+00	9.0E-01	3.1E+01	9.0E-01	200

TABLE 2-5 (CONTINUED)
TOXICITY DATA FOR MPRA COPCS

COPC	CANCER SLOPE FACTORS [1]			REFERENCE DOSES/CONCENTRATIONS [2]			AIEC [3]
	INGESTION	INHALATION	D. WATER	INGESTION	INHALATION	D. WATER	
Other Semivolatile and Volatile Organics (continued)							
Acetonitrile	0.0E+00	0.0E+00	0.0E+00	1.7E-02	6.0E-02	1.7E-02	13
Acrolein	0.0+00	0.0+00	0.0+00	2.0E-02	2.0E-05	2.0E-02	0.03
Acrylonitrile	5.4E-01	2.4E-01	5.3E-01	1.0E-03	2.0E-03	1.0E-03	0.15
Anthracene	0.0E+00	0.0E+00	0.0E+00	3.0E-01	1.1E+00	3.0E-01	48
Benzene	5.5E-02	2.7E-02	3.6E-02	4.0E-03	3.0E-02	4.0E-03	52
Carbon tetrachloride	7.0E-02	2.1E-02	1.3E-01	4.0E-03	1.0E-01	4.0E-03	1.2
Chloroethane	0.0E+00	0.0E+00	0.0E+00	4.0E-01	1.0E+01	4.0E-01	300
Chloroform	3.1E-02	8.1E-02	3.1E-02	1.0E-02	9.8E-02	1.0E-02	2
Chloromethane	1.3E-02	6.3E-03	1.3E-02	2.6E-03	9.0E-02	2.6E-03	150
Crotonaldehyde	1.9E+00	1.9E+00	0.0E+00	1.0E-03	3.5E-03	1.0E-03	0.19
Cumene	0.0E+00	0.0E+00	0.0E+00	1.0E-01	4.0E-01	1.0E-01	50
Dichlorodifluoromethane	0.0E+00	0.0E+00	0.0E+00	2.0E-01	1.0E-01	2.0E-01	3,000
Ethyl acrylate	0.0E+00	0.0E+00	0.0E+00	5.0E-03	8.0E-03	5.0E-03	8.3
Ethylbenzene	1.1E-02	8.8E-03	1.1E-02	1.0E-01	1.0E+00	1.0E-01	33
Fluoranthene	0.0E+00	0.0E+00	0.0E+00	4.0E-02	1.4E-01	4.0E-02	8.2
Formaldehyde	1.3E-05	4.6E-02	1.3E-05	2.0E-01	9.8E-03	2.0E-01	0.9
n-Hexane	0.0E+00	0.0E+00	0.0E+00	2.0E-01	7.0E-01	2.0E-01	260
Methylene chloride	2.0E-03	3.5E-05	7.4E-03	6.0E-03	6.0E-01	6.0E-03	200
Naphthalene	1.2E-01	1.2E-01	1.2E-01	2.0E-02	3.0E-03	2.0E-02	15
Phenanthrene	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.4
Phenol	0.0E+00	0.0E+00	0.0E+00	3.0E-01	2.0E-01	3.0E-01	15
Propionaldehyde	0.0E+00	0.0E+00	0.0E+00	2.3E-03	8.0E-03	2.3E-03	45
Pyrene	0.0E+00	0.0E+00	0.0E+00	3.0E-02	1.1E-01	3.0E-02	0.15
Styrene	0.0E+00	0.0E+00	0.0E+00	2.0E-01	1.0E+00	2.0E-01	20
Tetrachloroethene	2.1E-03	9.1E-04	2.1E-03	6.0E-03	4.0E-02	6.0E-03	35
Tetrahydrofuran	7.6E-03	6.7E-03	7.6E-03	9.0E-01	2.0E+00	9.0E-01	100
Toluene	0.0E+00	0.0E+00	0.0E+00	8.0E-02	5.0E+00	8.0E-02	67
Trichlorofluoromethane	0.0E+00	0.0E+00	0.0E+00	3.0E-01	7.0E-01	3.0E-01	91
m,p-Xylenes	0.0E+00	0.0E+00	0.0E+00	2.0E-01	1.0E-01	2.0E-01	130
o-Xylene	0.0E+00	0.0E+00	0.0E+00	2.0E-01	1.0E-01	2.0E-01	130
Xylenes	0.0E+00	0.0E+00	0.0E+00	2.0E-01	1.0E-01	2.0E-01	130

TABLE 2-5 (CONTINUED)
TOXICITY DATA FOR MPRA COPCS

COPC	CANCER SLOPE FACTORS [1]			REFERENCE DOSES/CONCENTRATIONS [2]			AIEC [3]
	INGESTION	INHALATION	D. WATER	INGESTION	INHALATION	D. WATER	
Metals							
Aluminum	0.0E+00	0.0E+00	0.0E+00	1.0E+00	5.0E-03	1.0E+00	3
Antimony	0.0E+00	0.0E+00	0.0E+00	4.0E-04	1.4E-03	4.0E-04	1.5
Arsenic	1.5E+00	1.5E+01	1.8E+00	3.0E-04	1.5E-05	3.0E-04	1.5
Barium	0.0E+00	0.0E+00	0.0E+00	2.0E-01	5.0E-04	2.0E-01	1.5
Beryllium	0.0E+00	8.4E+00	0.0E+00	2.0E-03	2.0E-05	2.0E-03	0.0023
Cadmium	3.8E-01	6.3E+00	3.8E-01	1.0E-03	1.0E-05	5.0E-04	0.1
Chromium	0.0E+00	0.0E+00	0.0E+00	1.5E+00	5.3E+00	1.5E+00	1.5
Copper	0.0E+00	0.0E+00	0.0E+00	4.0E-02	1.4E-01	4.0E-02	3
Hexavalent chromium	5.0E-01	2.9E+02	5.0E-01	3.0E-03	1.0E-04	3.0E-03	0
Lead	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.15
Manganese	0.0E+00	0.0E+00	0.0E+00	1.4E-01	5.0E-05	2.4E-02	3
Molybdenum	0.0E+00	0.0E+00	0.0E+00	5.0E-03	1.8E-02	5.0E-03	30
Phosphorous	0.0E+00	0.0E+00	0.0E+00	2.0E-05	7.0E-05	2.0E-05	0.27
Silver	0.0E+00	0.0E+00	0.0E+00	5.0E-03	1.8E-02	5.0E-03	0.3
Strontium	0.0E+00	0.0E+00	0.0E+00	6.0E-01	2.1E+00	6.0E-01	30
Tin	0.0E+00	0.0E+00	0.0E+00	6.0E-01	2.1E+00	6.0E-01	6
Zinc	0.0E+00	0.0E+00	0.0E+00	3.0E-01	5.3E+00	3.0E-01	6
Other Inorganics							
Ammonia	0.0E+00	0.0E+00	0.0E+00	1.7E-01	6.0E-01	1.7E-01	30
Cyanide	0.0E+00	0.0E+00	0.0E+00	6.0E-04	8.0E-04	6.0E-04	6
Hydrogen chloride	0.0E+00	0.0E+00	0.0E+00	5.7E-03	2.0E-02	5.7E-03	1.8
Hydrogen cyanide	0.0E+00	0.0E+00	0.0E+00	6.0E-04	8.0E-04	6.0E-04	2
Hydrogen fluoride	0.0E+00	0.0E+00	0.0E+00	4.0E-02	1.4E-02	4.0E-02	1
Sulfuric acid (skid burn only)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-03	0.0E+00	0.2

1 All cancer slope factors are presented in the units of $(mg/kg\text{-}BW/day)^{-1}$.

2 All reference doses are presented in the units of mg/kg-BW/day. All reference concentrations are presented in the units of mg/m^3.

3 All acute inhalation exposure criteria are presented in the units of mg/m^3.

4 Values shown are for tetrachlorodibenzo(p)dioxin (TCDD). The concentration of these COPCs is adjusted to TCDD toxic equivalents (TEQs) using the toxicity equivalent factors (TEFs) of 0.03 and 0.3, respectfully, as explained in the MPRA Protocol

3.0 AIR MODELING

The first step in the MPRA process is the modeling of air emissions from the OBG. The protocol for this modeling effort was described in the *Multipathway Risk Assessment Protocol for the Radford Army Ammunition Plant*, approved for the human health assessment in February 2019 (VDEQ, 2019). A memorandum documenting the process and the results of the air modeling was submitted to VDEQ in October 2018 (RFAAP, 2018a). Approval of the air modeling was subsequently received on December 14, 2018 (VDEQ, 2018a). This section details the air modeling process that was used by RFAAP and approved by VDEQ. A complete copy of the air modeling files for this MPRA are provided in Appendix A**.**

3.1 METHODOLOGY

The modeling of the open burning operations at Radford was completed using the Open Burn and Open Detonation Model (OBODM version 01.3.0024). Rationale supporting the use of OBODM for the RFAAP activities was provided to the VDEQ in a letter dated March 22, 2018 (RFAAP, 2018b), and the use of OBODM was approved by the VDEQ in a response dated May 8, 2018 (VDEQ, 2018b).

3.2 MODELED SCENARIOS

As per the MPRA Protocol, the OBODM modeling included two separate open burning scenarios (propellant burns and skid burns) and used five years of representative meteorological data and approved surrogate constituents to determine both vapor and particulate phase characteristics. The model output provided concentration and deposition values for 1-hour and annual averaging periods over an extensive receptor grid.

3.2.1 PROPELLANT BURNS

The first of the two modeled scenarios was the propellant, or dry burn. The propellant burn utilizes 8 of the 16 available burn pans, each burning up to 1,000 pounds of NEW during a single hour. These burns consist of dry propellant materials that burn quickly and generally consume all of the waste materials in a 30-second time frame. However, because some energetic material burns can last a bit longer in duration, OBODM was programmed to simulate the dry burn to last 300 seconds (5 minutes). The use of a longer burn time in OBODM will return lower plume heights and therefore typically larger downwind concentration and deposition values than shorter duration burns.

The 8-pan, 1,000-lb NEW per pan propellant burns were simulated for vapor phase surrogates using carbon dioxide (CO_2) as the surrogate. The scenario was simulated to occur each hour during the 10-hour daily available operating window each day of the year. The OBODM library of energetic materiel was applied and the propellant MK-23 was used as the surrogate energetic material with a CO_2 cloud fraction noted as 0.54. For the particulate phase simulation, aluminum was the surrogate constituent selected and the energetic family used ammonium perchlorate propellant containing aluminum with an aluminum cloud fraction shown to be 0.011.

3.2.2 Skid Burns

The second of the two modeled scenarios is referred to as the skid burn and includes a combination of energetic-contaminated hazardous waste, dunnage, and diesel fuel. These materials are placed on cardboard and spread on pallets in the burn pans to help increase airflow to the burn and enhance the aided combustion process. These burns happen in 2 of the 16 available burn pans, each holding up to 1,000-lb of NEW. These burns typically happen over the duration of a few minutes to several hours. However, because OBODM is limited to simulating a one-hour duration burn scenario, the skid burns were simulated to occur over the one-hour period.

The 2-pan, 1,000-lb NEW per pan skid burns were, like the propellant burn, simulated for vapor and particulate phases to occur each hour during the 10-hour daily operating window each day of the year. However, the skid burns used a common energetic family for both (diesel and dunnage). The vapor phase for the skid burn used CO_2 as the surrogate with a cloud fraction noted to be 1.5, whereas the particulate phase used zinc as the surrogate and a cloud fraction of 0.000063.

3.3 Modeled Burn Restrictions

Additional restrictions were introduced to the OBODM model simulations due to limitations that are placed on the open burning operations at the RFAAP. Open burning is limited to only daylight conditions and certain wind speed conditions. In addition, no open burning is permitted during precipitation events or if precipitation is anticipated.

Generally, all burns are conducted in the morning hours. However, as there are considerable safety precautions involved in preparing for treatment events, no specific window of operations is provided other than limiting burns to daylight hours (0800-1700 local time). As a result, OBODM was run to simulate a burn each hour of the day and derive the maximum downwind concentration and/or deposition value for any hour within that day. For the daily and annual averaging periods simulating a burn each hour of the day considerably overstates the actual activity level. However, adjustments were made in the post-processing of the OBDOM results to reduce this overestimation. (See discussions in Section 3.5 regarding post-processing of the data).

In regard to wind conditions, open burning is only permitted when wind speeds are between 3 and 15 miles per hour (mph). As a result, OBODM was setup such that it did not calculate concentration or deposition values for time periods when wind speeds were outside of the acceptable range of 3 mph to 15 mph.

While RFAAP is precluded from operations during precipitation events no accounting for this was included in the OBODM model for the five-year period of meteorological data as processed and provided by VDEQ (2011-2015). Modeling was conducted regardless of whether precipitation was occurring. While this likely overestimates the deposition term, it allows for unexpected rain events that may sometimes happen during a burn.

3.4 Receptor Grid

Receptor locations were placed in accordance with the MPRA Protocol and included 9,720 individual offsite receptor locations placed through a grid extending 10 kilometers from the OBG in all directions, representing a total modeled area of 400 square kilometers (over 150 square miles). Concentration and deposition values were calculated at each of the receptor locations. A representation of the modeled receptor grid is provided in Figure 3-1.

Because OBODM is limited to processing a maximum of 100 discrete receptor locations at once, a total of 98 individual receptor files were used in the OBODM modeling. The receptor elevations above mean sea level (MSL) were determined using the USEPA terrain processor AERMAP (version 18081) and were applied to each receptor location in the vapor phase OBODM modeling. As OBODM cannot apply terrain heights while simulating particulate concentration and deposition values, the terrain heights for the particulate runs were set to zero as were the source elevations to simulate flat terrain.

Given the 98 individual receptor files required and the two phases for each scenario modeled, more than 400 individual OBODM input files were necessary to complete the modeling. The first few receptor files that corresponded to the closest receptors to the open burning activity locations were modeled for individual years of the five-year period to understand any yearly variability and to allow for more detailed output viewing and retrieval. As it was found this was not necessary, the remaining input and receptor files were run using the full five years in a single iteration, allowing the model to determine the maximum values across the full five years.

3.5 Modeling Output

As with the input files, there were 98 separate output files from the OBODM modeling runs. The output files are similar in form and, given the same number of receptors, each output file except for the last receptor group was formatted similarly for the run type and averaging periods. Copies of each of the output files were provided to VDEQ with the original result submittal (RFAAP, 2018a) and are included in Appendix A of this report for completeness.

The modeled concentration and deposition values for each model run and averaging period were then extracted from the OBODM output files and processed in a spreadsheet format so that each output file returned an aggregated spreadsheet of results for each receptor location associated with that receptor file and for each averaging period of interest (1-hour and annual). A copy of the spreadsheets containing all of the modeled output are also included in Appendix A.

3.5.1 Post-Processing of Model Output

After all modeling is complete, the OBODM output must be adjusted to account for the use of a modeled surrogate (instead of each individual COPC) and to account for the actual operating scenario of one burn per day instead of one burn per hour of daylight operations. An explanation of these adjustments is provided below.

3.5.1.1 Surrogate Adjustments

As discussed previously, modeled concentrations from the OBODM files are based on the results of modeling the surrogate value as representative of other constituents that would behave in the atmosphere in a similar manner. To be able to calculate the concentrations or deposition values from the modeled surrogate requires adjustment of the OBODM output with the cloud fraction for each surrogate, noted earlier. For example, the vapor concentration values for the propellant burns utilized CO_2 as a surrogate, which has a cloud fraction of 0.54. Therefore, as modeled, the output data from OBODM presents results based on micrograms per cubic meter ($\mu g/m^3$) per fraction of CO_2 per averaging period.

To convert the air concentration to a normalized value that can be applied for any COPC requires that the modeled concentration be divided by the cloud fraction. This conversion from surrogate to "normal" values applies to deposition values as well, requiring that the modeled deposition term be divided by the cloud fraction for the specified surrogate. For deposition values it should be noted that OBODM calculated the deposition in terms of micrograms per square meter ($\mu g/m^2$), whereas the typical deposition metric is based on grams per square meter (g/m^2) and therefore the OBODM normalized values must also be converted to grams from the microgram output.

3.5.1.2 Actual vs. Simulated Activity

The normalized values must then be adjusted to account for differences in simulated activity at the OBG versus actual activity. For example, the OBODM simulation included a single burn for each hour of the 10-hour day, which means that for the typical 8-pan, 1,000-lb NEW per pan propellant burn a total of 80,000-lb NEW are simulated to be burned in day. The actual activity is limited however to a single hour in that 10-hour operating window. Therefore, the actual activity is 8,000-lb NEW per day of propellant burn, not the 80,000-lb NEW per day that was modeled.

To convert the modeled annual average concentration and deposition values to reflect the difference between the simulated activity and the actual activity, the normalized results must be adjusted by the ratio of actual NEW to simulated NEW (8,000/80,000 = 0.1). In addition, an adjustment is required to reflect the actual number of days of each type of burn. As discussed previously, RFAAP conducts two types of burns: propellant burns and skid burns. These two burns can never be conducted on the same day for two reasons:

- Safety restrictions prevent completion of propellant burns at the same time as skid burns, and

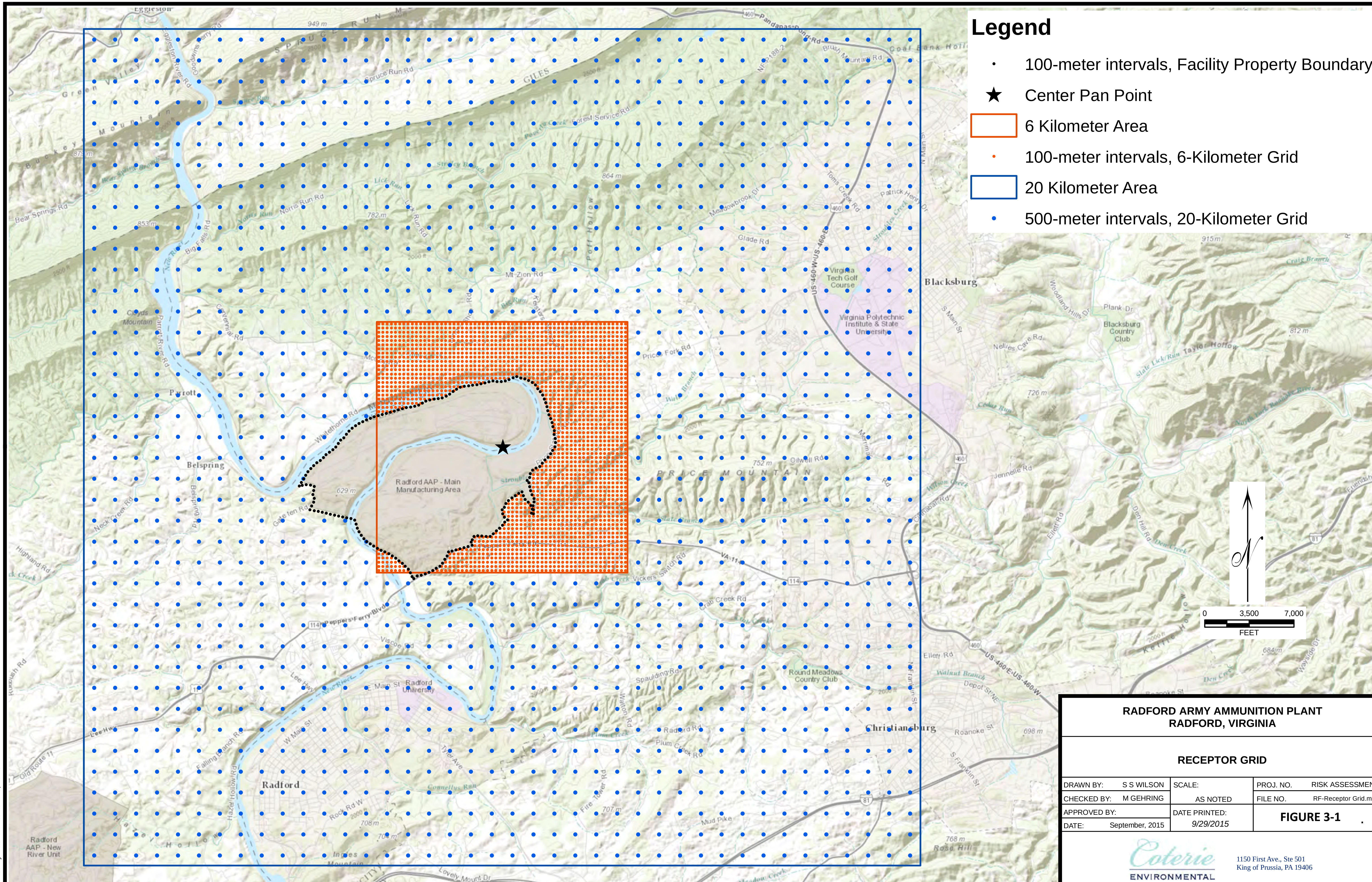
- The burn pans and the area immediately surrounding them cannot be accessed until 24 hours after a burn, hence preventing a scenario in which a propellant burn and a skid burn could be completed in a single day.

To provide a basis for the actual number of days per year that each type of burn is conducted, RFAAP conducted a review of the past six years of operating data. That review demonstrated that propellant burns are conducted with a much lower frequency than are skid burns, as the majority of propellant waste at the RFAAP is processed in the hazardous waste incinerators. In addition, the number of propellant burns has significantly declined over the past few years due to a new process that allows the primary manufactured propellant item that was processed in propellant burns to be cut and then ground for processing in the incinerator. Moving forward, RFAAP expects this process to continue and expects the overall number of propellant burns to continue to remain fairly minimal.

Based on this review, RFAAP modeled results for both the propellant burns and the skid burns under two different scenarios. The first scenario, shown in this report as Scenario "A", reflects completion of a skid burn each day of the year and completion of a propellant burn each day of the year, providing 365 days of operation for each type of burn. As discussed, this is extremely conservative and not physically possible, but was performed to reflect operation of the OBG without any restrictions on the number of operating days. The second scenario, shown in this report as Scenario "B", reflects completion of a skid burn and a propellant burn on alternating days per year, with 183 days of operation for each type of burn throughout the year. This is intended to provide a more representative assessment of the actual way in which the OBG functions for comparison purposes.

3.5.2 FINAL MODELED RESULTS

A summary of the normalized and adjusted results is provided graphically in Figures 3-2 through 3-13 and is detailed in the spreadsheets in Appendix A for each burn, modeling phase, and averaging period. As discussed further in Section 4, the MPRA assesses risk for various members of the population in different exposure scenarios. Each exposure scenario utilizes the air modeling results from various locations from throughout the assessment area based on the activity that the receptor being assessed is engaging in. The specific air modeling values utilized for each exposure scenario are provided in Section 4.



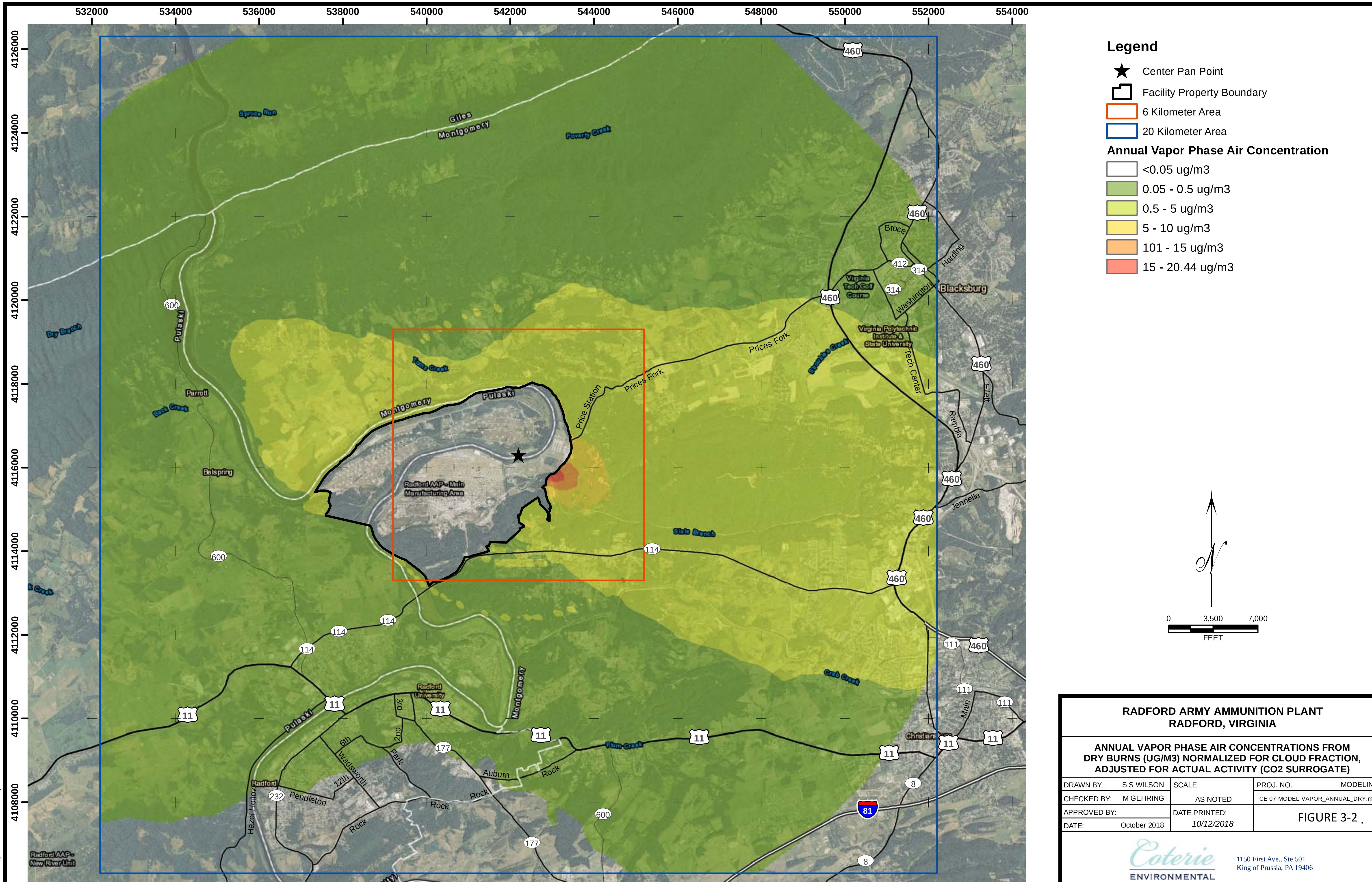
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

RECEPTOR GRID

DRAWN BY:	S S WILSON	SCALE:		PROJ. NO.	RISK ASSESSMENT
CHECKED BY:	M GEHRING		AS NOTED	FILE NO.	RF-Receptor Grid.mxd
APPROVED BY:		DATE PRINTED:		**FIGURE 3-1**	
DATE:	September, 2015		9/29/2015		

Coterie ENVIRONMENTAL
1150 First Ave., Ste 501
King of Prussia, PA 19406

J:\Prj\RFAAP\Risk Assessment\RF-Receptor Grid.mxd
Printed By: Laurie on 9/29/2015, 16:48 PM



RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

ANNUAL VAPOR PHASE AIR CONCENTRATIONS FROM DRY BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (CO2 SURROGATE)

DRAWN BY: S S WILSON	SCALE: AS NOTED	PROJ. NO. MODELING	CE-07-MODEL-VAPOR_ANNUAL_DRY.mxd
CHECKED BY: M GEHRING			
APPROVED BY:	DATE PRINTED: 10/12/2018	FIGURE 3-2	
DATE: October 2018			

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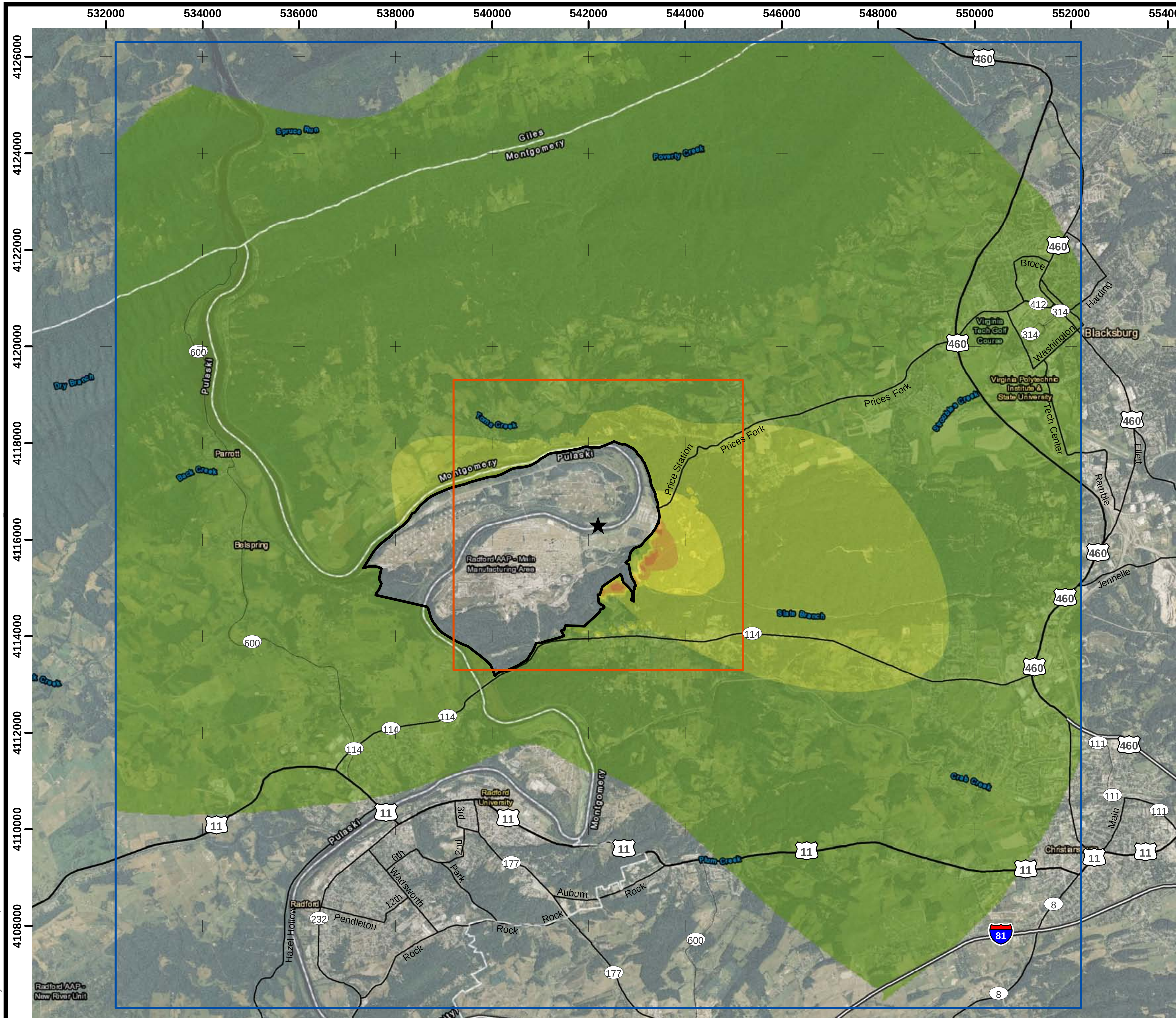
1150 First Ave., Ste 501
King of Prussia, PA 19406

J:\Prj\RFAAP\Modeling - Vapor\CE-07-MODEL-VAPOR_ANNUAL_DRY.mxd
Printed By: lauri on 10/12/2018, 16:44 PM



Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Annual Particulate Air Concentrations

- <0.1 ug/m3
- 0.1 - 1 ug/m3
- 1 - 4 ug/m3
- 4 - 8 ug/m3
- 8 - 12 ug/m3
- 12 - 16 ug/m3
- 16 - 17.25 ug/m3

N

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

ANNUAL PARTICULATE AIR CONCENTRATIONS FROM DRY BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (ALUMINUM SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO.	MODELING
CHECKED BY: M GEHRING	AS NOTED	CE-01-MODEL_ANNUAL_PART CONC DRY.mxd	
APPROVED BY:	DATE PRINTED: 10/15/2018	FIGURE 3-3	
DATE: October 2018			

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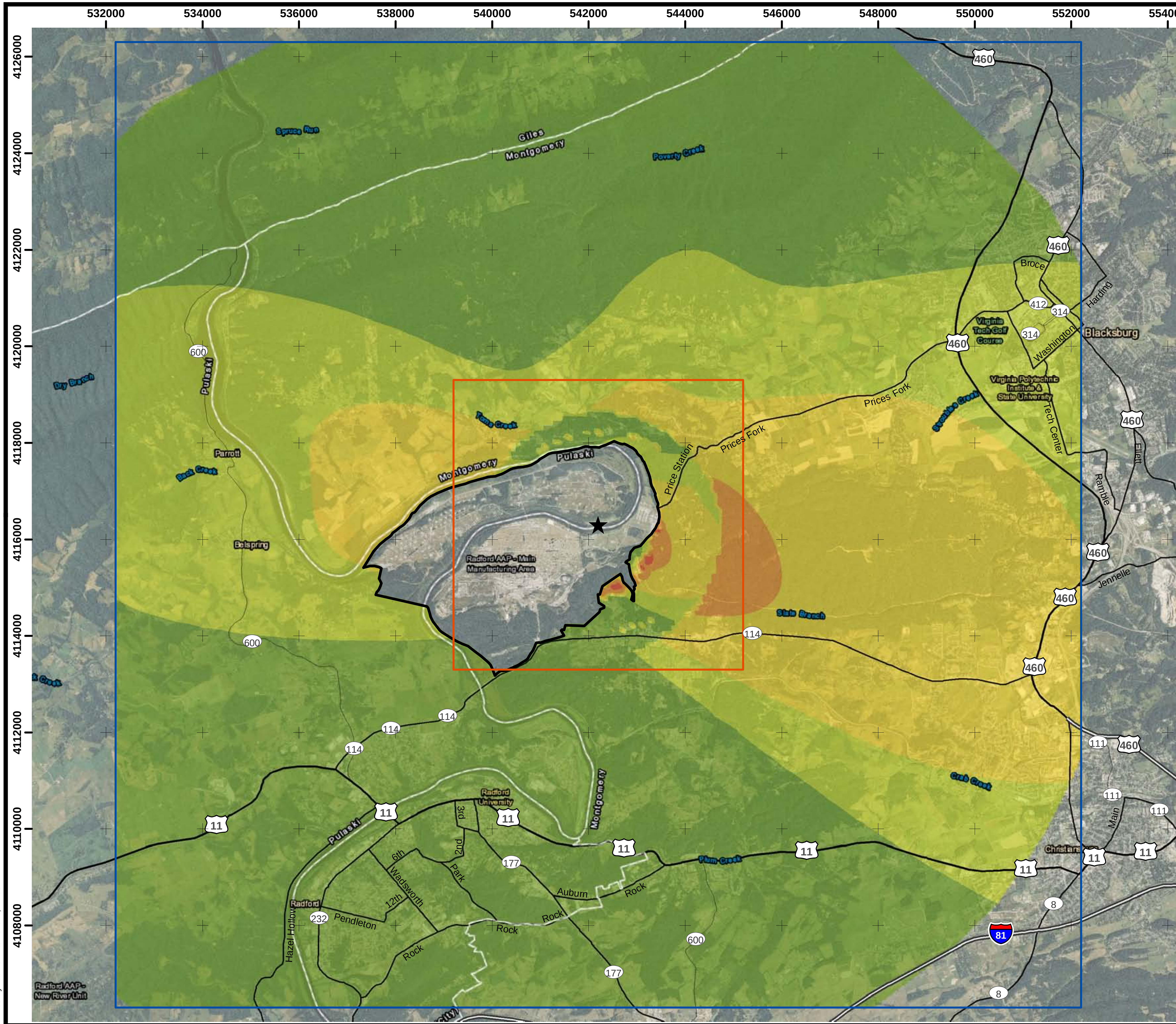

Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Annual Particulate Deposition

- <0.05 g/m2
- 0.05 - 0.5 g/m2
- 0.5 - 1 g/m2
- 1 - 3 g/m2
- 3 - 6 g/m2
- 6 - 9.155 g/m2

N

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

ANNUAL PARTICULATE DEPOSITION FROM DRY BURNS (G/M2) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (ALUMINUM SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO. MODELING
CHECKED BY: M GEHRING	AS NOTED	CE-09-MODEL_ANNUAL_PART DEP DRY.mxd
APPROVED BY:	DATE PRINTED:	FIGURE 3-4
DATE: October 2018	10/12/2018	

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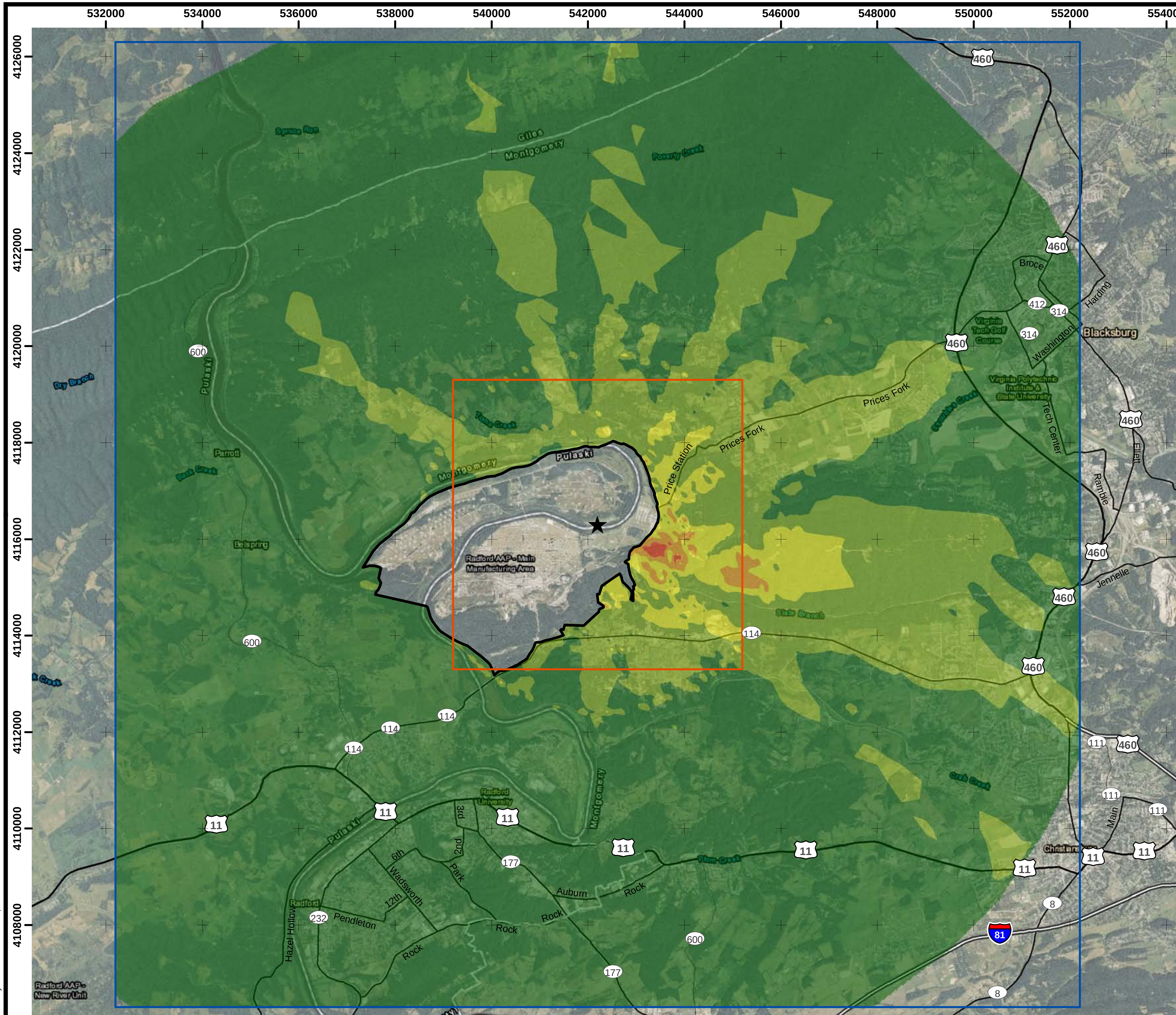

Legend

★ Center Pan Point

Facility Property Boundary

6 Kilometer Area

20 Kilometer Area

Hourly Vapor Phase Air Concentrations

- 0 - 2,100 ug/m3
- 2,100 - 4,200 ug/m3
- 4,200 - 6,300 ug/m3
- 6,300 - 8,400 ug/m3
- 8,400 - 10,419.44 ug/m3

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

HOURLY VAPOR PHASE AIR CONCENTRATIONS FROM DRY BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (CO2 SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO.	MODELING
CHECKED BY: M GEHRING	AS NOTED		CE-03-MODEL_VAPOR_CONC DRY.mxd
APPROVED BY:	DATE PRINTED: 10/15/2018	FIGURE 3-5	
DATE: October 2018			

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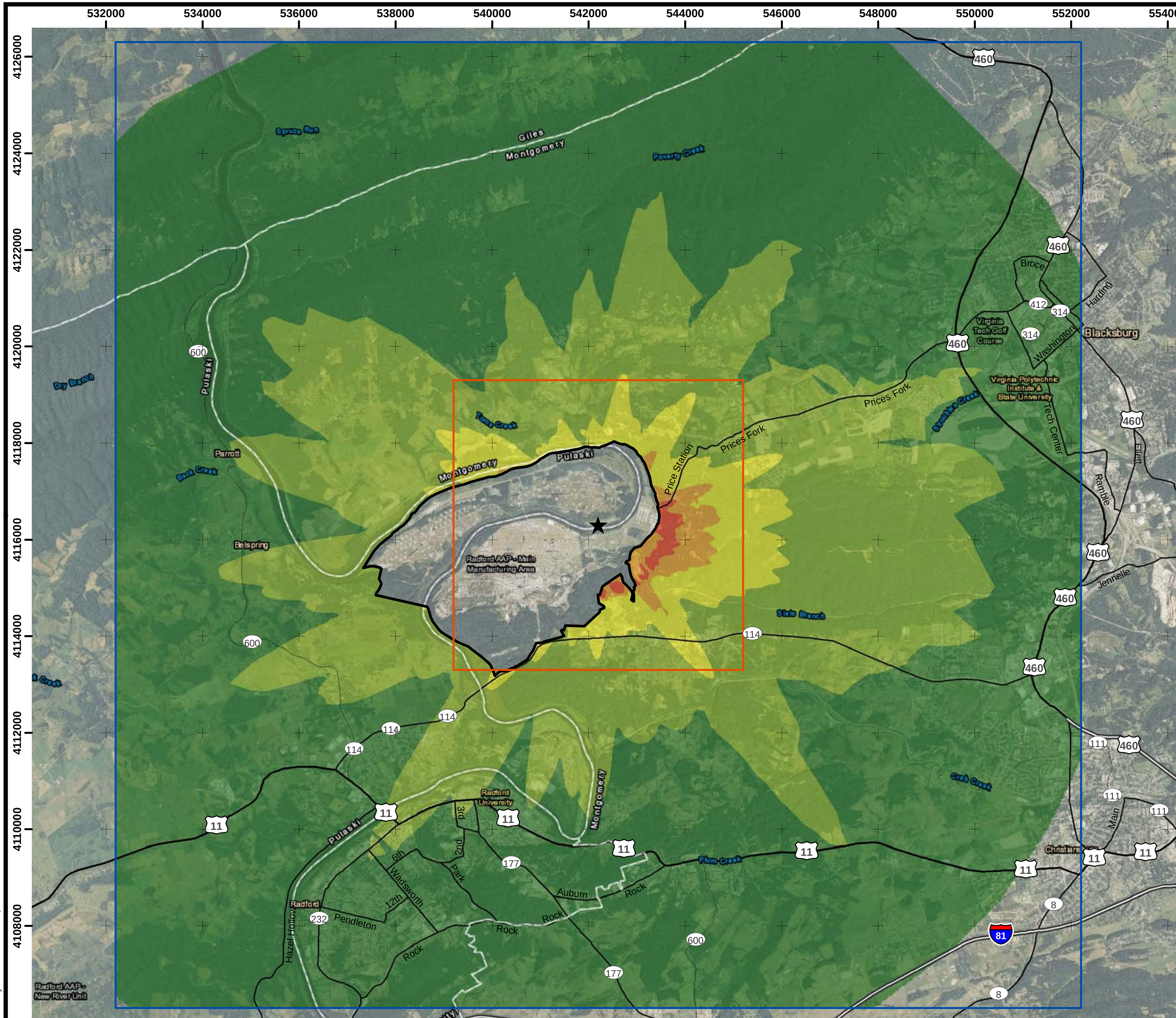

Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Hourly Particulate Air Concentrations

- 0 - 1,000 ug/m3
- 1,000 - 2,000 ug/m3
- 2,000 - 3,000 ug/m3
- 3,000 - 4,000 ug/m3
- 4,000 - 5,176.5 ug/m3

N

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

HOURLY PARTICULATE AIR CONCENTRATIONS FROM DRY BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (ALUMINUM SURROGATE)

DRAWN BY: S S WILSON	SCALE: AS NOTED	PROJ. NO. MODELING	CE-05-MODEL_HOURLY_PART CONC DRY.mxd
CHECKED BY: M GEHRING			
APPROVED BY:	DATE PRINTED: 10/15/2018	FIGURE 3-6	
DATE: October 2018			

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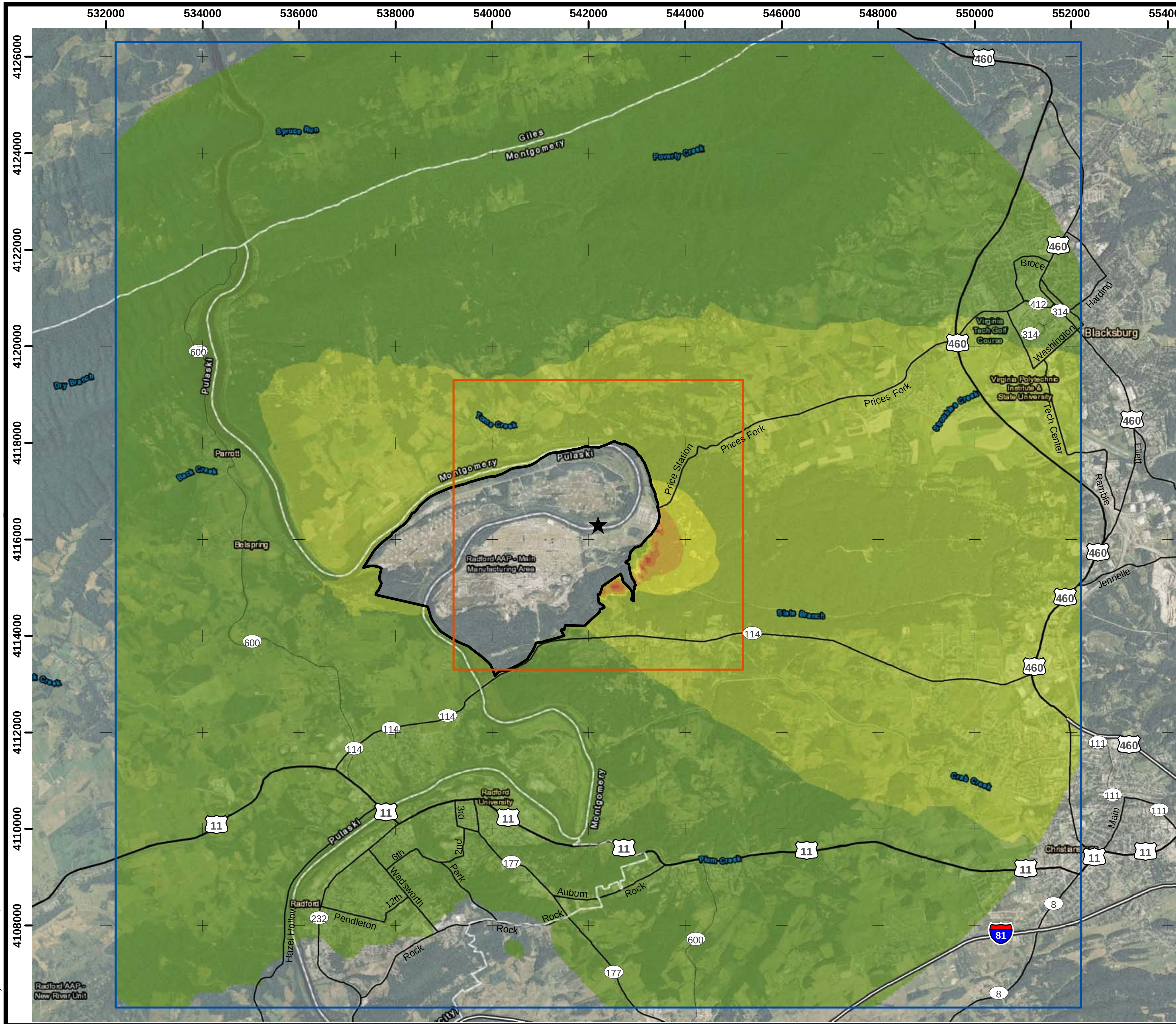

Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Annual Vapor Phase Air Concentration

- <0.01 ug/m3
- 0.01 - 0.1 ug/m3
- 0.1 - 1 ug/m3
- 1 - 2 ug/m3
- 2 - 4 ug/m3
- 4 - 6 ug/m3
- 6 - 7.712 ug/m3

N

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

ANNUAL VAPOR PHASE AIR CONCENTRATIONS FROM SKID BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (CO2 SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO. MODELING	
CHECKED BY: M GEHRING	AS NOTED	CE-06-MODEL-VAPOR_ANNUAL_SKID.mxd	
APPROVED BY:	DATE PRINTED:	FIGURE 3-7	
DATE: October 2018	10/12/2018		

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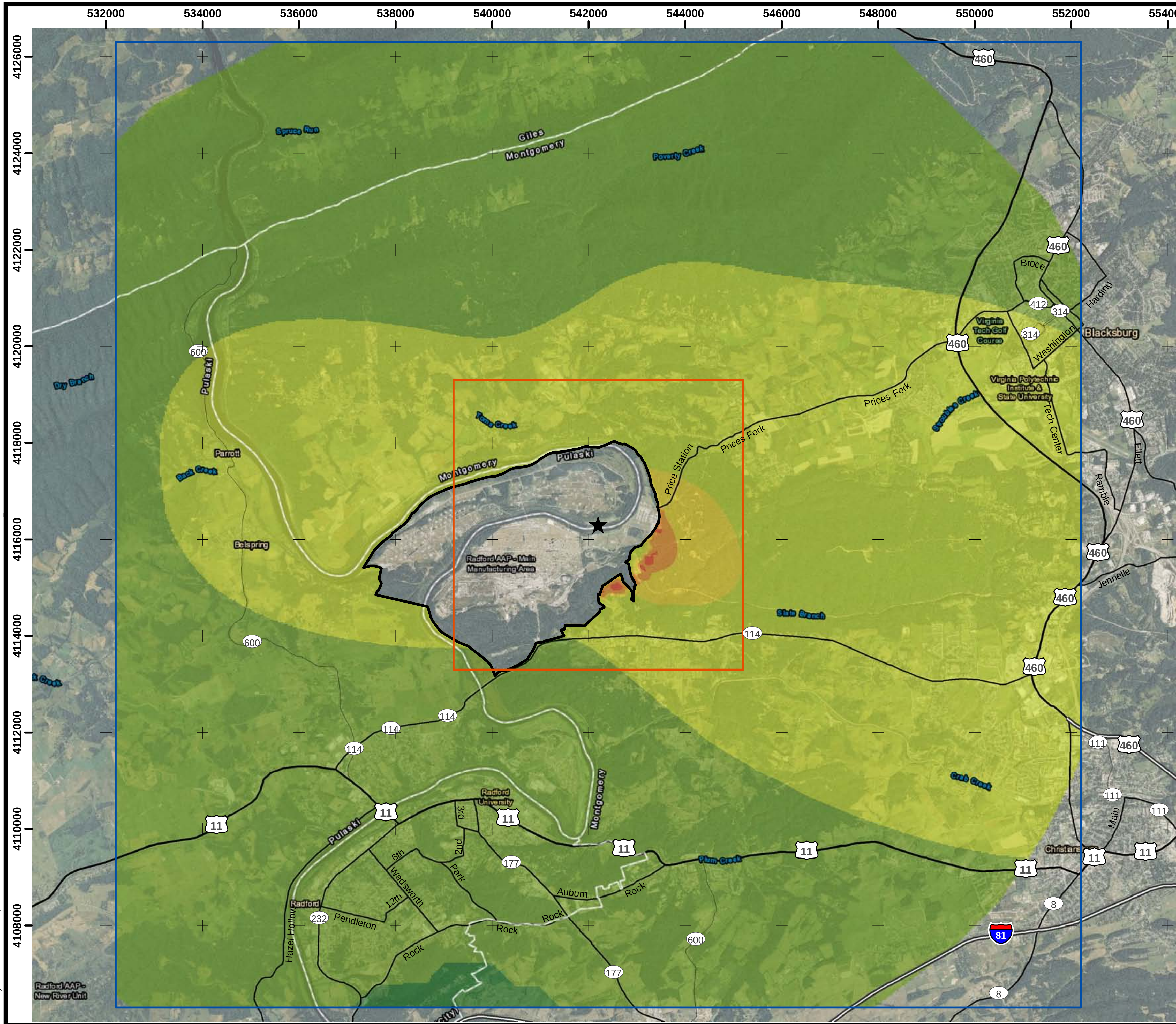

Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Annual Particulate Air Concentrations

- <0.01 ug/m3
- 0.01 - 0.1 ug/m3
- 0.1 - 1 ug/m3
- 1 - 3 ug/m3
- 3 - 6 ug/m3
- 6 - 9.23 ug/m3

N

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

ANNUAL PARTICULATE AIR CONCENTRATIONS FROM SKID BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (ZINC SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO.	MODELING
CHECKED BY: M GEHRING	AS NOTED	CE-10-MODEL_ANNUAL_PART CONC SKID.mxd	
APPROVED BY:	DATE PRINTED:	FIGURE 3-8	
DATE: October 2018	10/15/2018		

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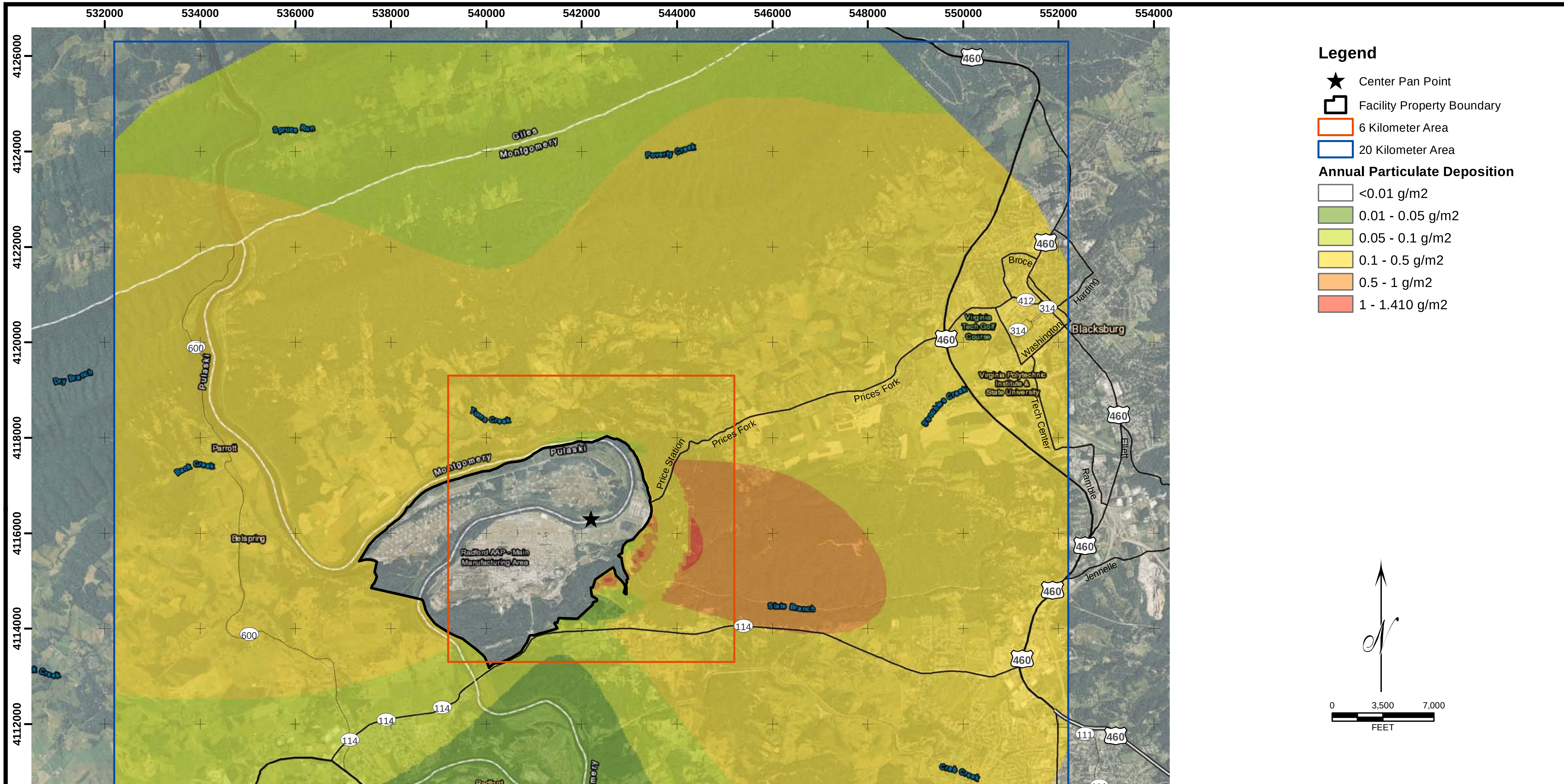

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

ANNUAL PARTICULATE DEPOSITION FROM SKID BURNS (G/M2) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (ZINC SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO. MODELING
CHECKED BY: M GEHRING	AS NOTED	CE-08-MODEL_ANNUAL_PART DEP SKID.mxd
APPROVED BY:	DATE PRINTED: 10/12/2018	FIGURE 3-9 .
DATE: October 2018		

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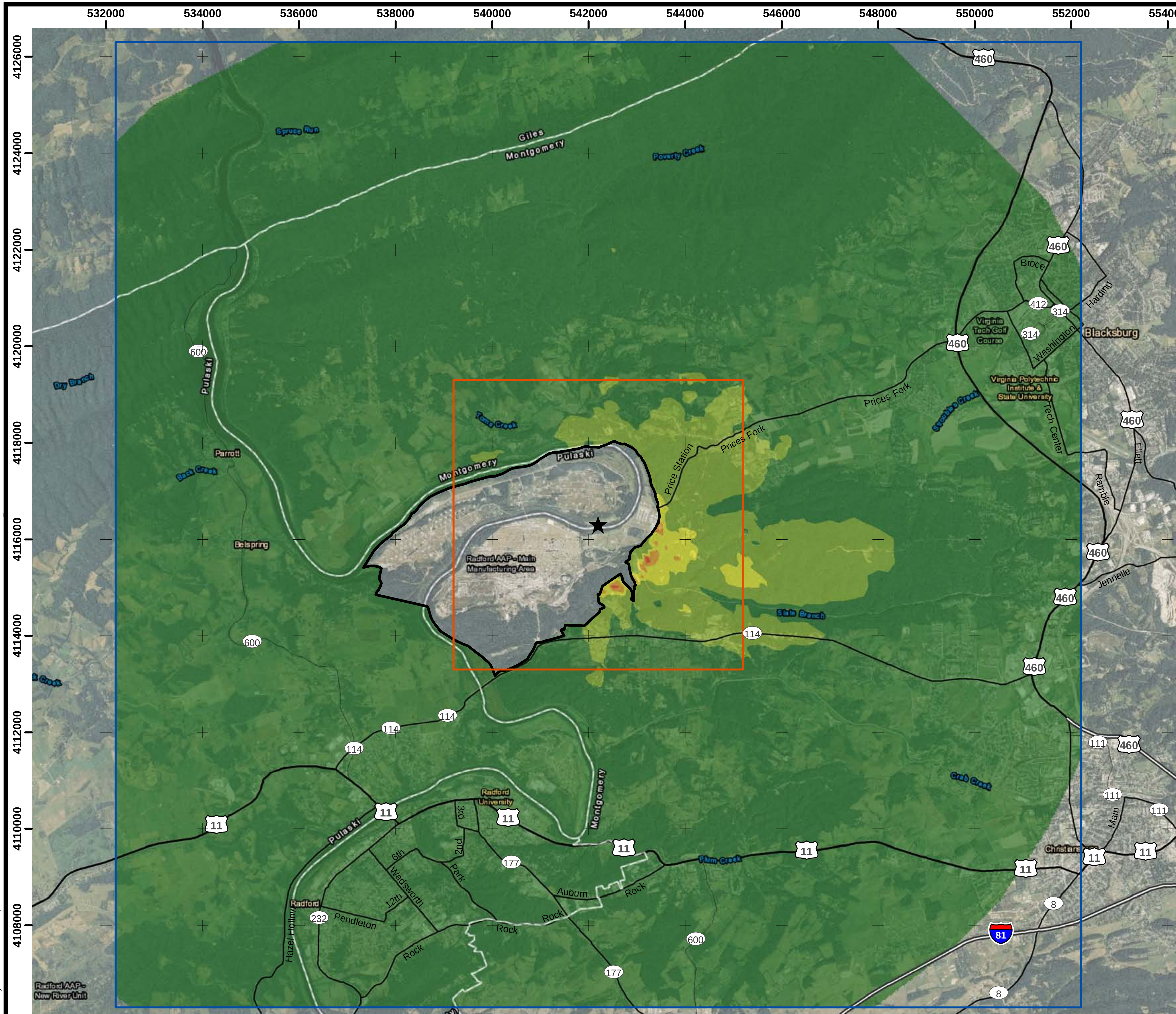

Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Hourly Vapor Phase Air Concentrations

- 0 - 500 ug/m3
- 500 - 1,000 ug/m3
- 1,000 - 1,500 ug/m3
- 1,500 - 2,000 ug/m3
- 2,000 - 2,491.17 ug/m3

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

HOURLY VAPOR PHASE AIR CONCENTRATIONS FROM SKID BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (CO2 SURROGATE)

DRAWN BY: S S WILSON	SCALE: AS NOTED	PROJ. NO. MODELING	
CHECKED BY: M GEHRING		CE-02-MODEL_VAPOR_CONC SKID.mxd	
APPROVED BY:	DATE PRINTED: 10/15/2018	FIGURE 3-10	
DATE: October 2018			

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1150 First Ave., Ste 501
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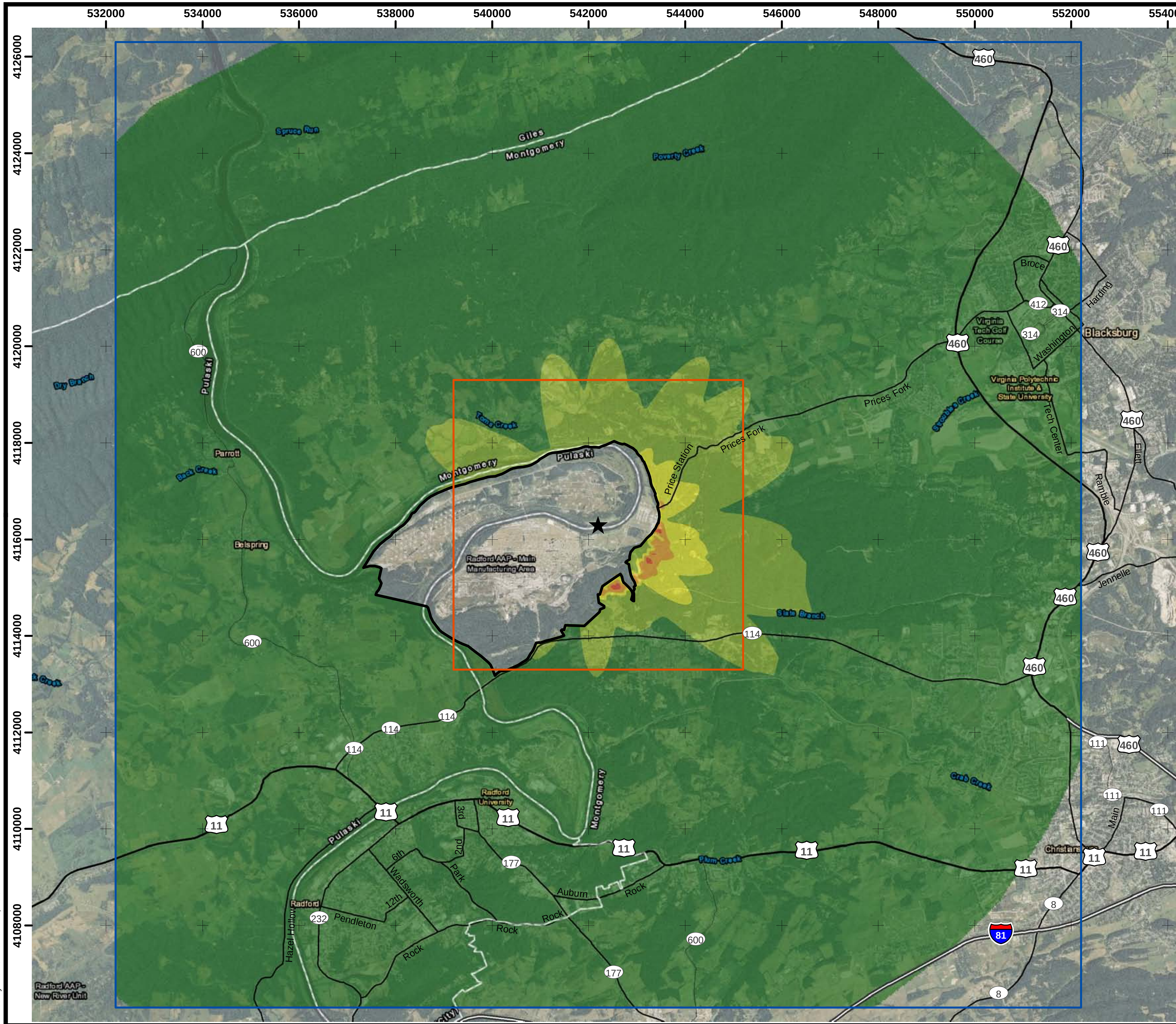
Printed By: lauri on 10/15/2018, 13:21 PM



J:\Prj\RFAAP\Modeling - Vapor\CE-04-MODEL_HOURLY_PART CONC SKID.mxd
Printed By: lauri on 10/15/2018, 13:31 PM

Legend

- ★ Center Pan Point
- Facility Property Boundary
- 6 Kilometer Area
- 20 Kilometer Area

Hourly Particulate Air Concentrations

- 0 - 700 ug/m3
- 700 - 1,400 ug/m3
- 1,400 - 2,100 ug/m3
- 2,100 - 2,800 ug/m3
- 2,800 - 3,386.25 ug/m3

N

0 3,500 7,000
FEET

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

HOURLY PARTICULATE AIR CONCENTRATIONS FROM SKID BURNS (UG/M3) NORMALIZED FOR CLOUD FRACTION, ADJUSTED FOR ACTUAL ACTIVITY (ZINC SURROGATE)

DRAWN BY: S S WILSON	SCALE:	PROJ. NO.	MODELING
CHECKED BY: M GEHRING	AS NOTED	CE-04-MODEL_HOURLY_PART CONC SKID.mxd	
APPROVED BY:	DATE PRINTED:	FIGURE 3-11	
DATE: October 2018	10/15/2018		

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4.0 EXPOSURE SCENARIOS

Before proceeding with the risk and hazard calculations, the surrounding land use and human activities were evaluated, and potential locations for each exposure scenario were identified. This section discusses the exposure scenarios that were evaluated in the MPRA and the methodology used to select the location for the assessment. Information is provided on the exposure setting characterization, the selected exposure scenarios, and the location of each.

4.1 CHARACTERIZATION OF EXPOSURE SETTING

A characterization of the exposure setting is necessary to determine the potential receptors and their expected types of exposure to the constituents being evaluated in the MPRA. Such a characterization includes identifying the potential receptors and the methods for exposure to the COPCs based on both current and reasonable future human activities and land uses. To complete the characterization, human activities, land use, and terrain characteristics, as well as the waterbody and watershed arrangement, were reviewed.

4.1.1 LAND USE AND HUMAN ACTIVITY

RFAAP occupies approximately 4,100 acres in Pulaski and Montgomery counties in southwest Virginia. The New River separates Pulaski and Montgomery Counties and divides the RFAAP into two portions commonly known as the Horseshoe Area and the Main Manufacturing Area. Nearby towns of Blacksburg, Christiansburg, and Roanoke serve as the primary population centers in the area. United States Census Bureau (USCB) data from the 2010 census was reviewed to determine local population demographics (USCB, 2010). Table 4-1 presents an overview of some of this data. As shown in the table, the majority of the population in both counties consists of adults between the ages of 18 and 65. The large discrepancy between the median age in Montgomery and Pulaski counties is largely contributed to the high student population attending Virginia Tech, with over 30,000 students enrolled in either undergraduate, graduate, or professional programs in 2010 (SCHEV, 2019). In comparison, Radford University, which is in Pulaski County, had a total enrollment of just over 9,000 students in 2010 (SCHEV, 2019).

TABLE 4-1
POPULATION DEMOGRAPHICS

PARAMETER	MONTGOMERY COUNTY	PULASKI COUNTY
Total population	94,392	34,872
Persons per square mile	244	109
Median age	27 years old	44 years old
Persons under 5 years old	4.7 percent of population	4.9 percent of population
Persons under 18 years old	16 percent of population	19 percent of population
Persons over 65 years old	9.8 percent of population	18 percent of population
Male: Female Ratio	1.07	0.978
Households	35,767	14,821
Persons per household	2.38	2.29
Households with persons under 18	24 percent of households	27 percent of households
Households with persons over 65	18 percent of households	31 percent of households

Montgomery and Pulaski counties also have a diverse business profile. Table 4-2 provides a summary of the 2016 economic census data provided by the USCB (USCB, 2016). As shown in the table, nearly 30 percent of Montgomery County is engaged in retail or professional, scientific, or technical services, with very limited establishments engaged in agriculture, forestry, fishing, and/or hunting. Pulaski county provides a much more even distribution of business sectors, but still shows very few businesses engaged in the agricultural sector.

TABLE 4-2
BUSINESS PROFILE

PARAMETER	MONTGOMERY COUNTY	PULASKI COUNTY
Total number of establishments	1,966	592
Agriculture, forestry, fishing, and hunting	7	0
Mining, quarrying, and oil/gas extraction	4	1
Utilities	1	3
Construction	173	53
Manufacturing	49	35
Wholesale trade	41	21
Retail trade	298	95
Transportation and warehousing	35	18
Information	45	10
Finance and insurance	112	33
Real estate and rental and leasing	97	25

TABLE 4-2 (CONTINUED)
BUSINESS PROFILE

PARAMETER	MONTGOMERY COUNTY	PULASKI COUNTY
Professional, scientific, and technical services	270	39
Management of companies and enterprises	8	0
Administration and support and waste management and remediation services	98	17
Educational services	26	4
Health care and social assistance	224	71
Arts, entertainment, and recreation	35	10
Accommodation and food services	211	71
Other services	227	84
Industries not classified	5	2

A review of the National Land Cover Data Set, aerial photographs, and local zoning maps was conducted to characterize the current and potential future land use patterns throughout the assessment area. This extensive review reveals that a large fraction (nearly 50 percent) of the area consists of deciduous, pine, or mixed forests, which are unsuitable for agricultural uses unless cleared. This grouping is followed by developed areas, which represent 36 percent of the land within assessment area. Only slightly over 10 percent of the land is currently used for agriculture.

4.1.2 TERRAIN CHARACTERISTICS

The RFAAP lies within the Ridge and Valley province of the great Appalachian Mountain region that extends from the Canadian maritime provinces south to northern Georgia and Alabama. Developed in the same Paleozoic basin as the Cumberland and Allegheny Mountains, the Ridge and Valley province was developed as the thick sedimentary deposits were extensively folded and then thrust faulted during the late Paleozoic orogeny. The ridge and valley alignments were determined by the long axes of these folds, while differential erosion of underlying bedrock formations controlled the structural development of current landforms. In this modern age, the region is characterized by long, parallel, narrow, even-crested ridges rising above intervening valleys of varying size. The linear strike-ridges are largely underlain by more resistant sandstones, quartzites, and shales, whereas the valleys are underlain by less resistant limestones, dolomites, and shales.

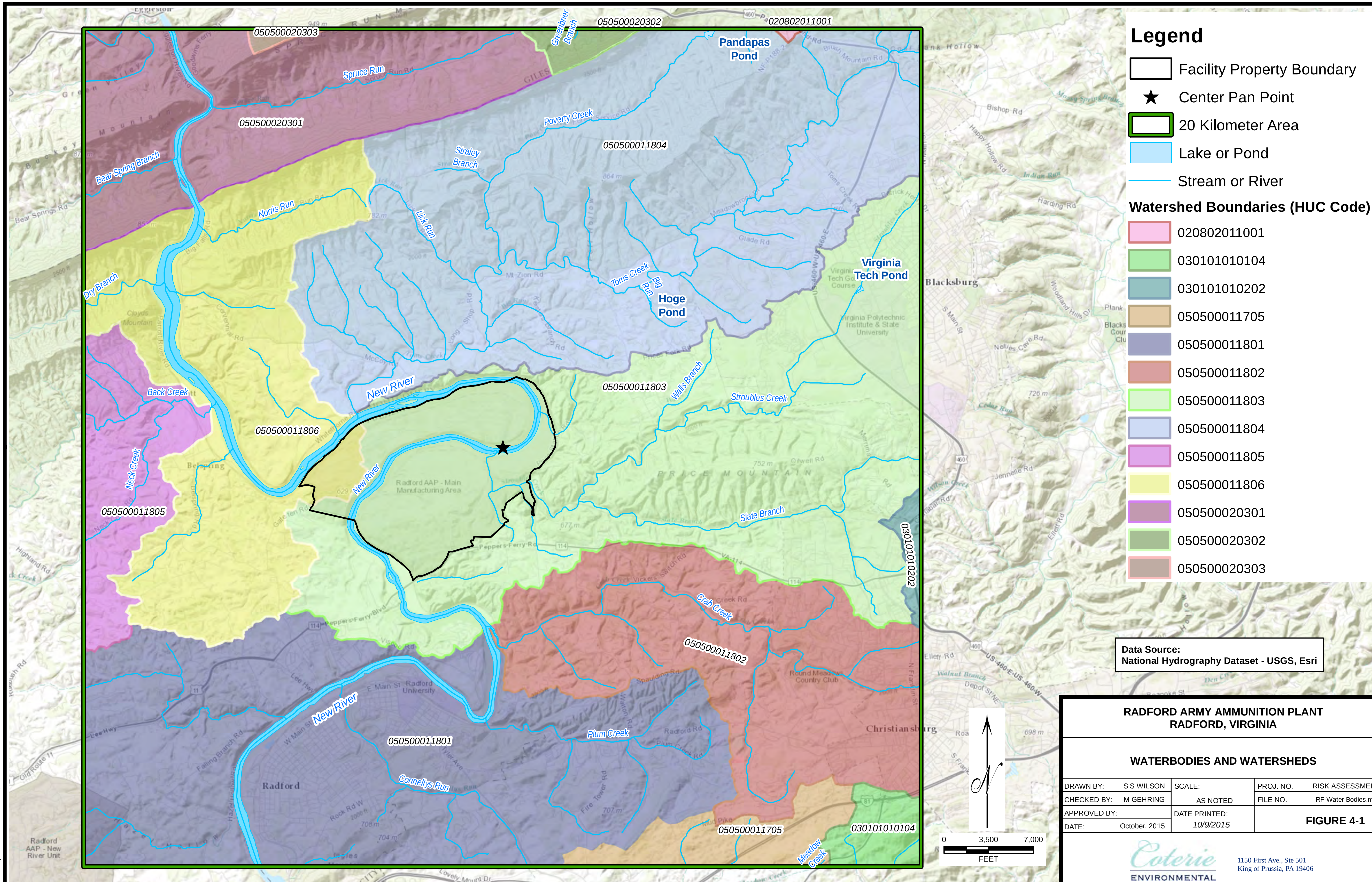
Much of the Ridge and Valley province lies at relatively low elevation (less than 3,000 feet mean sea level (ft-MSL)), with scattered peaks along the ridges between 4,000 and 4,600 ft-MSL. Within the assessment area, elevations range from approximately 1,600 ft-MSL up to 2,900 ft-MSL. The most significant rise in terrain is found north to northwest of the facility along Brush and Cloyds Mountains, which are part of the Appalachian ridgeline. A second, much smaller terrain rise is seen east to southeast of the facility along Price Mountain. The RFAAP lies in a narrow valley between these ridges. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long. The valley ranges from 8 miles wide at the southeast end to 2 miles wide in the northeast end. RFAAP lies along the New River in the relatively narrow northeastern corner of the valley.

4.1.3 Waterbodies and Watersheds

The southwestern Virginia mountains in which RFAAP is located are drained by west or south-flowing streams of the Ohio and Tennessee River systems, principally the New River, the Clinch River, the Powell River, and the forks of the Holston River. The New River actually flows through the RFAAP, dividing the Horseshoe and main plant areas. The systems within the assessment area drain through 12 hydrologic units that all empty to the New River, the James River, and the Roanoke River. Figure 4-1 provides a graphical representation of their arrangement. Because data on the flow and depth of each waterbody is limited, the MPRA only focused on those waterbodies with United States Geological Survey (USGS) or community monitored stream characteristics. In addition, the watershed of each waterbody was limited to the affected watershed located within the assessment area. Table 4-3 provides a summary of the hydrogeological data for each waterbody that was included in the assessment. A separate, discrete set of receptors was not required to capture impact to the identified waterbodies and watersheds; the main receptor grid discussed previously provided adequate coverage, with at least one or more receptors falling within or near each identified waterbody. RFAAP utilized geographic information systems to identify those receptors in each watershed and determined the total impact to each watershed accordingly.

Table 4-3
Waterbodies Included in the MPRA and their Characteristics

Waterbody Name	Impervious Watershed Area (m^2)	Total Watershed Area (m^2)	Waterbody Surface Area (m^2)	Depth of Water Column (m)	Current Velocity (m/s)	Average Flow Rate (m^3/yr)
Back Creek	1,294,994	42,216,804	100,032	1.129	0.226	64,295,399
Little River	336,698	10,100,953	263,135	0.630	0.228	467,927,623
Lick Run	258,999	5,956,972	13,504	0.891	0.039	3,482,667
New River	92,462,572	487,953,739	8,155,143	1.319	0.631	4,589,977,064



RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

WATERBODIES AND WATERSHEDS

DRAWN BY:	S S WILSON	SCALE:		PROJ. NO.	RISK ASSESSMENT
CHECKED BY:	M GEHRING	AS NOTED		FILE NO.	RF-Water Bodies.mxd
APPROVED BY:		DATE PRINTED:		**FIGURE 4-1**	
DATE:	October, 2015	10/9/2015			

Coterie ENVIRONMENTAL
1150 First Ave., Ste 501
King of Prussia, PA 19406

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4.1.4 Special Subpopulations

As with most communities, the population surrounding the RFAAP consists of several groups of people that may be more susceptible to the effects from OBG emissions than the general population. These include children that attend local elementary schools and day cares, children and adult patients at local hospitals, elderly persons residing at local nursing homes, and infants consuming their mother's breast milk. Table 4-4 identifies the special subpopulations found within the assessment area.

Table 4-4
Identification of Special Subpopulations

Name	Receptor Type	UTM E	UTM N
Early Challenges	Day care center	551,814	4,113,560
Christiansburg Mennonite School	Day care center	551,554	4,112,542
Cedarwood Preschool	Day care center	551,554	4,112,542
Carol's Family Day care	Day care center	548,967	4,108,859
New River Community Action	Day care center	537,715	4,109,806
Central United Methodist Preschool	Day care center	538,035	4,108,889
Radford Adventure Club	Day care center	538,227	4,108,383
Radford worship Center/Rock Club	Day care center	536,571	4,107,906
Children's Garden primary	Day care center	546,497	4,118,602
The Adventure Club	Day care center	550,305	4,121,042
Valley Interfaith Childcare	Day care center	549,064	4,118,921
St. Mary's Little Angels	Day care center	547,369	4,119,377
Commonwealth Assisted Living	Nursing home	551,762	4,112,621
Commonwealth Assisted Living	Nursing home	537,356	4,110,479
Warm Hearth Village	Nursing home	551,162	4,117,325
Carilion New River Valley Hospital	Hospital	539,467	4,109,745
LewisGale Montgomery Hospital	Hospital	552,396	4,115,835
Gilbert Linkous Elementary	Elementary school	550,979	4,120,906
Tall Oaks Montessori	Elementary school	549,298	4,118,722
Prices Fork Elementary	Elementary school	545,459	4,118,381
Kipps Elementary	Elementary school	546,497	4,118,602
McHarg Elementary	Elementary school	538,082	4,108,443
Belle Heth Elementary	Elementary school	539,279	4,109,668
Riverlawn Elementary	Elementary school	539,477	4,110,479
Belview Elementary	Elementary school	543,347	4,113,992

4.2 Exposure Scenarios

An exposure scenario is a combination of exposure pathways to which a single receptor may be subjected. An exposure pathway is the means by which a constituent moves from a source to a receptor. A completed exposure pathway has the following four elements:

- A constituent source and mechanism for release of the constituent;
- An environmental transport medium;
- A feasible route of potential exposure; and
- A specific point of exposure with an identified receptor.

The focus of the MPRA was to evaluate the potential effects that the OBG emissions could have on the health of humans residing and working offsite within the assessment area. In this respect two main groups of receptors were identified: general members of the population residing, farming, and fishing in the local community and special groups of receptors that may be more susceptible to the effects from OBG emissions.

4.2.1 Generic Receptors

Four general types of human health receptors were evaluated in the MPRA:

- Adult and children residents living at the maximum impacted offsite location(s) that could allow a domicile to be established. This could include any forested area, agricultural area, or urban area within the assessment area.
- Adult and children subsistence fishers residing at the maximum impacted offsite location(s) that could allow a domicile to be established and fishing surface waterbodies with the highest modeled fish tissue concentrations in the assessment area.
- Adult and children subsistence farmers residing at the maximum impacted offsite location(s) of agricultural land use or potential agricultural land use and subsisting off of homegrown produce and animal products grown and raised at this location.
- Adult and children acute receptors spending at least one hour at the offsite location with the highest hourly air concentrations.

Based upon a review of the land use and population demographics for the assessment area, it is highly unlikely that any subsistence farmers or fishers actually reside in the area. However, these exposure scenarios were included to provide reasonable maximum exposure (RME) estimates for the risk calculations.

The location at which each of these receptors were assessed was determined by superimposing the deposition and concentration model outputs onto topographic and land use maps. Combined, this data was used to select receptor locations that represent the RME to each type of offsite receptor.

Tables 4-5 and 4-6 identify the maximum impacted location(s) for each type of receptor in both the propellant and skid burn scenarios. Figure 4-2 shows each of these locations on a map.

Table 4-5
Locations and Modeling Data for
General Receptors in the MPRA Chronic Assessments

Receptor	Impact	UTM Location	Annual Average Modeling Results [1]			
			Vapor-Phase Concentration [2]	Particle-Phase Concentration [2]	Particle-Phase Deposition [3]	A/B
Propellant Burns						
Resident	Maximum vapor-phase air concentration	542,989E, 4,115,759N	0.020	0.00090	0.00037	A
			0.10	0.00045	0.00018	B
	Maximum particle-phase air concentration	542,500E, 4,115,000N	0.0015	0.017	0.0084	A
			0.00074	0.0084	0.0042	B
	Maximum deposition rate	543,200E, 4,115,600N	0.013	0.016	0.0086	A
			0.0066	0.0078	0.0043	B
Subsistence farmer	Maximum vapor-phase air concentration	543,200E, 4,115,700N	0.016	0.0022	0.00087	A
			0.0078	0.0011	0.00043	B
	Maximum particle-phase air concentration	542,500E, 4,115,000N	0.0015	0.017	0.0084	A
			0.00074	0.0084	0.0042	B
	Maximum deposition rate	543,200E, 4,115,600N	0.013	0.016	0.0086	A
			0.0066	0.0078	0.0043	B
Subsistence fisher	Maximum vapor-phase air concentration	542,989E, 4,115,759N	0.020	0.00090	0.00037	A
			0.10	0.00045	0.00018	B
	Maximum particle-phase air concentration	542,500E, 4,115,000N	0.0015	0.017	0.0084	A
			0.00074	0.0084	0.0042	B
	Maximum deposition rate	543,200E, 4,115,600N	0.013	0.016	0.0086	A
			0.0066	0.0078	0.0043	B

TABLE 4-5 (CONTINUED)
LOCATIONS AND MODELING DATA FOR GENERAL RECEPTORS IN THE MPRA CHRONIC ASSESSMENTS

RECEPTOR	IMPACT	UTM LOCATION	ANNUAL AVERAGE MODELING RESULTS [1]			
			VAPOR-PHASE CONCENTRATION [1]	PARTICLE-PHASE CONCENTRATION [1]	PARTICLE-PHASE DEPOSITION [2]	A/B
SKID BURNS						
Resident	Maximum air concentrations and deposition	542,500E, 4,115,000N	0.030	0.036	0.0054	A
			0.015	0.018	0.0027	B
Subsistence fisher	Maximum air concentrations and deposition	542,500E, 4,115,000N	0.030	0.036	0.0054	A
			0.015	0.018	0.0027	B
Subsistence farmer	Maximum air concentrations and deposition	542,500E, 4,115,000N	0.030	0.036	0.0054	A
			0.015	0.018	0.0027	B

1 Values presented in the "A" rows are associated with operating Scenario A (365 days per year operation per type of burn), and those presented in the "B" rows are associated with operating Scenario B (183 days per year operation per type of burn).

2 Units: micrograms per cubic meter per gram per second of pollutant emissions µg-s/(g-m^3)

3 Units: grams per square meter per second per gram per second of pollutant emissions (g/m^2/s)/(g/s)

TABLE 4-6
LOCATIONS AND MODELING DATA FOR GENERAL RECEPTORS IN THE MPRA ACUTE ASSESSMENTS

IMPACT	COORDINATES	HOURLY AVERAGE MODELING RESULTS	
		VAPOR-PHASE CONCENTRATION [1]	PARTICLE-PHASE CONCENTRATION [1]
PROPELLANT BURNS			
Maximum vapor-phase air concentration	543,400E, 4,115,700N	10.34	4.93
Maximum particle-phase air concentration	543,300E, 4,115,500N	6.17	5.14
SKID BURNS			
Maximum vapor-phase air concentration	543,200E, 4,115,600N	9.89	12.47
Maximum particle-phase air concentration	542,500E, 4,115,000N	9.11	13.44

1 Units: micrograms per cubic meter per gram per second of pollutant emissions µg-s/(g-m^3)

4.2.2 Special Subpopulations

As discussed previously, several types of subpopulations were also assessed in the MPRA. These included:

- Children and teachers at the most impacted school and day care center;
- Elderly residents at the most impacted nursing home; and
- Child and adult patients at the most impacted hospital.

Of the many special subpopulations identified within the assessment area, those that had the highest overall modeling results were included in the risk calculations. Table 4-7 identifies the most impacted receptors in each special subpopulation. The geographic coordinates for each were shown on Table 4-4 previously. Figure 4-3 shows each of the assessed subpopulations on a map.

Table 4-7
Locations and Modeling Data for Special Subpopulations

Subpopulation Name	Annual Average Modeling Results				Hourly Modeling Results	
	Vapor-Phase Conc. [2]	Particle-Phase Conc. [2]	Particle-Phase Deposition [3]	A/B	Vapor-Phase Conc. [2]	Particle-Phase Conc. [2]
Propellant Burns						
Cedarwood Preschool [4]	0.00073	0.00068	0.0012	A	2.30	1.03
	0.00036	0.00034	0.00060	B		
Belview Elementary	0.00087	0.00085	0.00023	A	3.07	1.80
	0.00044	0.00043	0.00011	B		
Prices Fork Elementary	0.00097	0.00098	0.0013	A	2.82	1.46
	0.00049	0.00049	0.00064	B		
LewisGale Hospital Montgomery [5]	0.00062	0.00055	0.00097	A	1.96	1.02
	0.00031	0.00023	0.00049	B		
Commonwealth Assisted Living Christiansburg [6]	0.00071	0.00064	0.0012	A	2.48	0.84
	0.00035	0.00032	0.00058	B		

Table 4-7 (continued)
Locations and Modeling Data for Special Subpopulations

Subpopulation Name	Annual Average Modeling Results				Hourly Modeling Results	
	Vapor-Phase Conc. [2]	Particle-Phase Conc. [2]	Particle-Phase Deposition [3]	A/B	Vapor-Phase Conc. [2]	Particle-Phase Conc. [2]
Skid Burns						
Cedarwood Preschool [4]	0.00062	0.00069	0.0014	A	1.29	1.65
	0.00031	0.00035	0.00069	B		
Belview Elementary	0.00096	0.0013	0.00078	A	1.75	2.56
	0.00048	0.00064	0.00039	B		
Prices Fork Elementary	0.00097	0.0012	0.0014	A	1.87	2.59
	0.00048	0.00063	0.00068	B		
LewisGale Hospital Montgomery [5]	0.00056	0.00059	0.0012	A	1.07	1.01
	0.00028	0.00030	0.00060	B		
Commonwealth Assisted Living Christiansburg [6]	0.00060	0.00065	0.0013	A	1.35	1.05
	0.00030	0.00033	0.00067	B		

1 Values presented in the "A" rows are associated with operating Scenario A (365 days per year operation per type of burn), and those presented in the "B" rows are associated with operating Scenario B (183 days per year operation per type of burn).

2 Units: micrograms per cubic meter per gram per second of pollutant emissions µg-s/(g-m^3)

3 Units: grams per square meter per second per gram per second of pollutant emissions (g/m^2/s)/(g/s)

4 Hourly particulate phase concentrations for the propellant burn are from New River Community Action Center, and hourly particulate phase concentrations for skid burns are from St. Mary's Little Angels. Overall, these two, day care locations had lower air modeling results than Cedarwood Preschool. However, the hourly particle-phase concentrations were higher than those from Cedarwood. Instead of modeling the risk as each individual location, the highest air modeling results from each location were combined into one, theoretical worst-case day care center for each type of burn.

5 Hourly particle-phase concentrations are those from Carilion New River Hospital. Overall, Carilion New River Hospital had much lower air modeling results than LewisGale Montgomery hospital. However, the hourly particle-phase concentrations were higher than those from LewisGale Montgomery.

6 Hourly particle-phase concentrations are those from Commonwealth Assisted Living in Radford. Overall, the Radford location had much lower air modeling results than the Christiansburg location. However, the hourly particle-phase concentrations were higher than those from the Christiansburg location.

4.2.3 Waterbodies

Air modeling data for each of the four studied waterbodies is used in two ways in the MPRA: in the assessment of risk due to drinking water ingestion and in the assessment of risk to the subsistence fisher from the consumption of fish living in the waterbodies. Table 4-8 provides a summary of the air modeling results for each of the assessed waterbodies. The values provided represent the average values measured across all of the receptors associated with a given waterbody.

TABLE 4-8
MODELING DATA FOR WATERBODIES

WATERBODY	NUMBER OF RECEPTORS	ANNUAL AVERAGE MODELING RESULTS		
		VAPOR-PHASE CONCENTRATION [2]	PARTICLE-PHASE DEPOSITION [3]	A/B
PROPELLANT BURNS				
Back Creek	47	0.00033	0.00069	A
		0.00016	0.00035	B
Little River	5	0.000018	0.000039	A
		0.0000090	0.000020	B
Lick Run	51	0.00027	0.00039	A
		0.00013	0.00019	B
New River	977	0.00053	0.00064	A
		0.00027	0.00032	B
SKID BURNS				
Back Creek	47	0.00029	0.00082	A
		0.00015	0.00041	B
Little River	5	0.000021	0.000057	A
		0.000010	0.000028	B
Lick Run	51	0.00027	0.00045	A
		0.00014	0.00023	B
New River	977	0.00049	0.00067	A
		0.00025	0.00034	B

1 Values presented in the "A" rows are associated with operating Scenario A (365 days per year operation per type of burn), and those presented in the "B" rows are associated with operating Scenario B (183 days per year operation per type of burn).

2 Units: micrograms per cubic meter per gram per second of pollutant emissions µg-s/(g-m^3)

3 Units: grams per square meter per second per gram per second of pollutant emissions (g/m^2/s)/(g/s)

5.0 EXPOSURE ASSESSMENT

The air modeling described in Section 3 generated a range of modeled COPC concentrations from the OBG based on the RME for both ambient air concentrations and deposition rates. These COPC concentrations were used to determine the exposure, or average daily chemical intake, at each receptor.

Average daily intake (ADI) is exposure expressed as the mass of a substance contacted per unit body weight per unit time, averaged over a period of years. The ADIs for COPCs at selected receptor locations were calculated using the exposure equations and, where applicable, the assumptions summarized in the MPRA Protocol and detailed in the HHRAP, Volume Three (USEPA, 1998c). For non-carcinogenic exposures, the intake is referred to as an average daily dose (ADD); for carcinogenic exposures, the intake is referred to as the lifetime average daily dose (LADD). The general formula for calculating intake is:

$$I = \frac{C_{GEN} \times CR \times EF \times ED}{BW \times AT}$$

Where: -

I	=	Intake (either ADD or LADD), expressed in amount/kg body weight/day
CGEN	=	COPC concentration in media of concern (i.e., mg/kg in soil)
CR	=	Consumption rate, expressed in amount per day
EF	=	Exposure frequency, expressed in days per year
ED	=	Exposure duration, expressed in years
BW	=	Average body weight of receptor, expressed in kilograms
AT	=	Averaging time, expressed in days

The following sections provide more detail on how the media concentrations were determined and combined with assumptions for intake to arrive at the ADD and LADD for each selected receptor.

5.1 COPC CONCENTRATIONS IN ENVIRONMENTAL MEDIA

The concentration of each COPC in environmental media was determined from the deposition rates and air concentrations predicted by the OBODM model. For this MPRA, concentrations of COPCs were calculated for various media, including the ambient air, soil, water, sediment, produce, and animal products.

5.1.1 AIR CONCENTRATIONS

For each modeling location, the air dispersion model provided the ambient air concentration of vapor and particulate-phase COPCs. These were normalized to reflect actual facility operations and were then unitized to provide emissions on a 1 gram per second (g/s) basis as described in Section 3. The following equation was used to estimate air concentrations of COPCs at each modeling location using the air modeling outputs and the emission factors described in Section 3. These air concentrations were used directly in the calculation of inhalation intake.

$$C_a = Q \times \left[F_v \times Cyv + \left(1 - F_v\right) \times Cyp\right]$$

Where:

Ca	=	concentration of COPC in air (µg/m^3)
Q	=	COPC emission rate (g/s), determined by multiplying the EF (lb COPC/lb NEW) by the amount (lb) of material burned
Fv	=	fraction of COPC in vapor phase (unitless)
Cyv	=	model output vapor phase concentration (µg/m^3)
Cyp	=	model output particle phase concentration (µg/m^3)

5.1.2 SOIL CONCENTRATIONS

COPC concentrations in soil were calculated from the COPC deposition rates determined via air modeling. The calculated soil concentrations were averaged over the exposure period in order to quantify risk for incidental soil ingestion and consumption of homegrown food. The equations for the determination of soil concentration from deposition rates were obtained from Volume Three of the HHRAP (USEPA, 1998c). The calculation assumes the following:

- Only a thin layer of soil becomes contaminated;
- This layer can be assumed to be either "tilled" – mixed to 20 centimeters, or "untilled" – mixed to one centimeter; and
- Soil residues are assumed to dissipate at a rate related to the combined effects of degradation, erosion, runoff, leaching, and volatilization.

As recommended in the HHRAP, a mixing depth of one centimeter was used for all calculations involving non-tilled land (i.e. incidental soil ingestion and animal product concentrations). A mixing depth of 20 centimeters was used for calculations involving tilled land (i.e. produce, forage, silage and grain uptake). For calculations dealing with surface water runoff, a mixing depth of one centimeter was used.

5.1.3 WATER AND SEDIMENT CONCENTRATIONS

As discussed previously, the air dispersion model provided COPC deposition rates in terms of grams per square meter per year per gram per second of material burned ((g/m^2/yr)/(g/s)). Deposition rates were converted to total water column and sediment concentrations averaged over the exposure period in order to quantify risk for fish consumption and drinking water ingestion. The equations for this conversion were obtained from the HHRAP, Volume Three (USEPA, 1998c). The equations distribute deposition on the surface of the waterbody and on soil in the drainage basin to the waterbody, to the water column, and to the upper benthic sediment layer.

5.1.4 PRODUCE CONCENTRATIONS

The air dispersion model provided air concentration and deposition rate values for each receptor node. These values were converted to aboveground exposed produce concentration due to direct deposition, aboveground exposed produce concentration due to air-to-plant transfer, aboveground exposed and protected produce concentration due to root uptake, and below ground produce concentration due to root uptake. The equations for this conversion were obtained from HHRAP, Volume Three (USEPA, 1998c). For each exposure scenario involving ingestion of homegrown produce, soil concentrations were calculated assuming a mixing depth of 20 centimeters.

5.1.5 ANIMAL PRODUCT AND FISH CONCENTRATIONS

The air dispersion model provided air concentration and deposition rate values for each receptor node. These values were first converted to silage, forage, and grain concentrations. Then animal product concentrations were calculated based on animal ingestion of silage, forage, grain, and soil. Animal products include beef, milk, poultry, eggs, and pork. The equations for this conversion were obtained from HHRAP, Volume Three (USEPA, 1998c).

Fish concentrations were determined for each of the evaluated surface waterbodies using the calculated total water column and sediment concentrations. The total water column and sediment concentrations were determined as described previously. The calculated fish concentrations for each COPC were then determined using the equations provided in the HHRAP, Volume Three.

5.2 EXPOSURE RATES

Exposure rates, such as inhalation rates for air and consumption rates for soil, produce, animal products, fish, and drinking water, determine the amount of COPC to which each receptor is exposed through the indirect pathway. Lower consumption rates of contaminated materials will result in lower exposure to the receptor. The following sections provide descriptions of the consumption rates employed in this MPRA. Table 5-1 provides a summary of the exposure rates used for each of the assessed scenarios. Further discussion on the basis for these rates is provided in the sections that follow.

TABLE 5-1
EXPOSURE RATES FOR TARGETED RECEPTORS

RECEPTOR	INHALATION (M^3/HR)	SOIL INGESTION (KG/DAY)	FOOD CONSUMPTION (KG/KG-BW-DAY)	DRINKING WATER CONSUMPTION (L/DAY)	SKIN ABSORPTION (MG/CM^2/EVENT)
Farmer	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	Adult: $Produce_{AGE}$: 0.00047 $Produce_{AGP}$: 0.00064 $Produce_{BG}$: 0.00017 Beef: 0.00122 Milk: 0.01367 Pork: 0.00055 Poultry: 0.00066 Eggs: 0.00075 Child: $Produce_{AGE}$: 0.00113 $Produce_{AGP}$: 0.00157 $Produce_{BG}$: 0.00028 Beef: 0.00075 Milk: 0.02268 Pork: 0.00042 Poultry: 0.00045 Eggs: 0.00054	Adult: 1.4 Child: 0.67	Adult: 0.0503 Child: 0.026
Fisher	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	Adult: $Produce_{AGE}$: 0.00032 $Produce_{AGP}$: 0.00061 $Produce_{BG}$: 0.00014 Fish: 0.00125 Child: $Produce_{AGE}$: 0.00077 $Produce_{AGP}$: 0.0015 $Produce_{BG}$: 0.00023 Fish: 0.00088	Adult: 1.4 Child: 0.67	Adult: 0.0503 Child: 0.026
Resident	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	Adult: $Produce_{AGE}$: 0.00032 $Produce_{AGP}$: 0.00061 $Produce_{BG}$: 0.00014 Child: $Produce_{AGE}$: 0.00077 $Produce_{AGP}$: 0.0015 $Produce_{BG}$: 0.00023	Adult: 1.4 Child: 0.67	Adult: 0.0503 Child: 0.026

Table 5-1 (continued)
Exposure Rates for Targeted Receptors

Receptor	Inhalation (m^3/hr)	Soil Ingestion (kg/day)	Food Consumption (kg/kg-BW-day)	Drinking Water Consumption (L/Day)	Skin Absorption (mg/cm^2/event)
Daycare centers	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	N/A	N/A	N/A
Elementary schools	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0001	N/A	N/A	N/A
Nursing home	Adult: 0.83	N/A	N/A	N/A	N/A
Hospital	Adult: 0.83 Child: 0.30	N/A	N/A	N/A	N/A
Acute risk	Adult: 0.83 Child: 0.30	N/A	N/A	N/A	N/A

5.2.1 Inhalation Rate

Air concentrations calculated from the air dispersion model are used directly in the calculation of inhalation intake. The breathing rate was varied with the age of the receptor in each exposure scenario. For all adult receptors, the default inhalation rate of 0.83 cubic meters per hour (m^3/hr) was used. For child and student receptors, an inhalation rate of 0.30 m^3/hr was used. Direct inhalation of COPCs was included in all exposure scenarios.

5.2.2 Soil Consumption Rate

Exposure to constituents in soil occurs by direct, inadvertent ingestion of soil. The quantity of incidental ingestion varies with the age of the receptor in each exposure scenario. For all adult receptors, the default soil consumption rate of 0.0001 kilograms per day (kg/day) was used. For child and student receptors, a soil consumption rate of 0.0002 to 0.0001 kg/day was used. The very small difference (0.0002 kg/day for daycare and non-school aged children versus 0.0001 kg/day for elementary school children) reflects a slight increased rate for daycare and non-school age children to mouth objects and suck on their hands and fingers more than those of school-aged children. Incidental soil ingestion of COPCs was included for the farmer, fisher, and resident, as well as for the workers and students in the elementary school and day care exposure scenarios.

5.2.3 Food Consumption Rates

The food consumed and the rate of consumption varies with exposure scenario. Additionally, the consumption of homegrown or locally caught food was not included in every exposure scenario. Ingestion of homegrown or locally caught food was only included in the three general exposure scenarios. Workers and students at the school and the day care center do not ingest any COPC contaminated food grown at the exposure location; neither due residents of the nursing home or patients at the hospital.

For the farmer and farmer child scenarios, it was assumed that 100 percent of the produce consumed is contaminated and that 100 percent of the tissues from the consumed beef, milk, pork, poultry, and eggs is contaminated. Default distributions for the relative amounts of homegrown fruits, vegetables, beef, pork, poultry, eggs, and milk consumed by the farmer and farmer child were used in the MPRA. No modifications to these distributions were made based on local farming trends or consumption habits.

For the fisher and fisher child scenarios, it was assumed that only 25 percent of the produce consumed by the fisher and fisher child is homegrown at the exposure location and that the overall consumption rates of produce are slightly less than those associated with the farming scenario. In addition, it is assumed that 100 percent of the fish consumed is contaminated. The fisher and fisher child are the only receptors that included fish consumption as an exposure pathway. Conservative default values for consumed fish were used in all calculations. No modifications to fish type or consumption rates were varied based on local trends.

For the adult and child resident scenarios, it was assumed that the only contaminated food consumed was from homegrown produce. Considering that the resident scenario is not based on the resident subsisting off of the homegrown produce, it was assumed that only 25 percent of the produce consumed is homegrown and consequently contaminated. In addition, since the resident is not subsiding off of this produce, the consumption rates utilized for those were slightly less than those associated with the farming scenario.

5.2.4 Drinking Water Consumption Rates

Surface water from the New River is the source of drinking water for many residents in the vicinity of the RFAAP. A study of water use in the area indicated that the majority of the population relies on a public supply of drinking water from surface waterbodies. Therefore, human consumption of untreated surface water was included in the assessment of risk for the farmer, fisher, and resident scenarios. However, the inclusion of modeled, untreated surface water concentrations as drinking water in the MPRA is extremely conservative because the surface water used for public supply is treated prior to being used by the public. According to information available from the New River Valley Regional Water Authority, the water sourced from the New River is treated via several processes, including coagulation, flocculation, chlorination, sedimentation, and filtration. Following disinfection, a small amount of ammonia is added to the disinfected water to react with the chlorine to form chloramines to provide a long-lasting disinfectant in the water distribution system. These treatment processes aid in disinfecting the water supply and assist in removing both inorganic and organic compounds.

5.2.5 Skin Absorption Rates

Dermal absorption of COPCs was included in the risk assessment based on requests received by VDEQ, despite the recommendations in the HHRAP to exclude dermal exposure due to the relatively low risks typically resulting from it relative to other exposure scenarios. For assessment of dermal exposure, two receptor-specific factors must be established: the adherence factor, which is provided in units of mg COPC per square centimeter of skin (mg/cm^2) per event, and the skin surface area, which provided in terms of square meters (m^2). For adult receptors, a skin surface area of 2.5 m^2 was used, and for children receptors, a skin surface area of 0.95 m^2 was utilized. Adherence rates were set at 0.0503 mg/cm^2 for adults and 0.026 mg/cm^2 for children.

Another factor used in the dermal calculations is the absorption factor, or ABS. The ABS is a chemical-specific value that accounts for desorption of the chemical from the soil matrix and absorption of the chemical across the skin. Per the methodology used in determining dermal exposure, four criteria are used for determining the ABS fraction:

- If the compound is inorganic, an ABS fraction of 0.01 is assigned;
- If the compound is Semivolatile, an ABS fraction of 0.1 is assigned;
- If the compound is volatile but has a vapor pressure lower than benzene, an ABS fraction of 0.03 is assigned;
- If the compound is volatile but has a vapor pressure equal to or greater than benzene (indicated by the "volatile" notation), an ABS fraction of 0.005 is assigned.

In the Constituents table in Appendix B, the volatility of each compound is indicated under Column 45, which is labeled "Volatile/Semivolatile." Those compounds without a designation in this column as inorganic. Those compounds that are Semivolatile are labeled as such. And, finally, those compounds that are volatile are labeled as either "volatile" or "< volatile." Compounds labeled as "< volatile" have a vapor pressure less than benzene, and compounds labeled as "volatile" have a vapor pressure equal to or greater than benzene. The ABS factor used for each chemical is then identified in the column immediately to the right (Column 46), which is labeled "ABS Fraction."

5.3 Exposure Frequency and Duration

Exposure duration is the length of time (in years) that a receptor is exposed via a specific exposure pathway. Exposure frequency is the number of days in each year that the receptor is assumed to be exposed. Table 5-2 provides the exposure frequency and duration for each receptor in the MPRA.

TABLE 5-2
EXPOSURE FREQUENCY AND DURATION FOR TARGETED RECEPTORS

RECEPTOR	EXPOSURE FREQUENCY	EXPOSURE DURATION
Farmer	Adult: 350 days/year for 40 years Child: 350 days/year for 6 years	24 hours/day
Fisher	Adult: 350 days/year for 30 years Child: 350 days/year for 6 years	24 hours/day
Resident	Adult: 350 days/year for 30 years Child: 350 days/year for 6 years	24 hours/day
Daycare centers	Adult: 350 days/year for 25 years Child: 350 days/year for 6 years	8 hours/day
Elementary schools	Adult: 180 days/year for 25 years Child: 180 days/year for 5 years	8 hours/day
Nursing home	350 days/year for 3 years	24 hours/day
Hospital	7 days/year for 1 year	24 hours/day
Acute risk	1 day per year	1 hour/day

5.4 AVERAGING TIME

Averaging time represents the time over which exposure to the COPCs is averaged. For non-carcinogenic COPCs, an averaging time of the exposure duration multiplied by 365 days per year was used. For carcinogenic COPCs, the averaging time used was 25,550 days, based on a lifetime exposure of 70 years. Note that this is the most conservative of the three possible exposure situations discussed in the HHRAP.

5.5 BODY WEIGHT

The body weight values used in the exposure calculations affect the daily intake for a given exposure pathway, as the intake is expressed as dose per body weight. The lesser the weight of the receptor, the greater the likely intake for that receptor. For all adult receptors, this MPRA used a body weight of 70 kilograms, as recommended in the HHRAP. For child receptors, a body weight of 17 kilograms was used for the general receptors and the hospital and daycare scenarios; a body weight of 27 kilograms was used for the elementary school scenario as elementary school children are aged from 6 to 10 and all other children are aged 1 to 6 years old.

6.0 RISK ASSESSMENT RESULTS

Characterization of risk and hazard to the selected human health receptors is the final step of the MPRA process. Using the calculated media concentrations and COPC toxicity values, risk and hazard resulting from the intake of COPCs via each potential pathway are determined. Once complete, these individual risk and hazard estimates are summed to determine the total theoretical risk and hazard predicted for each selected receptor. This section provides a discussion on the results of the human health analysis. Details on the uncertainties associated with this and other stages of the MPRA are provided in Section 7 of this report.

6.1 SCOPE AND METHODOLOGY

As discussed in previous sections, the MPRA was conducted to evaluate the potential risk and hazard to members of the population resulting from exposure to COPCs emitted from the RFAAP OBG. The following individual human exposures were evaluated:

- Risk and hazard to residents living at the maximum impacted offsite location(s) that could allow a domicile to be established. This could include any forested area, agricultural area, or urban area within the assessment area.
- Risk and hazard to subsistence fishers and their children residing at the maximum impacted offsite location(s) that could allow a domicile to be established and fishing in surface waterbodies with the highest modeled fish tissue concentrations in the assessment area.
- Risk and hazard to subsistence farmers and their children residing at the maximum impacted offsite location(s) of agricultural land use and subsisting off of homegrown produce and animal products grown and raised at this location.
- Polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/PCDF) exposure to a breast-feeding infant being fed by mothers in each of the three general exposure scenarios (subsistence farmer, subsistence fisher, and resident);
- Lead exposure to receptors in each of the three general exposure scenarios (subsistence farmer, subsistence fisher, and resident);
- Acute hazard to a generic human receptor located at the offsite location with the highest hourly air concentrations;
- Risk and hazard to an elementary school worker and student present at the elementary school(s) with the highest modeled air concentrations and deposition rates;
- Risk and hazard to a daycare worker and child present at the day care center(s) with the highest modeled air concentrations and deposition rates;
- Risk and hazard to a nursing home resident living at the nursing home(s) with the highest modeled air concentrations and deposition rates; and,
- Risk and hazard to adult and child hospital patients at the hospital(s) with the highest modeled air concentrations and deposition rates.

Copies of the risk and hazard calculation worksheets for each of these exposure scenarios are provided in Appendix B. An explanation of the methodology used for each assessment is provided below.

6.1.1 Chronic Risk

Chronic risk was determined by multiplying the appropriate CSF by the site-specific exposure dose using the equations defined in the HHRAP (USEPA, 1998c). Chemical-specific risks that are the result of the same exposure route are summed to contributed to the pathway incremental risk; if multiple pathways exist in an exposure scenario, appropriate pathway risks are summed, creating the total incremental carcinogenic risk for a specific receptor population. For this assessment, VDEQ set the following targets:

- The target individual risk from any one chemical in a given exposure scenario was set at $1x10^{-6}$;
- The target cumulative risk from all chemicals in any given exposure scenario was set at $1x10^{-4}$.

In the event that any of these target values were exceeded, RFAAP conducted additional calculations to determine the risk management parameters that could be used to mitigate excessive risk.

6.1.2 Chronic Hazard

Chronic, non-carcinogenic hazard for each receptor was determined by dividing the estimated exposure dose by appropriate dose-response values, such as RfDs derived by the USEPA, using the equations defined in Appendix B of HHRAP (USEPA, 1998c). The resulting ratio is referred to as the "chemical-specific risk ratio" or hazard quotient (HQ). HQs for individual COPCs are summed to calculate the hazard index (HI) for a pathway. If multiple pathways exist in an exposure scenario, appropriate pathway HIs are added together to calculate a total HI. For this assessment, VDEQ set the following targets:

- The target level HQ for any individual non-carcinogen was set at 0.25, irrespective of target organ;
- The target HI for all non-carcinogens was set at 1.0, irrespective of target organ.

In the event that any of these target values were exceeded, RFAAP conducted additional calculations to determine the risk management parameters that could be used to mitigate excessive risk.

6.1.3 Infant Exposure To Dioxins and Furans in Breast Milk

For each of the general receptors (resident, fisher, and farmer), the effects of infant exposure to PCDD/PCDF through breast milk were also examined. An average daily dose to both the mother and infant was determined based on the mother's intake of PCDD/PCDF in each generic exposure scenario. The ADD calculated for the infant ($ADD_{i/m}$) was compared to a USEPA-estimated ADD for an infant who is exposed to PCDD/PCDF through the ingestion of breast milk from a mother receiving an average background PCDD/PCDF exposure, rather than the exposure due to facility emissions. This USEPA calculated baseline, or threshold value is equal to 60 picograms per kilogram-body weight per day (pg/kg-BW/day).

6.1.4 LEAD EXPOSURE

Due to the lack of toxicity parameters (CSFs and RfDs) for chronic lead exposure, USEPA developed the Integrated Exposure Uptake Biokinetic (IEUBK) model for Lead in Children and the Adult Lead Exposure Model (ALM) for worker exposure to lead. These models were used to calculate predicted lead concentrations in the blood of each of the general receptors. The target threshold for this assessment was a blood lead level of 10 micrograms per deciliter (µg/dL) for at least 95 percent of the receptors.

6.1.5 ACUTE EXPOSURE

In addition to chronic risks, those risks resulting from acute exposure via the inhalation of OBG emissions were also evaluated for a generic acute receptor and each of the special subpopulations. An acute hazard quotient (AHQ) was calculated for each COPC by dividing the hourly air concentration at the assessed location by the AIEC for that COPC. AIECs were determined from NOAA's PACs, which is a hierarchy-based system of the three common public exposure guideline systems: AEGLs, ERPGs, and TEELs, with preference in the hierarchy being assigned in the order listed. At the request of VDEQ, the initial target AHQ for any individual non-carcinogen, irrespective of target organ, was set at 0.25.

6.1.6 CHRONIC RESULTS FOR GENERAL RECEPTORS

For each of the general receptors, the chronic risk and hazard resulting from long-term, day-to-day exposure to the OBG emissions was calculated at each of the maximum impacted locations defined in Section 4. In addition, infant exposure to PCDD/PCDF in mother's breast milk, and lead exposure to both adults and children were assessed for each of the general receptors.

As discussed previously, for the propellant burns, three different locations were evaluated; for the skid burns, one location was evaluated. In addition, two emission scenarios were assessed for each location: Scenario A, which reflected completion of each type of burn 365 days per year, and Scenario B, which reflected completion of each type of burn every other day throughout the year (183 days per year). The results of each of these assessments are summarized below.

6.1.7 RESIDENT

The maximum exposure locations for each of the resident scenarios were located southeast of the OBG in the general vicinity of Prices Fork Road in woody areas with hilly to steep terrain. None of the locations had a current residence at the location; however, one did have a residence located in the nearby vicinity. Specific exposure criteria utilized for the chronic risk and hazard assessment for the resident were provided in Section 5. In summary, the resident was assumed to reside at the location for 30 years and be present at that location 24 hours per day, 350 days per year. The resident is exposed to emissions via direct inhalation, incidental soil ingestion, dermal exposure to soil, the consumption of homegrown produce, and the ingestion of surface water supplied drinking water. The results of the resident assessment for the propellant and skid burn scenarios are presented in Tables 6-1 and 6-2. Individual pathway risks, which had no set risk targets, and the chemical-specific risks for each constituent are provided in the detailed calculations in Appendix B.

TABLE 6-1
SUMMARY OF RISK AND HAZARD TO THE RESIDENT RECEPTORS FROM PROPELLANT BURNS

RESULTS	LOCATION 1: MAXIMUM DEPOSITION		LOCATION 2: MAXIMUM VAPOR-PHASE AIR CONCENTRATION		LOCATION 3: MAXIMUM PARTICLE-PHASE AIR CONCENTRATION	
	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD
Scenario A – Operation 365 Days Per Year						
Chronic cancer risk (total)	1.09×10^{-6}	2.43×10^{-7}	6.26×10^{-7}	1.27×10^{-7}	7.89×10^{-7}	1.82×10^{-7}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds					
Chronic hazard index	0.104	0.105	0.117	0.117	0.0395	0.0408
PCDD/PCDF ADD [1]	0.000023	0.00067	0.0000023	0.000068	0.000022	0.00064
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.5 – 0.9	---	0.0 – 0.1	---	0.5 – 0.9
Scenario B – Operation 183 Days Per Year						
Chronic cancer risk (total)	5.39×10^{-7}	1.20×10^{-7}	3.18×10^{-7}	6.43×10^{-8}	3.88×10^{-7}	8.98×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds					
Chronic hazard index	0.0521	0.0528	0.0594	0.0595	0.0194	0.0201
PCDD/PCDF ADD [1]	0.000011	0.00034	0.0000012	0.000034	0.000011	0.00032
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.2 – 0.4	---	0.0	---	0.2 – 0.4

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. IEUBK used to calculate child lead exposure. All exposures are presented in micrograms per deciliter (µg/dL) of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled residential scenarios were below the targets established by VDEQ for the propellant burns. Even at the unrealistic operating scenario of 365 days per year, none of the established targets are exceeded for the residential receptors at any of the maximum impacted locations. Absent a limitation on the total quantity of material in each propellant burn, RFAAP does not believe any risk management limits are required to control exposure to these receptors. The existing limit of 8,000 pounds of material in each propellant burn remains appropriate.

TABLE 6-2
SUMMARY OF RISK AND HAZARD TO THE RESIDENT RECEPTORS FROM SKID BURNS

RESULTS	MAXIMUM IMPACTED LOCATION	
	ADULT	CHILD
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk (total)	5.82×10^{-7}	1.20×10^{-7}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds	
Chronic hazard index	0.104	0.105
PCDD/PCDF ADD [1]	0.0000047	0.00014
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.1 – 0.2
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk (total)	2.91×10^{-7}	6.01×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds	
Chronic hazard index	0.0522	0.0523
PCDD/PCDF ADD [1]	0.0000024	0.000069
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.1

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled residential scenarios were below the targets established by VDEQ for the skid burns. Even at the unrealistic operating scenario of 365 days per year, none of the established targets are exceeded for the residential receptors at the maximum impacted locations. Absent a limitation on the total quantity of material in each skid burn, RFAAP does not believe any risk management limits are required to control exposure to these receptors. The existing limit of 2,000 pounds of material in each skid burn remains appropriate.

6.1.8 FISHER

The maximum exposure locations for each of the fisher scenarios were located southeast of the OBG in the general vicinity of Prices Fork Road in woody areas with hilly to steep terrain. None of the locations had a current residence at the location; however, one did have a residence located in the nearby vicinity. The waterbodies with the highest COPC fish tissue concentrations were Back Creek, Lick Run, and the New River. Specific exposure criteria utilized for the chronic risk and hazard assessment for the fisher were provided in Section 5. In summary, the fisher was assumed to reside at the location for 30 years and be present at that location 24 hours per day, 350 days per year. The fisher is exposed to emissions via direct inhalation, incidental soil ingestion, dermal exposure to soil, the consumption of homegrown produce and locally caught fish, and the ingestion of surface water supplied drinking water. The results of the fisher assessment for the propellant and skid burn scenarios are presented in Tables 6-3 and 6-4. Individual pathway risks, which had no set risk targets, and the chemical-specific risks for each constituent are provided in the detailed calculations in Appendix B.

TABLE 6-3
SUMMARY OF RISK AND HAZARD TO THE FISHER RECEPTORS FROM PROPELLANT BURNS

RESULTS	LOCATION 1: MAXIMUM DEPOSITION		LOCATION 2: MAXIMUM VAPOR-PHASE AIR CONCENTRATION		LOCATION 3: MAXIMUM PARTICLE-PHASE AIR CONCENTRATION	
	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD
Scenario A – Operation 365 Days Per Year						
Chronic cancer risk (total)	1.17×10^{-6}	2.55×10^{-7}	7.10×10^{-7}	1.39×10^{-7}	8.73×10^{-7}	1.94×10^{-7}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds					
Chronic hazard index	0.104	0.106	0.117	0.117	0.0399	0.0411
PCDD/PCDF ADD [1]	0.00046	0.013	0.00044	0.013	0.00046	0.013
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.5 – 0.9	---	0.0 – 0.1	---	0.5 – 0.9
Scenario B – Operation 183 Days Per Year						
Chronic cancer risk (total)	5.82×10^{-7}	1.26×10^{-7}	3.60×10^{-7}	7.03×10^{-8}	4.31×10^{-7}	9.58×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds					
Chronic hazard index	0.0523	0.0529	0.0596	0.0596	0.0196	0.0202
PCDD/PCDF ADD [1]	0.00023	0.0067	0.00022	0.0064	0.00023	0.0067
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.2 – 0.4	---	0.0	---	0.2 – 0.4

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled fisher scenarios were below the targets established by VDEQ for the propellant burns. Even at the unrealistic operating scenario of 365 days per year, none of the established targets are exceeded for the fisher receptors at any of the maximum impacted locations. Absent a limitation on the total quantity of material in each propellant burn, RFAAP does not believe any risk management limits are required to control exposure to these receptors. The existing limit of 8,000 pounds of material in each propellant burn remains appropriate.

TABLE 6-4
SUMMARY OF RISK AND HAZARD TO THE FISHER RECEPTORS FROM SKID BURNS

RESULTS	MAXIMUM IMPACTED LOCATION	
	ADULT	CHILD
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk (total)	9.87×10^{-7}	1.77×10^{-7}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds	
Chronic hazard index	0.107	0.106
PCDD/PCDF ADD [1]	0.00014	0.0040
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.1 – 0.2
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk (total)	4.94×10^{-7}	8.87×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds	
Chronic hazard index	0.0533	0.0530
PCDD/PCDF ADD [1]	0.000069	0.0020
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.1

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled fisher scenarios were below the targets established by VDEQ for the skid burns. Even at the unrealistic operating scenario of 365 days per year, none of the established targets are exceeded for the fisher receptors at the maximum impacted location. Absent a limitation on the total quantity of material in each skid burn, RFAAP does not believe any risk management limits are required to control exposure to these receptors. The existing limit of 2,000 pounds of material in each skid burn remains appropriate.

6.1.9 FARMER

The maximum exposure locations for each of the farmer scenarios were located southeast of the OBG in the general vicinity of Prices Fork Road in woody areas with hilly terrain that would require extensive clearing to locate a farm. No actual farm was present at any of these locations and the true feasibility of locating a farm in this location was not researched. Specific exposure criteria utilized for the chronic risk and hazard assessment for the farmer were provided in Section 5. In summary, the farmer was assumed to reside at the location for 40 years and be present at that location 24 hours per day, 350 days per year. The farmer is exposed to emissions via direct inhalation, incidental soil ingestion, dermal exposure to soil, the consumption of homegrown produce and animal products, and the ingestion of surface water supplied drinking water. The results of the farmer assessment for the propellant and skid burn scenarios are presented in Tables 6-5 and 6-6. Any values that exceed VDEQ-established targets are provided in **bold** type. Individual pathway risks, which had no set risk targets, are provided in the detailed calculations in Appendix B.

TABLE 6-5
SUMMARY OF RISK AND HAZARD TO THE FARMER RECEPTORS FROM PROPELLANT BURNS

RESULTS	LOCATION WITH MAXIMUM DEPOSITION		LOCATION WITH MAXIMUM VAPOR-PHASE AIR CONCENTRATION		LOCATION WITH MAXIMUM PARTICLE-PHASE AIR CONCENTRATION	
	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD
Scenario A – Operation 365 Days Per Year						
Chronic cancer risk (total)	4.38×10^{-6}	9.12×10^{-7}	2.24×10^{-6}	4.38×10^{-7}	3.00×10^{-6}	6.42×10^{-7}
Chronic cancer risk (arsenic)	**1.95×10^{-6}**	4.24×10^{-7}	2.33×10^{-7}	4.85×10^{-8}	**1.97×10^{-6}**	4.24×10^{-7}
Chronic hazard index	0.119	0.131	0.104	0.108	0.0498	0.0589
PCDD/PCDF ADD [1]	0.0026	0.076	0.00092	0.027	0.0020	0.060
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	3.9 – 6.7	---	0.4 – 0.8	---	3.8 – 6.6

Table 6-5 (continued)
Summary of Risk and Hazard to the Farmer Receptors from Propellant Burns

Results	Location with Maximum Deposition		Location with Maximum Vapor-Phase Air Concentration		Location with Maximum Particle-Phase Air Concentration	
	Adult	Child	Adult	Child	Adult	Child
Scenario B – Operation 183 Days Per Year						
Chronic cancer risk (total)	2.18×10^{-6}	4.56×10^{-7}	1.10×10^{-6}	2.15×10^{-7}	1.49×10^{-6}	3.19×10^{-7}
Chronic cancer risk (arsenic)	9.66×10^{-7}	2.10×10^{-7}	1.16×10^{-7}	2.40×10^{-8}	9.78×10^{-7}	2.10×10^{-7}
Chronic hazard index	0.0598	0.0655	0.0509	0.0528	0.0246	0.0291
PCDD/PCDF ADD [1]	0.0013	0.038	0.00045	0.013	0.0010	0.030
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	2.0 – 3.6	---	0.2 – 0.4	---	2.0 – 3.6

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index for the modeled farmer locations were below the targets established by VDEQ for this risk assessment. However, the cancer risk from one individual chemical, arsenic, exceeded the target set by VDEQ under Scenario A, with modeled risk from chronic arsenic exposure for the adult farmer calculated to be 1.95×10^{-6} at the area of maximum annual deposition and 1.97×10^{-6} at the area of maximum annual vapor phase air concentration. These values compare to a target for individual chemicals of 1.0×10^{-6}. As noted previously, the operations modeled under Scenario A are not physically possible, as it assumes that propellant burns and skid burns can be conducted every single day of the year. The operations modeled under Scenario B, which are a more realistic reflection of OBG operations, demonstrate acceptable risk across all targets. To limit the risk due to arsenic emissions from propellant burns, RFAAP recommends applying a risk management limit. By limiting the quantity of material in a propellant burn to 8,000 pounds per burn and limiting propellant burn operations to no more than 183 days per year, risk due to arsenic exposure will be below those levels deemed appropriate by VDEQ. As the risk is due to an annual average deposition and annual average air concentration of arsenic, a day-per-year limit should be adequate to mitigate the risk.

TABLE 6-6
SUMMARY OF RISK AND HAZARD TO THE FARMER RECEPTORS FROM SKID BURNS

RESULTS	MAXIMUM IMPACTED LOCATION	
	ADULT	CHILD
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk (total)	1.68×10^{-6}	3.28×10^{-7}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds	
Chronic hazard index	0.109	0.112
PCDD/PCDF ADD [1]	0.00066	0.019
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.7 – 1.3
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk (total)	8.35×10^{-7}	1.63×10^{-7}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds	
Chronic hazard index	0.0545	0.0560
PCDD/PCDF ADD [1]	0.00033	0.0095
Lead (ALM) [2]	0.6 – 1.5	1.4 – 4.6
Lead (IEUBK) [2]	---	0.1

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled farmer scenarios were below the targets established by VDEQ for the skid burns. Even at the unrealistic operating scenario of 365 days per year, none of the established targets are exceeded for the fisher receptors at the maximum impacted location. Absent a limitation on the total quantity of material in each skid burn, RFAAP does not believe any risk management limits are required to control exposure to these receptors. The existing limit of 2,000 pounds of material in each skid burn remains appropriate.

6.2 ACUTE EXPOSURE RESULTS

An acute exposure analysis was conducted for the general population exposed to off-site air concentrations of compounds emitted from the OBG. The exposure compared the hourly air concentrations generated by OBODM to the AIEC for each constituent of concern. Two separate locations were assessed: the location associated with the maximum off-site vapor phase air concentration and the location associated with the maximum off-site particle phase air concentration. The acute receptor was assumed to be exposed to OBG emissions one hour a day for one day per year. Additional exposure criteria for the acute analysis were detailed in Section 5. The results of the acute exposure assessment for the propellant and skid burn scenarios are summarized in Tables 6-7 and 6-8. The constituents with the ten highest AHQs in each location are detailed in the table. Any AHQs that exceed VDEQ-established targets are provided in **bold** type. A complete list of the AHQs for each scenario and each modeled location are provided in Appendix B.

TABLE 6-7
SUMMARY OF ACUTE HAZARD QUOTIENTS FROM PROPELLANT BURNS

CONSTITUENT	LOCATION 1: MAXIMUM VAPOR-PHASE AIR CONCENTRATION			LOCATION 2: MAXIMUM PARTICLE-PHASE AIR CONCENTRATION		
	CAIR (MG/M^3)	AIEC (MG/M^3)	AHQ	CAIR (MG/M^3)	AIEC (MG/M^3)	AHQ
Lead	0.0512	0.15	**0.341**	0.0529	0.15	**0.353**
Hydrogen Cyanide	0.0386	2	0.0193	0.0230	2	0.0115
Formaldehyde	0.0125	0.9	0.0139	0.00746	0.9	0.00829
Acrylonitrile	0.00135	0.15	0.00903	0.000809	0.15	0.00539
Copper	0.0153	3	0.00509	0.0159	3	0.00530
Acrolein	0.000104	0.03	0.00347	0.000062	0.03	0.00207
Ammonia	0.104	30	0.00347	0.0622	30	0.00207
Hydrogen Chloride	0.00478	1.8	0.00266	0.00285	1.8	0.00159
Beryllium	0.0000016	0.0023	0.000698	0.0000017	0.0023	0.000722
Cyanide	0.00302	6	0.000504	0.00180	6	0.000301

As shown in the table, the AHQ for each constituent was below the VDEQ-established target of 0.25 except for lead in the 8,000-pound propellant burn. The highest AHQ for lead was 0.353. When the total quantity of propellant in a propellant burn is reduced from 8,000 to 5,600 pounds, the AHQ from lead lowers to 0.247. Therefore, RFAAP proposes limiting the quantity of waste in each propellant burn to 5,600 pounds to mitigate risks from acute lead exposure.

TABLE 6-8
SUMMARY OF ACUTE HAZARD QUOTIENTS FROM SKID BURNS

CONSTITUENT	LOCATION 1: MAXIMUM VAPOR-PHASE AIR CONCENTRATION			LOCATION 2: MAXIMUM PARTICLE-PHASE AIR CONCENTRATION		
	CAIR (MG/M^3)	AIEC (MG/M^3)	AHQ	CAIR (MG/M^3)	AIEC (MG/M^3)	AHQ
Lead	0.0320	0.15	0.213	0.0345	0.15	0.230
Sulfuric Acid	0.0163	0.2	0.0817	0.0176	0.2	0.0881
Hydrogen Cyanide	0.00922	2	0.00461	0.00849	2	0.00425
Formaldehyde	0.00299	0.9	0.00332	0.00275	0.9	0.00306
Copper	0.00965	3	0.00322	0.0104	3	0.00347
Acrylonitrile	0.000324	0.15	0.00216	0.000298	0.15	0.00199
Ammonia	0.0249	30	0.000831	0.0230	30	0.000765
Acrolein	0.0000249	0.03	0.000831	0.0000230	0.03	0.000765
Hydrogen Chloride	0.00114	1.8	0.000636	0.00105	1.8	0.000585
Beryllium	0.00000100	0.0023	0.000436	0.00000108	0.0023	0.000470

As the table shows, the AHQ for every constituent was below the VDEQ-established target of 0.25 in the 2,000-pound skid burns. Absent a limitation on the total quantity of material in each skid burn, RFAAP does not believe any risk management limits are required to control acute exposure from skid burns.

6.3 CHRONIC AND ACUTE RESULTS FOR SPECIAL SUBPOPULATIONS

In addition to assessing risk for the general receptors, the chronic and acute risk and hazard to special subpopulations within the assessment area was evaluated in the MPRA. As described in Section 4, these assessments were conducted at the elementary schools, day care centers, nursing homes, and hospitals with the highest modeled air concentrations and deposition rates.

As with all other evaluations, risk was assessed for both propellant burns and skid burns, and two different emission scenarios were assessed. Scenario A reflected completion of each type of burn 365 days per year, and Scenario B reflected completion of each type of burn every other day throughout the year (183 days per year). The results of each of these assessments are summarized below.

6.3.1 ELEMENTARY SCHOOLS

Risk assessment calculations were performed for teachers and students at two separate elementary schools within the assessment area: Belview Elementary and Prices Fork Elementary. Both the teachers and students were assumed to be exposed to emissions 8 hours per day for 180 days per year via the inhalation of emissions and the incidental ingestion of soil. Acute risk to both the students and the teachers was also assessed. The results of the assessment for the receptors for the propellant and skid burn scenarios are presented in Tables 6-9 and 6-10. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in the detailed calculations in Appendix B.

TABLE 6-9
SUMMARY OF RISK AND HAZARD TO ELEMENTARY SCHOOL STUDENTS AND TEACHERS FROM PROPELLANT BURNS

RESULTS	BELVIEW ELEMENTARY SCHOOL		PRICES FORK ELEMENTARY SCHOOL	
	TEACHER	STUDENT	TEACHER	STUDENT
Scenario A – Operation 365 Days Per Year				
Chronic cancer risk	2.50×10^{-8}	5.01×10^{-9}	2.84×10^{-8}	5.69×10^{-9}
Chronic hazard index	0.00334	0.00335	0.00376	0.00376
Acute risk	No AHQs above 0.25		No AHQs above 0.25	
Scenario B – Operation 183 Days Per Year				
Chronic cancer risk	1.26×10^{-8}	2.51×10^{-9}	1.42×10^{-8}	2.85×10^{-9}
Chronic hazard index	0.00168	0.00168	0.00188	0.00188
Acute risk	No AHQs above 0.25		No AHQs above 0.25	

TABLE 6-10
SUMMARY OF RISK AND HAZARD TO ELEMENTARY SCHOOL STUDENTS AND TEACHERS FROM SKID BURNS

RESULTS	BELVIEW ELEMENTARY SCHOOL		PRICES FORK ELEMENTARY SCHOOL	
	TEACHER	STUDENT	TEACHER	STUDENT
Scenario A – Operation 365 Days Per Year				
Chronic cancer risk	8.35×10^{-9}	1.67×10^{-9}	8.21×10^{-9}	1.64×10^{-9}
Chronic hazard index	0.00183	0.00183	0.00180	0.00180
Acute risk	No AHQs above 0.25		No AHQs above 0.25	
Scenario B – Operation 183 Days Per Year				
Chronic cancer risk	4.18×10^{-9}	8.38×10^{-10}	4.12×10^{-9}	8.24×10^{-10}
Chronic hazard index	0.000919	0.000919	0.000904	0.000904
Acute risk	No AHQs above 0.25		No AHQs above 0.25	

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for exposure at either Belview Elementary School or Prices Fork

Elementary School. Therefore, absent a limitation on the total quantity of material in each type of burn, RFAAP does not believe any risk management limits are required to control exposure of students or teachers at either school.

6.3.2 Day Care Centers

Risk assessment calculations were performed for teachers and students at Cedarwood preschool. As explained in Section 4.2.2, the annual average air modeling results for Cedarwood preschool were the highest under both the propellant and skid burn scenarios. However, the hourly particle-phase air concentration for the New River Community Action Center was higher than the modeled value for Cedarwood preschool (1.03 versus 0.66) in the propellant burn scenario. Likewise, in the skid burn scenario, the hourly air concentration from particle phase was higher at St. Mary's Little Angels than it was at Cedarwood Preschool (1.65 versus 1.05). Instead of modeling each of these three locations individually, the annual air modeling data from Cedarwood Preschool was combined with the hourly modeling data from the other two locations to create a theoretical, worst-case daycare center for each burn scenario.

Both the teachers and students were assumed to be exposed to emissions 8 hours per day for 350 days per year via the inhalation of emissions and the incidental ingestion of soil. Acute risk to both the students and the teachers was also assessed. The results of the assessment for the receptors for the propellant and skid burn scenarios are presented in Tables 6-11 and 6-12. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in the detailed calculations in Appendix B.

Table 6-11
Summary of Risk and Hazard to Day Care Students and Teachers from Propellant Burns

Results	Cedarwood Preschool	
	Teacher	Student
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk	3.96×10^{-8}	9.59×10^{-9}
Chronic hazard index	0.00538	0.00538
Acute risk	No AHQs above 0.25	No AHQs above 0.25
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk	1.99×10^{-8}	4.81×10^{-9}
Chronic hazard index	0.00273	0.00273
Acute risk	No AHQs above 0.25	No AHQs above 0.25

TABLE 6-12
SUMMARY OF RISK AND HAZARD TO DAY CARE STUDENTS AND TEACHERS FROM SKID BURNS

RESULTS	CEDARWOOD PRESCHOOL	
	ADULT	CHILD
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk	9.36×10^{-9}	2.27×10^{-9}
Chronic hazard index	0.00206	0.00206
Acute risk	No AHQs above 0.25	No AHQs above 0.25
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk	4.69×10^{-9}	1.14×10^{-9}
Chronic hazard index	0.00103	0.00103
Acute risk	No AHQs above 0.25	No AHQs above 0.25

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for exposure at the preschool. Therefore, absent a limitation on the total quantity of material in each type of burn, RFAAP does not believe any risk management limits are required to control exposure of students or teachers at either school.

6.3.3 NURSING HOMES

Risk assessment calculations were performed for elderly residents at Commonwealth Assisted Living in Christiansburg. As explained in Section 4.2.2, the acute risk estimates were performed with air modeling data from the Radford location. Overall, Commonwealth Assisted Living in Radford had lower air modeling results than the Christiansburg facility. However, the hourly particle-phase concentrations were higher than those from Christiansburg. The residents were assumed to be exposed to emissions 24 hours per day for 350 days per year via the inhalation of emissions. Acute risk was also assessed. The results of the assessment for the residents for the propellant and skid burn scenarios are presented in Tables 6-13 and 6-14. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in the detailed calculations in Appendix B.

TABLE 6-13
SUMMARY OF RISK AND HAZARD TO ELDERLY RESIDENTS DUE TO PROPELLANT BURNS

RESULTS	COMMONWEALTH ASSISTED LIVING
	RESIDENT
Scenario A – Operation 365 Days Per Year	
Chronic cancer risk	4.54×10^{-9}
Chronic hazard index	0.00519
Acute risk	No AHQs above 0.25
Scenario B – Operation 183 Days Per Year	
Chronic cancer risk	2.28×10^{-9}
Chronic hazard index	0.00260
Acute risk	No AHQs above 0.25

TABLE 6-14
SUMMARY OF RISK AND HAZARD TO ELDERLY RESIDENTS DUE TO SKID BURNS

RESULTS	COMMONWEALTH ASSISTED LIVING
	RESIDENT
Scenario A – Operation 365 Days Per Year	
Chronic cancer risk	1.07×10^{-9}
Chronic hazard index	0.00198
Acute risk	No AHQs above 0.25
Scenario B – Operation 183 Days Per Year	
Chronic cancer risk	5.38×10^{-10}
Chronic hazard index	0.000990
Acute risk	No AHQs above 0.25

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for exposure at the nursing home. Therefore, absent a limitation on the total quantity of material in each type of burn, RFAAP does not believe any risk management limits are required to control exposure of elderly residents in the community.

6.3.4 HOSPITALS

Risk assessment calculations were performed for adult and child patients at LewisGale Hospital Montgomery. As explained in Section 4.2.2, the acute risk estimates were performed with the hourly particle-phase concentrations from Carilion New River Hospital. Overall, Carilion New River Hospital had much lower air modeling results than LewisGale Montgomery hospital. However, the hourly particle-phase concentrations were higher than those from LewisGale Montgomery. The hospital patients were assumed to be exposed to emissions 24 hours per day for 7 days per year via the inhalation of emissions. Acute risk was also assessed. The results of the assessment for the patients for the propellant and skid burn scenarios are presented in Tables 6-15 and 6-16. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in the detailed calculations in Appendix B.

TABLE 6-15
SUMMARY OF RISK AND HAZARD TO HOSPITAL PATIENTS DUE TO PROPELLANT BURNS

RESULTS	LEWISGALE HOSPITAL MONTGOMERY	
	ADULT	CHILD
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk	2.64×10^{-11}	2.64×10^{-11}
Chronic hazard index	0.0000910	0.0000910
Acute risk	No AHQs above 0.25	
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk	1.32×10^{-11}	1.32×10^{-11}
Chronic hazard index	0.0000456	0.0000456
Acute risk	No AHQs above 0.25	

TABLE 6-16
SUMMARY OF RISK AND HAZARD TO HOSPITAL PATIENTS FROM SKID BURNS

RESULTS	LEWISGALE HOSPITAL MONTGOMERY	
	ADULT	CHILD
Scenario A – Operation 365 Days Per Year		
Chronic cancer risk	6.55×10^{-12}	6.55×10^{-12}
Chronic hazard index	0.0000362	0.0000362
Acute risk	No AHQs above 0.25	No AHQs above 0.25
Scenario B – Operation 183 Days Per Year		
Chronic cancer risk	3.28×10^{-12}	3.28×10^{-12}
Chronic hazard index	0.0000182	0.0000182
Acute risk	No AHQs above 0.25	No AHQs above 0.25

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for exposure at the hospital. Therefore, absent a limitation on the total quantity of material in each type of burn, RFAAP does not believe any risk management limits are required to control exposure of patients at the hospital.

7.0 UNCERTAINTY ANALYSIS

The primary goal of the uncertainty analysis is to provide a discussion of the key assumptions used in the risk evaluation that significantly influence the estimate of risk. Uncertainty is inherent in all of the principle components of the risk evaluation. Uncertainty in the MPRA can result from various sources, including:

- The use of conservative assumptions and estimated variable values;
- The application of emission factors established using non-site-specific data during limited testing events or emission factors derived from site-specific data using analytical methods with limits to precision and accuracy;
- The application of air dispersion models with limited accuracy and the use of air models that do not provide wet deposition rates;
- The utilization of theoretical and experimentally based fate and transport equations;
- The use of USEPA toxicity reference values (TRVs), some of which are derived from animal studies, that have low confidence ratings and high uncertainty factors (UFs); and
- The lack of fate, transport, and toxicity data for every identified COPC, making a complete quantitative characterization of risk from the OBG activities unfeasible.

When combined, these compounded uncertainties result in a conservative estimate of risk. Unfortunately, the degree of conservatism in risk estimates cannot be measured; however, the assumptions combine many conservative factors and are likely to overestimate actual exposure. Furthermore, the methodologies utilized in the MPRA are complex and involve the integration of numerous algorithms that are intended to simulate the release of pollutants into the environment, the fate and transport of those pollutants through environmental media, and the potential of adverse health effects that may result from human exposure to the pollutants. Inherent in all of these evaluations are varying degrees of uncertainty.

Table 7-1 summarizes uncertainties associated with the various steps undertaken to estimate risk. The table includes the potential effect of the uncertainty on the conclusions of the MPRA (overestimation, underestimation, neutral) and the magnitude of the effect, if known.

TABLE 7-1
SUMMARY OF KEY UNCERTAINTIES

UNCERTAINTY	LIKELY EFFECT ON RISK ESTIMATE
Emission factors	The emissions factors established from the site-specific sampling program were based on a series of test runs conducted on a mixture of waste streams. As it was not possible to do this sampling during the treatment of every single waste stream processed at the OBG, the measured emission factors have some inherent uncertainty. This uncertainty may overestimate or underestimate the COPC emissions from the OBG. This may overestimate or underestimate risk.
Emission factors	The emissions factors established from the AP-42 database are not directly related to the treatment of RFAAP wastes at the OBG. They were generated from the open burning and open detonation of conventional munitions items containing RFAAP products, as well as other items. Therefore, the emissions factors derived from the AP-42 database likely overestimate COPC emissions as they contain contributions from other items not present in the RFAAP products. This overestimates risk. However, it is important to note, as documented in USEPA 2002, the data from the BangBox studies that led to many of the AP-42 factors was, and remains, a considerable resource for data on emission factors from OB/OD and, while it has its limitations is one of "the best available OB/OD emission factor database[s]."
Emission scenarios	The initial run of the risk calculations assumed operation of each type of burn scenario (propellant burn and skid burn) 365 days per year. RFAAP safety requirements prevent this scenario from existing, as alternate pans must be used on different days, requiring an oscillation between propellant burns and skid burns. Calculating risk on this basis overestimates risk.
Emission scenarios	The initial run of the risk calculations assumed operation of each type of burn scenario (propellant burn and skid burn) 365 days per year. Given the operating restrictions on the OBG, *e.g.,* no burning during precipitation events or certain wind scenarios, operation 365 days per year is not possible. Therefore, these assumptions overestimate risk.
Emission scenarios	The emission scenarios for the propellant burn assume 8,000 pounds of NEW per propellant burn. In reviewing historical data, this level of burn is far from standard practice. In most cases, the actual amount of propellant material open burned is significantly less than this amount. Furthermore, many of these propellant materials are being redirected to the incinerators. Therefore, an assumption that every single propellant burn contains 8,000 pounds of NEW per burn significantly overestimates risk.
Emission scenarios	The emission scenarios for the skid burn assume 2,000 pounds of material per skid burn. In reviewing historical data, this level of burn is far from standard practice. In most cases, the actual amount of skid material open burned is less than this amount. Therefore, an assumption that every single skid burn contains 2,000 pounds of NEW per burn overestimates risk.
Dispersion/Deposition Modeling	The accuracy of the dispersion/deposition modeling output is limited by the ability of the model algorithms to correctly depict atmospheric transport and dispersion of contaminants. It is also limited by the applicability of the meteorological input data to the site; the model uses the most appropriate data that is available. Dispersion/deposition modeling uncertainties may overestimate or underestimate risk. A detailed analysis on the limitations and uncertainties that the OBODM model provides and comparison of the OBODM model to the AERMOD program, which is USEPA's preferred model for stack-type emission sources, was prepared as part of the permitting effort of the OB facility and the air modeling protocol for this assessment. That sensitivity analysis is part of the Administrative record and can be obtained for a separate review by those that are interested. (Please reference RFAAP, 2018b).

TABLE 7-1 (CONTINUED)
SUMMARY OF KEY UNCERTAINTIES

UNCERTAINTY	LIKELY EFFECT ON RISK ESTIMATE
Calculation of media concentrations	The accuracy of media concentration calculations is limited by the ability of the guidance document equations to correctly estimate media concentrations. Media concentration uncertainties may overestimate or underestimate risk.
Calculation of media concentrations	The media concentrations used in the risk assessment modeling are determined from, among other things, the air modeling concentrations and deposition rates. Therefore, the accuracy of the concentrations is limited by the accuracy of the air modeling programs to accurately predict air concentrations and deposition rates at the modeled locations.
Assumptions regarding exposure duration, frequency and time.	Risk calculations assume that the exposed individuals under the general receptor scenarios are at a single location for 24 hours per day, 350 days per year, for 30 to 40 years. Given the more mobile and working nature of our society, it is unlikely that an individual would reside in the same location for 30 years and/or spend 24 hours per day at that location. This exposure basis, therefore, likely overestimates risk.
Calculation of receptor intake	The accuracy of receptor intake calculations is limited by how closely the intake assumptions fit the actual receptors. The intake rates uses and the calculations employed are established to be conservative estimates based on latest guidance but may underestimate or overestimate intake for some receptors.
Calculation of receptor intake	The drinking water source for receptors within the assessment area is treated surface water from the New River. Constituent concentrations assumed for the drinking water are based on calculations from the model. However, the raw water is treated in a manner that effectively removes contaminants from the water. Therefore, intake from this source is overestimated, and risk and hazard resulting from exposure to COPCs in drinking water is most likely overestimated.
Location of the subsistence farmer	The subsistence farmer is located at the point of highest impact within an area of land that would require clearing to support the farming practice. Therefore, the location of the subsistence farmer likely overestimates risk, as the actual areas readily available to support such farming practice are further from the facility and have lower overall concentrations and deposition rates.
Presence of subsistence farmer	The type of consumption modeled for the subsistence farmer is likely not found within the largely suburban and wooded areas found within the assessment area. While farming does exist within the area, the practice of fully supporting the complete produce and animal product diet is unlikely. This "exaggerated" exposure scenario likely overestimates risk and hazard to the farming population in the area.
Location of subsistence fisher	Consumption of fish contributed significantly to the total incremental risk and hazard for the subsistence fisher. The fish tissue concentrations of COPCs used in the risk calculations were the highest for that constituent and did not necessarily occur in the same body of water. This idea of simultaneous achievability of the maximum tissue concentrations across multiple waterbodies is highly unlikely and overestimates risk to the fisher.
Presence of subsistence fisher	The consumption rates used for the subsistence fisher scenario are very high when compared to typical values for subsistence fishers presented in the Exposure Factors Handbook. In fact, it is more likely that a recreational fisher (freshwater angler) may exist in the assessment area. When compared to typical consumption rates for freshwater anglers in the Exposure Factors Handbook, the consumption rates used in this assessment are greatly exaggerated. These elevated consumption rates overestimate risk and hazard to the subsistence fisher. As part of the assessment, RFAAP reviewed actual fishing trends within the assessment area. These trends speak to the general absence of subsistence-style fishing and can be reviewed online at the HookandBullet and Fisheries references provided herein.

TABLE 7-1 (CONTINUED)
SUMMARY OF KEY UNCERTAINTIES

UNCERTAINTY	LIKELY EFFECT ON RISK ESTIMATE
Values used for cancer slope factors and reference doses.	As requested by VDEQ, toxicity information from the USEPA Region 3 risk screening tables were used in this MPRA. For many constituents, the potential for adverse effects in humans was extrapolated from animal studies, which may overestimate or underestimate risk. Many USEPA-approved toxicity values have low confidence ratings and high uncertainty factors, which may overestimate or underestimate risk.
Calculation of pathway risk and hazard	Total risk for each pathway is calculated by adding risks calculated for each constituent. This is likely to overestimate risk because the COPCs have different target organs and different mechanisms for carcinogenic effects. However, it is possible to underestimate risk if some COPCs have synergistic effects.
Calculation of total risk and hazard	Total risk for each receptor is calculated by adding pathway risks. This is likely to overestimate risk because individual receptors are not likely to simultaneously have reasonable maximum exposure to each pathway.

7.1 QUANTITATIVE UNCERTAINTIES

Some of the uncertainties with the MPRA process can be quantified better than others. These quantitative uncertainties allow an examination of the risk estimates and the relative scale of those estimates against the modeled versus actual conditions. The sections that follow describe the quantitative uncertainties with the drivers that were identified in this risk estimate.

7.1.1 RISK ASSESSMENTS

The most impacted exposure scenario for risk evaluations in the propellant burns was the subsistence farmer, with a total risk of 4.38×10^{-6} to the adult receptor. The scenario risk was driven by a combination of polynuclear aromatic hydrocarbons (PAHs) and phthalates in the milk consumption pathway. In this pathway, the exposure occurs as the cows raised by the farmer graze in the farmer's field and are milked. The farmer then drinks this milk as their sole source of milk intake. Furthermore, the farmer in this scenario is assumed to subsist off of homegrown animal products and produce, 100 percent of which are grown at the residence. The likelihood of one farmer raising beef cattle, dairy cattle, poultry, and pork and producing enough from this operation to subsist solely off of homegrown products is unlikely. Typical farming practices indicate that one farmer is not likely to raise substantial amounts of all of these animals simultaneously. Furthermore, this value is based on 365-day per operation of the propellant burns, which is technically unfeasible and demonstrated over the past five years to be a significant overestimate of unit operation. (On average in the last five years, the annual number of propellant burns was just over 50 burns per year).

For the skid burn scenarios, the risk was again greatest to the subsistence farmer. The driving pathways were inhalation and produce, beef, and milk consumption. The overestimation potential for this scenario is similar to that described above for the propellant scenario, both in terms of COPC exposure and operating frequency. While the frequency of skid burns is greater than that of the propellant burns, it is still grossly overestimated by the 365-day per year operating assumptions. Driving COPCs in the risk assessment included PAHs and arsenic.   All PAH emission factors were derived from AP-42 factors and therefore have inherent uncertainty and limited direct applicability to the RFAAP OBG emissions. The arsenic emission factors were measured during the site-specific emissions testing.

7.1.2 Hazard Assessments

The highest hazard indices in the propellant burn scenarios were modeled for the farmer, who was located at the point of maximum deposition in appropriate land use. The driver for this index derives from the inhalation pathway and is largely a result of the modeled hydrogen cyanide air concentrations. The hydrogen cyanide emission factors originate from AP-42 data. As discussed previously, the AP-42 data introduces considerable uncertainty to the risk assessment process due to the presence of non-RFAAP products in the items from which the AP-42 data was derived.

The hazard indices in the skid burn scenarios were fairly similar for all of the general receptors, with inhalation exposure driving the hazard index for each type of receptor and providing upwards of 90 percent of the hazard to each receptor. In all cases, the inhalation exposure was driven by the generation of sulfuric acid from the skid burns. Upon examination of the wastes burned at the OBG, RFAAP found that only a small fraction of the wastes (less than 3 percent of those burned over the last six years) contain sulfur. Conversely, the modeling that was performed for this MPRA assumed that each 2,000-pound burn contained the same amount of sulfur as the AP-42 item with the highest sulfuric acid content. This is extremely conservative and significantly overestimates risk. Furthermore, combustion chemistry would suggest that the more likely compound found from the combustion of sulfur in the waste would be sulfur dioxide (SO_2) rather than sulfuric acid. This suggests a further overestimation of risk.

7.2 Qualitative Uncertainties

The previous sections focused on the effect that some of the specific items discussed in Table 7-1 would have on hazard and risk estimates. However, for many of the items included in Table 7-1, a broader discussion is warranted. The sections below provide this broader analysis of uncertainty in the MPRA.

7.2.1 Assumptions and Variable Values

In the absence of empirical or site-specific data, assumptions and variable values are developed based on best estimates of exposure or dose-response relationships. To assist in the development of these estimates, USEPA recommends the use of guidelines and standard factors in MPRAs (USEPA, December 1989 and March 1991). The use of these standard factors is intended to promote consistency among risk evaluations where assumptions must be made. Although the use of standard factors undoubtedly promotes comparability, their usefulness in accurately predicting risk is directly proportional to their applicability to actual site-specific conditions.

This MPRA used many assumptions and variable values based on USEPA and other guidance documents. Different guidance documents often recommend different values for the same variables based on the studies referenced in that particular document. Table 7-2 provides a comparison between the variable values used in this assessment and recommended values provided in alternative USEPA guidance documents, estimating the impact to the risk and hazard calculations as a result of the varied values.

TABLE 7-2
POTENTIAL IMPACTS FROM VARIABLE VALUE UNCERTAINTIES

VARIABLE	DEFINITION	HHRA VALUE AND SOURCE	USEPA ALTERNATIVE VALUE AND SOURCE	IMPACT
IRWc	Child resident drinking water ingestion rate	0.67 L/day (USEPA, 2005. Equation C-1-5)	0.78 L/day (USEPA 2011a, Tables 3-15 and 3-33)	**Overall risk and hazard will increase an inappreciable amount.** Ingestion rate is directly proportional to risk, with one increasing as the other increases. For these changes, the higher ingestion rate will increase intake, and consequently, risk and hazard from drinking water ingestion by a factor of 1.16. However, both of these were very low for all assessed receptors. The highest drinking water risk for children was from the propellant burns. Calculated risk was 7.71E-10, and calculated hazard was 4.68E-05. Increasing either of these by a factor of 1.16 does not materially alter the results of the assessment, as the impact is minor and exposure via this pathway was already insignificant. Risk increases to 8.94E-10, and hazard increases to 5.43E-05.
IRWa	Adult resident drinking water ingestion rate	1.4 L/day (USEPA, 2005. Equation C-1-5)	2.5 L/day (USEPA 2011a, Table 3-33)	**Overall risk and hazard will increase an inappreciable amount.** Ingestion rate is directly proportional to risk, with one increasing as the other increases. For these changes, the higher ingestion rate will increase intake, and consequently, risk and hazard from drinking water ingestion by a factor of 1.785. However, both of these were very low for all assessed receptors. The highest drinking water risk for adults was from the propellant burns. Calculated risk was 2.61E-09, and calculated hazard was 2.37E-05. Increasing either of these by a factor of 1.785 does not materially alter the results of the assessment. Risk increases to 4.66E-09, and hazard increases to 4.23E-05.

TABLE 7-2 (CONTINUED)
POTENTIAL IMPACTS FROM VARIABLE VALUE UNCERTAINTIES

VARIABLE	DEFINITION	HHRA VALUE AND SOURCE	USEPA ALTERNATIVE VALUE AND SOURCE	IMPACT
SAsc	Child resident skin surface area	9,500 cm^2 (USEPA 2011a, Table 7-1 (95 percentile value for children 3 to 6 years))	2,373 cm^2 (USEPA 2011a, Tables 7-2 and 7-8 (weighted average of mean for various body parts))	**Overall risk and hazard will decrease slightly.** The proposed value is a significant decrease in the exposed skin surface area. This will cause a significant decrease to the intake through this pathway, as the intake is directly proportional to the skin surface area. The highest dermal risk was for the child farmer in the skid burn scenario. Risk from the dermal pathway was 7.89E-09, and hazard was 1.92E-04. Adjusting for the lesser surface area results in a risk of 1.97E-09 and a hazard of 4.80E-05.
SAsa	Adult resident skin surface area	25,000 cm^2 (USEPA 2011a, Table 7-1 (95 percentile value for adults 30 to 40 years))	6,032 cm^2 (USEPA 2011a, Tables 7-2 and 7-12 (weighted average of mean for various body parts))	**Overall risk and hazard will decrease inappreciably.** The proposed value is a significant decrease in the exposed skin surface area. This will result in a significant decrease to the intake through this pathway, as the intake is directly proportional to the skin surface area. The highest dermal risk was for the adult farmer in the skid burn scenario. Risk from the dermal pathway was 3.90E-10, and hazard was 1.42E-06. Adjusting for the lesser surface area results in a risk of 9.40E-11 and a hazard of 3.42E-07.
AFc	Child resident soil adherence factor	0.026 to 21 mg/cm^2 depending on receptor (*e.g.,* school student versus daycare child, versus resident and farmer child receptors). (USEPA 2011a, Table 7-4)	0.2 mg/cm^2 (USEPA 2004, Exhibit 3-5)	**Overall risk and hazard will decrease slightly.** The proposed value represents a significant decrease in the soil adherence factor. This will result in a significant decrease to the intake through this pathway, as the intake, and consequently risk, is directly proportional to the adherence factor. The highest overall dermal risk for any exposure pathway was for the child farmer in the skid burn scenario. Risk from the dermal pathway was 7.89E-09, and hazard was 1.92E-04. Adjusting these for the lesser adherence factor results in a risk of 7.51E-11 and a hazard of 1.83E-06.

TABLE 7-2 (CONTINUED)
POTENTIAL IMPACTS FROM VARIABLE VALUE UNCERTAINTIES

VARIABLE	DEFINITION	HHRA VALUE AND SOURCE	USEPA ALTERNATIVE VALUE AND SOURCE	IMPACT
AFa	Adult resident soil adherence factor	0.0503 to 0.2763 mg/cm^2 depending on receptor (*e.g.,* school student versus daycare child, versus resident and farmer child receptors). (USEPA 2011a, Table 7-4)	0.07 mg/cm^2 (USEPA 2004, Exhibit 3-5)	**Overall risk and hazard will decrease inappreciably.** The proposed value is a significant decrease in the soil adherence factor. This will cause significant decrease to the intake through this pathway, as the intake is directly proportional to the adherence factor. The highest dermal risk was for the adult farmer in the skid burn scenario. Risk from the dermal pathway was 3.90E-10, and hazard was 1.42E-06. Adjusting for the lesser surface area results in a risk of 9.88E-11 and a hazard of 3.6E-07.
BWc	Child resident body weight	15-27 kg, depending on receptor (*e.g.,* school student versus daycare child, versus general child receptor).	15 kg (USEPA 2011a, Table 8-1)	**Overall risk and hazard will increase slightly in cases where higher body weights were used.** Body weight is used in the intake equations, where consumption rates are divided by the body weight of the receptor. Therefore, body weight is inversely proportional to risk. As body weight decreases, intake and risk increase. Changing from the range of values used to the value recommended will result in an increase in intake up to 1.8 times the calculated intake in this risk assessment. The same impact will be made to the risk calculations – an increase in both risk and hazard by a factor of 1 to 1.8 times the calculated risk via all pathways. The highest risk recorded for a child was in the propellant burn, farmer scenario at 9.12E-07. The highest hazard was from the same scenario and was 0.131. For this scenario, a bodyweight of 17 kg was used. Applying the ratio of weights to these results, the resulting risk goes to 1.0E-06, and the hazard goes to 0.149. Adjustments have already been proposed that would reduce both of these factors below the target levels. These adjustments, with the body weights used, lowered risk to 4.56E-7 and hazard to 0.0655. With the adjustment for weight, these become 5.17E-07 and 0.074.

TABLE 7-2 (CONTINUED)
POTENTIAL IMPACTS FROM VARIABLE VALUE UNCERTAINTIES

VARIABLE	DEFINITION	HHRA VALUE AND SOURCE	USEPA ALTERNATIVE VALUE AND SOURCE	IMPACT
BWa	Adult resident body weight	70 kg (USEPA, 2005. Appendix C)	80 kg (USEPA 2011a, Table 8-3)	**Overall risk and hazard will decrease slightly.** Body weight is used in the intake equations, where consumption rates are divided by the body weight of the receptor. Therefore, body weight is inversely proportional to risk. As body weight increases, intake and risk decrease. Changing from the value used to the value recommended will result in a reduction in intake equal to 0.89 times the calculated intake in this risk assessment. The same impact will be made to the risk and hazard calculations – a reduction in both by a factor 0.89 via all pathways. The highest risk recorded for an adult was 4.38E-06, and the highest hazard index was 0.119. Both of these were for the farmer in the propellant burn scenarios. Applying this factor to those results would decrease the risk to 3.83E-06 and hazard to 0.104. Adjustments have already been proposed that would reduce both of these factors below the target levels. These adjustments, with the body weights used, lowered risk to 2.18E-06 and hazard to 0.0598. With the adjustment for weight, these become 4.52E-07 and 0.052.
EDa	Adult resident exposure duration	30 years (USEPA, 2005. Equation C-2-1 and Equation C-2-2)	20 years (USEPA 2011a, Table 16-108)	**Overall risk and hazard will decrease.** Exposure duration is directly proportional to the calculated risk and hazard. Therefore, a decrease in the adult exposure duration will reduce the overall risk to the receptor. In this case, risk and hazard would decrease by a factor of 0.67. The highest overall risk and hazard for an adult resident was for the propellant burn scenario, with risk and hazard equivalent to 1.09E-06 and 0.117, respectively. With this change, the risk and hazard would decrease to 7.27E-07 and 0.078, respectively.

TABLE 7-2 (CONTINUED)
POTENTIAL IMPACTS FROM VARIABLE VALUE UNCERTAINTIES

VARIABLE	DEFINITION	HHRA VALUE AND SOURCE	USEPA ALTERNATIVE VALUE AND SOURCE	IMPACT
IRfisha	Adult fish ingestion rate	8.75 x 10^{4} mg/day	Use site-specific value (USEPA 2014)	**Overall risk and hazard will likely decrease.** RFAAP has not researched site-specific fish consumption rates for the area. However, recognizing that this is an inland location and that consumption advisories exist for many of the fishable waterbodies and species, we expect that any site-specific value would be less than a default value based on a nationwide study. A reduction in the intake rate will directly correlate to a reduction in risk and hazard to the fishing receptor.
IRfishc	Child fish ingestion rate	2.125 x 10^{4} mg/day (USEPA, 2005. Equation C-1-4)	Use site-specific value (USEPA 2014)	**Overall risk and hazard will likely decrease.** RFAAP has not researched site-specific fish consumption rates for the area. However, recognizing that this is an inland location and that consumption advisories exist for many of the fishable waterbodies and species, we expect that any site-specific value would be less than a default value based on a nationwide study. A reduction in the intake rate will directly correlate to a reduction in risk and hazard to the fishing receptor.
IRproducea	Adult consumption of homegrown produce	9.8 g/day for belowground produce (BGP) to 42.7 g/day aboveground protected produce (AGPP) (USEPA, 2005. Equation C-1-2)	Use site-specific value (USEPA 2014)	**Overall risk and hazard will change; the degree and direction of that change cannot be assessed at this time.** RFAAP has not researched site-specific produce consumption rates for the area. The value used was taken from a Nationwide study. For adults, the relative percent difference between the highest and lowest mean consumption rates for belowground and aboveground protected produce in the study was approximately 30 percent for individuals in the age range from 20 to over 70. Therefore, using a site-specific rate instead of the default rate could either increase or decrease the risk by 30 percent depending on the relation of regional trends to national trends.

TABLE 7-2 (CONTINUED)
POTENTIAL IMPACTS FROM VARIABLE VALUE UNCERTAINTIES

VARIABLE	DEFINITION	HHRA VALUE AND SOURCE	USEPA ALTERNATIVE VALUE AND SOURCE	IMPACT
IRproducec	Child consumption of homegrown produce	2.38 g/day for BGP to 10.37 g/day for AGPP (USEPA, 2005. Equation C-1-2)	Use site-specific value (USEPA 2014)	**Overall risk and hazard will change; the degree and direction of that change cannot be assessed at this time.** RFAAP has not researched site-specific produce consumption rates for the area. The value used was taken from a Nationwide study. For children between zero and 6 years of age, the relative percent difference between the highest and lowest mean consumption rates for belowground and aboveground protected produce in the study was approximately 60 percent. Therefore, using a site-specific rate instead of the default rate could either increase or decrease the risk by 60 percent depending on the relation of regional trends to national trends.

Regardless of the source of the variable value, many of these values are considered conservative and are generally more likely to overestimate versus underestimate risk; however, the time needed to develop site-specific factors can be extensive and is not always necessary. In addition, VDEQ expressed a preference for use of these conservative values in place of site-specific values to help provide a cushion in the level of protection that the MPRA asserts. Therefore, the risk estimates provided herein are considered not only protective but conservative based on the default values that were applied.

7.2.2 EMISSION SAMPLING AND ESTIMATING METHODS

The ability to accurately sample emissions from open burning remains challenging. While USEPA is advancing research to allow collection of more representative and more accurate samples, this research is still in the early stages. RFAAP did, in fact, conduct site-specific emission sampling from the OBG activities using state-of-the-art sampling technologies and employing personnel and resources from USEPA's research, development, and testing centers of excellence. While this data is expected to be much more representative than the old emission estimating methods from DOE and the current AP-42 factors, the methods themselves have limits to precision, accuracy, and level of detection.

Furthermore, the AP-42 draft emission factors for open burning and open detonation of munitions, which were used to supplement the site-specific data, were generated from combustion in a closed chamber and were not generated from RFAAP waste materials, introducing additional layers of uncertainty to the process. While factors were selected from DODICs that contain RFAAP material, there are limits to their application and validity as explained previously.

In general, whether the use of site-specific data versus AP-42 data overestimates or underestimates risk varies. In some cases, the site-specific emissions data will underestimate risk and, in some cases, it may overestimate risk. In the case of closed-chamber combustion versus open pan the availability of oxygen for the process will significantly impact the completeness of combustion and, consequently, the estimated organic emissions from the process. In an enclosed chamber, the only oxygen available to support the combustion process is that which is supplied via a combustion air source, such as a blower or fan that injects outside air into the chamber. This rate-limited supply of oxygen can result in an oxygen deficiency and can lead to incomplete combustion. In the open-air environment, the air source is not limited, as any amount of oxygen required can easily be extracted from the ambient air. As a result, open-air combustion should generally result in more complete combustion than combustion in an enclosed chamber. When we consider how rapidly energetic materials consume oxygen in a combustion process, this difference is magnified. Therefore, using AP-42 factors for organic emissions from combustion of energetic material in an enclosed-chamber should result in a high-bias to the predicted emissions and the resulting risk. Emissions of polynuclear aromatic hydrocarbons (PAHs) and phthalates, which tend to be drivers in most risk assessments because they are particularly harmful to the environment, were based on AP-42 factors. Therefore, the risk from these compounds is likely overestimated.

Furthermore, efforts were made to create a more “worst-case” waste mix for the flyer testing, with the intention being to drive emissions to their maximum and result in a conservative, over-estimation of risk. However, it is possible that some burns may result in greater emissions or may lead to greater PIC formation than those that were tested. It is not possible to test every chemical combination of waste materials that can be burned at the OBG and therefore, situations exist where actual emissions from one chemical combination of waste materials may be higher than those generated during the site-specific emissions testing due to either different combustion conditions, different chemical reactions, or different formation mechanisms in each burn. Similarly, in some cases, the AP-42 data may overestimate risk, and in others, it may underestimate risk, as the emissions data represented by the AP-42 data is a combination of the initiation of the RFAAP-product in the specific munitions item and the many other components in the item. This combination of RFAAP-products with other emissions-producing chemicals and pollutants can bias the emission factors high or low.

Attempts may be made to compare the AP-42 emission factors and the flyer data for COPCs that are provided emissions factors under each dataset. However, this is not appropriate, as many different factors can affect the emissions of a compound. First, unless an AP-42 factor exists for the exact chemical makeup of the materials tested in the flyer testing, any such comparison is incommensurable. Many different elements effect the completeness of a combustion reaction and the PICs from it. Truly the presence of one additional compound in an AP-42 item that is not present in the RFAAP material can result in a completely different emissions factor for any other component. In addition, differing amounts of a constituent in items will also result in an inappropriate comparison. Both of these conclusions can be demonstrated through comparison of one potential scenario. Take, for example, the emission factor resulting from an item containing 450 pounds of lead styphnate ($PbC_6HN_3O_8$). The simple oxidation-reduction reaction for lead styphnate is as follows (absent any other outside influences):

$$2\ PbC_6HN_3O_8 + 11.5\ O_2 \dashrightarrow 2\ PbO + 12\ CO_2 + 6\ NO_2 + H_2O$$

This reaction says that for every 2 moles of lead styphnate (or 900 pounds), 2 moles of lead oxide (or 446 pounds) will be produced. This is an emission factor of approximately 0.5 pounds per pound combusted.

However, the combustion of the same amount of lead styphnate in a waste mixture that contains chlorine will result in a different reaction – one that generates a mixture of lead oxide and lead chloride (or a lower overall emission factor of lead oxide than in the simple, basic case presented above). If the RFAAP product being treated during the flyer testing contained only lead styphnate and some other compound that will not react or combine with the lead in the combustion process and the item producing the AP-42 factor contains lead styphnate and a chlorine compound, the AP-42 factor would underestimate lead oxide emissions from treatment of lead styphnate.

7.2.3 Risk and Hazard from Criteria Pollutants

Under the Clean Air Act, EPA establishes air quality standards for six principal air pollutants, referred to as criteria pollutants, to protect public health, including the health of "sensitive" populations such as people with asthma, children, and older adults. These pollutants include: particulate matter, nitrogen dioxide, ozone, sulfur dioxide, carbon monoxide, and lead. While the health effects from lead were assessed in this MPRA, the health effects from the other criteria pollutants were not directly assessed due to a lack of emissions data specific to RFAAP products. A discussion of this omission on the results of the MPRA is provided below for each criteria pollutant.

7.2.3.1 Particulate Matter

Particulate matter from combustion sources is generally characterized as a mixture of non-combustible emission products and metals. Most of this particulate matter falls in the micron to sub-micron category and is generally characterized as PM2.5. The cancer risk and hazard quotient evaluation included in the HHRA already addressed the impact of the PM-metallic fraction on the surrounding community. For the non-metallic fraction, a qualitative assessment can be performed by comparing the modeled PM2.5 emissions from the OBG to the PM2.5 National Ambient Air Quality Standards (NAAQS).

The site-specific emissions testing performed at the RFAAP OBG included an evaluation of PM2.5 emissions from each of the open burning scenarios. The testing found that the PM2.5 emissions were higher from the propellant burns than the skid burns. For propellant burns, the sampling reported an emissions factor of 0.0155 pounds of PM2.5 per pound of waste (lb/lb); for skid burns, the sampling reported an emissions factor of 0.0073 lb/lb. Applying these emission factors at the areas of highest particle phase air concentration results in an annual average PM2.5 air concentration of 0.265 μg/m^3 for propellant burns, and a PM2.5 concentration of 0.0662 μg/m^3 for skid burns.

The PM2.5 NAAQS to ensure protection of public health and the environment. The primary standards are designed to protect public health, including sensitive populations. The secondary standards are designed to protect public welfare, including protection against decrease visibility and damage to animals, crops, and vegetation. The current primary and secondary NAAQS for PM2.5 are 12.0 $\mu g/m^3$ and 15.0 $\mu g/m^3$, respectively. Comparing the NAAQS and the modeled PM2.5 concentrations from both burn scenarios, it does not appear as if the PM2.5 emissions from the OBG operations pose a threat to human health or the environment. The highest modeled PM2.5 concentration is only 2.2 percent of the primary NAAQS and 1.8 percent of the secondary NAAQS. Furthermore, these concentrations assume operation 365 days per year, which is not realistic. Therefore, the actual PM2.5 concentrations and impact should be even less than this prediction

7.2.3.2 Nitrogen Dioxide

Nitrogen dioxide, or NO_2, is a reddish brown, highly reactive gas that is formed in the ambient air through the oxidation of nitric oxide (NO). Nitrogen oxides (NOx), the generic term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts, play a major role in the formation of ozone, PM, haze, and acid rain. NOx are readily produced through the open burning of the highly nitrogenated wastes processed at the RFAAP OBG. In general, higher levels of NOx production have been observed with propellant burns than with skid burns (based on visual observations of a reddish-brown plume from the burn). Unfortunately, RFAAP was unable to collect site-specific emissions data on NOx from these burns during the flyer testing due to sampling limitations. Therefore, it is not possible to provide a direct quantitative impact of the risk from them in this MPRA.

Short-term exposures (e.g., less than 3 hours) to NO_2 may lead to respiratory disorders. Long-term exposures to NO_2 may lead to increased susceptibility to respiratory infection and may cause irreversible impacts on lung tissue. In addition, NOx can react in the air to form ground-level ozone and fine particle pollution, which are also associated with adverse health effects. Based on the air modeling results, the primary impact from these effects, based on the air modeling results, would be to the southeast of the burning ground, adjacent to Prices Fork Road. Being unable to characterize the quantitative risk from this exposure may underestimate risk.

7.2.3.3 Ozone

Ozone occurs naturally in the stratosphere above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays. Ozone is also formed at ground level by a chemical reaction of various air pollutants combined with sunlight. The pollutants that contribute to ozone formation are NOx and volatile organic compounds (VOCs). While very little VOCs were reported in the flyer testing, the OBG operations do, based on visible observations, produce NOx emissions. Therefore, the production of ozone from the OBG operations is possible.

Ground-level ozone, which is that ozone most likely to be formed at low levels from OBG operation, is an air pollutant that damages human health and the environment. Even at relatively low levels, ozone may cause inflammation and irritation of the respiratory tract, lead to breathing difficulty, coughing, and throat irritation. Elevated ozone levels can also worsen asthma attacks and, over long-term exposure, may damage lung tissue. Based on the air modeling results, the primary impact from these effects would be to the southeast of the burning ground, adjacent to Prices Fork Road. Being unable to characterize the quantitative risk from this exposure may underestimate risk.

7.2.3.4 Sulfur Dioxide

Sulfur dioxide (SO_2) is formed when fuel containing sulfur) is burned. The propellant burns do not contain any sulfur-bearing wastes and, therefore, do not contribute to SO_2 emissions. Only a small percentage of the skid burn wastes contain sulfur. Therefore, although the SO_2 emissions from the OBG were not quantified as part of this assessment, the overall SO_2 emissions are expected to be minor based on data that is known on the wastes being processed. Likewise, the impact of SO2 emissions from the OBG on the overall risk and hazard from burning ground emissions is expected to be negligible.

7.2.3.5 Carbon Monoxide

Carbon monoxide is a colorless and odorless gas, formed when carbon in fuel is not burned completely. At the OBG, CO is formed through the incomplete combustion of carbon-based elements in the waste, such as hydrocarbons and dunnage items used in skid burns. CO was measured as a “tracer” gas in the flyer testing that was conducted at the OBG, which the CO concentrations being used as an indicator that the flyer sampling device was still in and following the OBG plume. While high concentrations of CO were measured directly in the OBG plume near to the ignition point, no ambient data was collected to relate these “plume-based” concentrated measurements to ambient air concentrations.

CO enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. At extremely high levels, such as those found in a poorly tuned burner exhaust, CO can be poisonous to humans. However, the health threat from even elevated levels of CO found in the ambient air is most serious for those who suffer from cardiovascular disease. (USEPA, 1998c). Based on the air modeling results, the primary impact from these effects would be to the southeast of the burning ground, adjacent to Prices Fork Road. Being unable to characterize the quantitative risk from this exposure may underestimate risk to more sensitive members of the population.

7.2.4 Air Modeling Methods

Although air dispersion modeling is a valuable tool for estimating concentration and deposition impacts, it has many limitations. The accuracy of the model is limited by the ability of the model algorithms to depict atmospheric transport and dispersion of contaminants, and the accuracy and validity of the input data. For instance, most refined models require input of representative meteorological data from a single measurement station, while, in reality, a release will encounter highly variable meteorological conditions that are constantly changing as it moves downwind. These factors, coupled with variations in model algorithms, effect the predicted movement of COPCs through the atmosphere and to ground. These various and mitigating factors can directly impact the determination of media concentrations of each of the selected COPCs. Major uncertainties in all air modeling efforts, as explained in the USEPA’s HHRAP, include the determination of atmospheric deposition rates and the setting of deposition-related input variables, and the long-range transport of pollutants into and out of the study area (USEPA, 1998c).

In addition, the OBODM model, while the best available for approximating emissions from open burning, has its own limitations. For example, the model does not incorporate wet deposition algorithms and cannot model particle phase emissions in complex terrain. While RFAAP does not traditionally conduct OBG operations during precipitation events, the impact of pollutants that remain airborne at the initiation of a subsequent precipitation event was unaccounted for in the MPRA process. This deficiency in the selected model may underestimate risk.

A detailed analysis on the limitations and uncertainties that the OBODM model provides and a comparison of the OBODM model to the AERMOD program, which is USEPA's preferred model for stack-type emission sources, was prepared as part of the permitting effort of the OB facility and the air modeling protocol for this assessment. That sensitivity analysis is part of the Administrative record and can be obtained for a separate review by those that are interested. (Please reference RFAAP, 2018b). The primary focus of this sensitivity analysis was to evaluate whether USEPA's preferred model (AERMOD) would be more appropriate to model OBG emissions than would the lesser used OBODM, despite OBODM being specifically developed for open burning events. Some of the conclusions presented in the referenced study include:

- For the shorter-term burns AERMOD reports approximately a factor of two higher in mass adjusted concentration values than does OBODM. While a factor of 2 has been associated with historical model performance especially between modeled and monitored values, such a factor is a significant value especially when understanding and incorporating many other uncertainties associated with risk assessments and exposure scenarios. In these cases, AERMOD would be expected to overestimate risk.
- The receptor locations for each model run show good agreement in receptor height for the shorter-term burns, perhaps suggesting that plume heights are more consistently similar between the two models for higher energetic releases (same mass shorter burn time) than for less energetic releases (same mass longer burn time). This would result in a similar estimation of maximum exposed locations from both models.
- The results of the comparisons show the differences between the two models primarily in that OBODM allows for a dynamic calculation of buoyancy fluxes and plume heights for each meteorological condition and treatment event based on the characteristics of the material treated, whereas AERMOD requires fixed inputs based on assumptions of static conditions derived from OBODM values, and therefore not all differences in buoyancy fluxes and calculated plume heights from OBODM will be captured in AERMOD.

The reader is referred to the referenced document for a further, more detailed discussion on uncertainties and the measured impact of those differences on the risk assessment results.

7.2.5 Fate and Transport Equations

The HHRAP provides numerous equations to determine the fate and transport of pollutants through environmental media, and the impact that those pollutants have on the exposed population. These equations were developed from what USEPA determined to be the best-available information at the time the HHRAP was published. Unfortunately, these equations are based on either theoretical assumptions, experimentally determined relationships, or undetermined sources. Therefore, each equation employed has uncertainty associated with it. As with the other sources of uncertainty, when the uncertainties associated with each equation are compounded, the resultant media concentrations, intake rates, and risk determinations are highly conservative.

The ability of RFAAP to eliminate the uncertainties resulting from use of the recommended fate and transport equations is highly limited, unless alternative equations are used. VDEQ requested that RFAAP avoid seeking out alternative fate and transport equations other than those provided in the HHRAP. For the equations that were used, USEPA identified the uncertainties associated with each equation to the best extent possible in the Appendices to the HHRAP. In general, the uncertainties that are explained provide opportunities for both overestimation and underestimation of risk.

7.2.6 Toxicity Values

The determination of risk and hazard associated with a given pollutant is based largely on toxicity values recommended by USEPA. This MPRA used values from USEPA Region 3's RSL database. Even though the database values are reviewed and updated frequently by various USEPA work groups, each value has varying degrees of confidence and uncertainty associated with it. USEPA ranks the confidence level of the source study, the study database, and the derived risk factor on a three-point scale: low, medium and high. Using values with low confidence ratings increases the uncertainty in the MPRA. Also, each risk factor has an associated UF that allows for interspecies extrapolation, sensitive population protection, database deficiencies, and subchronic to chronic extrapolation. These UFs, which work as multipliers, can range from low (*e.g.* 10) to high (*e.g.* 3,000).

7.2.7 Unquantified Risk and Hazard

Not all of the constituents identified in the OBG emissions either from the site-specific emissions testing or the AP-42 review were included in the risk and hazard analyses. Some of these constituents lacked reliable fate and transport data, while others did not have sufficient toxicity data available. A discussion of the impact of each of these uncertainties on the MPRA is provided below.

Upwards of 150 COPCs were identified for inclusion in the MPRA. However, the actual quantitative assessment was limited to under 90 COPCs because 40 percent of those COPCs that were identified did not have sufficient fate, transport, or toxicity data to complete the evaluation. The majority of these compounds were rare earth metals and metallic compounds. Some organics were also excluded from the quantitative risk evaluations. It is possible that the omission of these compounds from the quantitative evaluation may underestimate the total risk and hazard to studied receptors. However, USEPA has made every effort to gather fate, transport, and toxicological data on compounds that they feel pose the most threat to human health and the environment through the establishment of lists of criteria pollutants and hazardous air pollutants in the Clean Air Act, priority pollutants in the Clean Water Act, principle organic hazardous constituents under the Resource Conservation and Recovery

Program, and other toxic chemicals under the Toxic Substances Control Act. Furthermore, USEPA specifically developed the Integrated Risk Information System (IRIS) to fulfill their mission of protecting human health and the environment. As explained by USEPA on the IRIS website, "EPA's IRIS program supports this mission by identifying and characterizing the health hazards of chemicals found in the environment." Through these and other related efforts, USEPA has made a considerable effort to characterize those compounds that pose the most harm to human health and the environment and generate the data necessary to assess the risks they pose.

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Appendix A: AIR MODELING DATA

Appendix B: RISK ASSESSMENT CALCULATIONS

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc*. For calculation of any field provided in the tables, please reference the associated HHRAP equation cited at the top of each field's column.