Marine Corps Installations Command

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FINAL

Range Environmental Vulnerability Assessment

5-Year Review

Marine Corps Air Station Beaufort and the Townsend Bombing Range

June 2013

Report Prepared By:

ARCADIS/Malcolm Pirnie
101 South Washington Square
Suite 400
Lansing, Michigan 48933

06285037.0000

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Table of Contents

List of Tables

List of Figures

Appendices

Acronym List

Acronym	Definition
^oF	Degrees Fahrenheit
µg/kg	Micrograms per Kilogram
µg/L	Micrograms per Liter
BDU	Bomb Dummy Unit
Bgs	Below Ground Surface
BJWSA	Beaufort-Jasper Water and Sewer Authority
CSM	Conceptual Site Model
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDIC	Department of Defense Identification Code
EOD	Explosive Ordnance Disposal
ft	Feet
ft/yr	Feet per year
FY	Fiscal Year
GA	Georgia
GEPD	Georgia Environmental Protection Department
GIS	Geographic Information System
HE	High Explosive
HMX	Cyclotetramethylene Tetranitramine
kg/m^2	Kilograms per Square Meter

Acronym	Definition
lb	Pound
m^2	Meters Squared
MAG-31	Marine Air Group – 31
Marine Corps	United States Marine Corps
MC	Munitions Constituents
MCAS	Marine Corps Air Station
MCI COM	Marine Corps Installations Command
mg/kg	Milligrams per kilogram
MIDAS	Munitions Items Disposition Action System
MK	Mark
mm	Millimeter
MMRP	Military Munitions Response Program
mph	Miles per Hour
msl	Mean Sea Level
NBC	Nuclear, Biological, Chemical
PGM	Precision Guided Missile
POL	Petroleum, Oils and Lubricants
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylene Trinitramine
REVA	Range Environmental Vulnerability Assessment
RFMSS	Range Facility Management Support System
RUSLE	Revised Universal Soil Loss Equation

Acronym	Definition
SAM	Surface-to-Air Missile
SAR	Small Arms Range
SARAP	Small Arms Range Assessment Protocol
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
TACTS	Tactical Air Crew Combat Training System
T/E	Threatened and Endangered
TECOM	Training and Education Command
Townsend Range	Townsend Bombing Range
TNT	Trinitrotoluene
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UXO	Unexploded Ordnance

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Executive Summary

The United States Marine Corps (Marine Corps) Range Environmental Vulnerability Assessment (REVA) program meets the requirements of the Department of Defense (DoD) Directive 4715.11 *Environmental and Explosives Safety Management on Operational Ranges within the United States* and DoD Instruction 4715.14 *Operational Range Assessments*.

The purpose of the REVA program is to identify whether there is a release or substantial threat of a release of munitions constituents (MC) from the operational range or range complex areas to off-range areas. This is accomplished through a baseline assessment of operational range areas, periodic five-year review assessments, and, where applicable, the use of fate and transport modeling of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas. Results of the model-predicted MC concentrations are compared to an established set of REVA trigger values. A REVA trigger value is a median value of method detection limits attained from several laboratories. REVA trigger values are not regulatory action levels. For purposes of REVA, these values are used to determine whether additional actions are necessary such as additional evaluation and/or sampling to determine if a release or threat of a release may be present.

Site-specific sampling is conducted under REVA if screening-level fate and transport analyses significantly exceed trigger values. The sampling is performed to further evaluate the potential of MC release and support the installation and Marine Corps Installations Command in assessing the potential for degradation of groundwater and/or surface water quality. The results of sampling will be compared to DoD screening values to determine if the release is a threat to human health and/or the environment.

This report presents the five-year review assessment results for the operational ranges and training areas at Marine Corps Air Station (MCAS) Beaufort, South Carolina, and the Townsend Bombing Range (Townsend Range), Georgia. This report serves as the first five-year review assessment documenting the period of munitions loading from 2006 through 2011. The baseline assessment completed in 2008 documented munitions used through 2005.

Military Munitions Training and Operations

MCAS Beaufort was established in 1943 to serve as a naval air station. Following a deactivation period between 1946 and 1956, MCAS Beaufort was reopened as an air station for the Marine Corps. Marine Aircraft Group 31 (MAG-31) is stationed at MCAS Beaufort, comprising approximately 4,200 Marines, sailors, and civilian employees. The mission of MAG-31 is to conduct anti-air warfare and offensive air support operations in support of Fleet Marine Forces from advanced bases, expeditionary airfields, and aircraft carriers and conduct such operations as may be directed.

Four operational ranges are located at MCAS Beaufort. These include the Explosive Ordnance Disposal (EOD) Range; Boresight Range; Nuclear, Biological, Chemical Training (NBC) Area; and the Pistol Range. The Pistol Range, a small arms range (SAR), is the only operational range at MCAS Beaufort that requires evaluation in this five-year review effort. The other ranges were not evaluated because they were either managed under a different program (EOD Range), a historical use (Boresight Range), or did not use MCs (NBC Area). The term historical use refers to formerly used areas that lie within a designated operational range area.

MCAS Beaufort operates the Tactical Air Crew Combat Training System (TACTS) Atlantic Ocean Range, which is located approximately 40 miles offshore and is about 80 miles by 40 miles in size. This combat training range consists of eight towers located within Special Operating Areas 3X (north range) and 4X (south range). The Beaufort TACTS provides aircrew training and performance evaluation in air-to-air combat. Ordnance is not expended on this range; therefore, it is not evaluated further in this REVA five-year review.

The Townsend Range is approximately 130 miles south of MCAS Beaufort in McIntosh County, Georgia. The 5,182-acre Townsend Range is used routinely by all services to enhance the bombing and air combat skills of fighter pilots. The United States Navy owned the bombing range until it was closed in 1972. The range was reopened in 1981 and currently is owned by the Marine Corps but operated by the Georgia Air National Guard.

The Townsend Range contains 12 target areas designed for use of various types of inert munitions. These include the Command Post Target; Heavy Weight Target; Helicopter Door Gunnery Target; High Angle Strafe Target; Main Bull Target; Petroleum, Oils, Lubricants (POL) Target; Surface-to-Air Missile (SAM) Site Target; Scud Target; Smokey SAM; two Strafe Targets; and Urban Target Area. A new target area at the Townsend Range, the Urban Target Area, was constructed in 2010. The site is adjacent to the POL Target and was constructed to simulate an urban attack scenario based on military operations in recent conflicts. A SAR was formerly located at the range.

MC loading areas are where the majority of MC are deposited within an operational range. MC loading areas were identified and evaluated during the baseline assessment. Prior to assessing the current data, the results of the baseline assessment were considered. **Table ES-1** provides a summary of the results of the baseline assessment.

The baseline consisted of conducting assessments of two SARs, one at MCAS Beaufort and one at the Townsend Range, and assessing the target areas at the Townsend Range for high explosives (HE) and perchlorate. Specific expenditure data were not available for the Townsend

Range at the time of the baseline assessment; therefore, conservative assumptions were used to identify potential munitions loads used at the component targets.

Table ES-1: Summary of Baseline Assessment Results for MCAS Beaufort and the Townsend Range [b]

MC Loading Area	Screening-Level Modeling Results[a] Predicted to Exceed REVA Trigger Values		Assessing in 5-Year Review
	Surface Water	Groundwater	
TOWNSEND RANGE			
Command Post	Not modeled		Yes
Heavy Weight	Yes	Yes	Yes
Main Bull	Yes	Yes	Yes
POL Target	Not modeled		Yes
SAM	Not modeled		Yes
Scud Site	Not modeled		Yes
Smokey SAM	Not modeled		Yes
SAR	**Surface Water Ranking**	**Groundwater Ranking**	**Assessing in 5-Year Review**
MCAS Beaufort Pistol Range	Moderate	Moderate	Yes
Townsend Range – SAR	Moderate	Moderate	No

[a] Result is indicated for downstream receptor.

[b] Additional action such as field monitoring for MC in surface water at the edge of Townsend Bombing Range Property may be conducted as necessary in the near future.

MC loading estimates and screening-level transport analyses of HE and perchlorate estimated that perchlorate loading focused at the Main Bull and Heavy Weight targets would reach the off-range Churchill Swamp via surface water and groundwater pathways at concentrations exceeding the REVA trigger values for perchlorate. However, the estimated concentrations did not exceed the chronic water quality criterion (DoD, 2012).

The baseline evaluation conducted at the Townsend Range identified perchlorate as a significant contributor to MC loading rates. Upon review of the baseline report and comparison to the findings of the five-year review, it was noted that overly conservative assumptions were used for the baseline assessment due to a lack of specific munitions information. In the absence of actual DoD Identification Code (DoDIC) information, the baseline team selected rocket motors that contained a large amount of perchlorate. The new, more detailed information obtained from Townsend Range range personnel in the five-year review indicates that the baseline conservative assumption no longer serves as the best estimation for munitions loading. A different DoDIC was selected based on the description of munitions use and additional Munitions Items Disposition Action System data.

During the baseline assessment, the MCAS Beaufort Pistol Range and the Townsend Range SAR were assessed qualitatively using the Small Arms Range Assessment Protocol (SARAP). According to Townsend Range personnel, the Townsend Range SAR was active from approximately 2002 to 2005, as small arms training operations were transferred to another location. The range has not been used since the baseline assessment and, therefore, does not warrant further evaluation during the five-year review effort. If the SAR status changes in the future, further evaluation may be warranted.

During the five-year review process, one SAR at MCAS Beaufort and seven MC loading areas at the Townsend Range were identified. Two of the seven MC loading areas (EOD MC loading area and Smokey SAM MC loading area) were prioritized for fate and transport modeling based on munitions use and potential for surface water / sediment and groundwater or surface water receptor exposure.

Conceptual Site Model for MCAS Beaufort and the Townsend Range

MCAS Beaufort and the Townsend Range are located in the Atlantic Lower Coastal Plain with hot and humid summers, with high temperatures reaching 90 degrees Fahrenheit (°F) to 100°F, and cool winters, with occasional brief cold spells with lows reaching 20°F. Precipitation averages about 50 inches annually. Tropical storms and hurricanes are not unusual in the area. The hurricane season generally is considered to be the period from June through November.

MCAS Beaufort is divided into two areas, the air station and the Laurel Bay Housing. The area around the installation is generally of low relief with elevations ranging from sea level to 35 feet above mean sea level. The installation is bounded by Brickyard Creek and adjacent tidal marshes to the east and Albergottie Creek and tidal wetlands to the south. Water drains from the marshes into the Beaufort River, which is east of Albergottie Creek. The Beaufort River flows into Port Royal Sound about 12 miles to the south.

The coastal area of South Carolina, in which MCAS Beaufort is located, is underlain by a thick sequence of unconsolidated to semiconsolidated layers of sand and clay and poorly indurated to very dense layers of limestone and dolomite. Geologic units at MCAS Beaufort ranging from the oldest (Eocene age) to the youngest (Pleistocene age) include the Ocala Limestone, Hawthorn Formation, and Pleistocene/Holocene sands and clay. MCAS Beaufort has three primary aquifers: the surficial aquifer (shallowest), the upper Floridan aquifer, and the lower Floridan aquifer (deepest). These aquifers generally are separated by the upper and middle confining units. The materials in the surficial aquifer and upper confining unit give rise to a thin, shallow water table, unconfined aquifer supported by local precipitation, with the water table typically within 4 to 6 feet (ft) below ground surface (bgs). The upper Floridan aquifer is the primary source of ground water supplies in Beaufort County, South Carolina. The Ocala Limestone in this area comprises the highly permeable upper portion of the Floridan aquifer and supplies most of the groundwater extracted from the Floridan aquifer. Due to concerns over saltwater intrusion in the Floridan aquifer, MCAS Beaufort obtains its drinking water from the Beaufort-Jasper Water & Sewer Authority. This water supply is treated surface water from the Savannah River.

Soils at MCAS Beaufort tend to be dominated by fine sands, sandy loams, and loams. Soils with a clay layer greater than 21 inches thick reside in the southern part of the installation and wrap around the southernmost MCAS Beaufort runway heading north and then northeast. The clayey soils may support a shallow water table during wet periods or they may crack during drier periods, thus creating preferential flow paths for infiltrated rainwater. Nonclayey soils mostly occur in the western and northwestern portions of MCAS Beaufort where elevations are higher. Soils in this area tend to be better drained and are very sandy throughout their profiles. The natural erosion potential for upland impact areas at MCAS Beaufort is low due to the flat topography and low slopes.

The Townsend Range is located approximately 130 miles south of MCAS Beaufort. The majority of the property is forested and undeveloped; only approximately 8% of the range is cleared for placement of targets and instrumentation. The Townsend Range is located between the Altamaha and South Newport Rivers in McIntosh County, Georgia. The range is generally flat with little elevation change. The topography of the Townsend Range generally slopes gently downward from the northwest to the southeast. Surface water features on the range include Snuff Box Canal (which traverses the Townsend Range), freshwater marshes/swamps and streams, and isolated depressions that hold water seasonally. Drainage on the range occurs in a southwesterly direction through a series of low ditches, some of which are maintained regularly, into the Snuff Box Swamp and Snuff Box Canal. Snuff Box Canal drains into Cathead Creek, which drains into the Darien River. The Darien River flows into the Rockdedundy River, which empties into Doboy Sound.

The coastal area of Georgia also is underlain by a thick sequence of unconsolidated to semiconsolidated layers of sand and clay. The geologic units found at the Townsend Range include Pliocene and younger sands and clays, Ebenezer Formation, Coosawatchie Formation, Marks Head Formation, Parachucla Formation, Tiger Leap Formation, Lazaretto Formation, and Suwannee Limestone / Ocala Limestone. The Townsend Range has three primary aquifers: the surficial saturated deposits, the lower Brunswick aquifer, and the Floridan aquifer, which are separated by an upper and middle confining unit. The Floridan aquifer is a principal source of groundwater supply in Georgia. The Suwannee and Ocala limestones comprise the highly permeable upper portion of the Floridan aquifer and supply most of the groundwater extracted from the Floridan aquifer. The water supply well at the Townsend Range draws water from the Floridan aquifer at a depth of approximately 700 ft bgs. Domestic water supply wells in the Townsend area are screened in the Floridan aquifer.

Brookman is the dominant soil composition in the area of the Townsend Range. Brookman soils are very poorly drained and have low permeability. Water runs off the surface very slowly and tends to pond at the site since the topography is relatively flat. The flat topography also causes the soils to have a low to moderate inherent soil erodibility.

Surface water/sediment and groundwater pathways were evaluated to determine if MCs have the likelihood to migrate off-range and impact human health and the environment. This evaluation determined the following:

- There are no known human receptors that are likely to be adversely affected from potential migration in surface water/sediment based on an evaluation of the surface water/sediment pathway, identified receptors, current research, and knowledge of the area. Potential ecological receptor at Townsend Range is the federally protected flatwood salamander.

- There are no known human receptors for groundwater potentially impacted by the ranges at MCAS Beaufort because the installation obtains its drinking water from the Beaufort-Jasper Water & Sewer Authority.

- The only known groundwater receptor pathway at MCAS Beaufort would be the discharge of groundwater from the surficial aquifer into the surface water bodies in the area of MCAS Beaufort.

- The Floridan aquifer is used as a drinking water source at the Townsend Range. The water supply well on site was not considered a potential pathway of MC migration because of the depth (700 ft bgs) and intervening aquifers and confining units separating it from the surficial aquifer.

- The groundwater receptor pathway that exists at the Townsend Range is discharge of groundwater to surface water bodies.

Surface Water and Sediment Analyses Summary

The screening-level analyses of MC fate and transport in surface water and sediment were conducted for two MC loading areas at the Townsend Range (EOD MC loading area and the Smokey SAM MC loading area), which are located within the Snuff Box Canal watershed area. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages leading to a potential receptor location. Annual average MC concentrations in surface water runoff and sediment at the edge of each MC loading area were estimated. Additionally, MC concentrations in surface water (including surface water runoff and base flow contributions) entering the identified downstream receptor location (Snuff Box Canal at the Townsend Range boundary) were estimated.

Annual average perchlorate concentrations in surface water runoff (including surface water runoff and base flow contributions) entering Snuff Box Canal at the Townsend Range boundary were predicted to be below REVA trigger values indicating no immediate threat to human health or the environment.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for two MC loading areas at the Townsend Range (EOD MC loading area and the Smokey SAM MC loading area). These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and their proximity to a potential receptor location in surface water where the shallow groundwater discharges. Predictive modeling was conducted at the MC loading areas. Perchlorate at the Smokey SAM MC loading area was predicted to reach the groundwater at a concentration above the REVA trigger value. Groundwater discharges to surface water bodies; therefore, the resulting predicted concentration in groundwater was added to the surface water screening-level analysis. As stated in the surface water analysis, annual average perchlorate concentrations in surface water runoff (including surface water runoff and base flow contributions) entering Snuff Box Canal at the Townsend Range boundary were predicted to be below REVA trigger values indicating no immediate threat to human health or the environment (**Table ES-2**).

Results and Conclusions of the REVA Five-Year Review

A summary of the results and conclusions for the MC loading areas assessed at MCAS Beaufort and the Townsend Range in the REVA five-year review are presented in **Table ES-2**.

Small Arms Range Assessments

The primary MC of concern at SARs is lead because it is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. Modeling parameters for lead fate and transport are contingent upon site-specific geochemical data that are generally unavailable unless site-specific investigations are conducted. Therefore, SARs are qualitatively assessed under the REVA program to identify factors that influence the potential for lead migration.

There is one SAR located at MCAS Beaufort, the Pistol Range. The SAR was evaluated qualitatively using the SARAP. The SARAP incorporates information such as lead loading, surface water and groundwater characteristics, and potential receptors to determine if there is a possible threat of a release of lead from the sites. The surface water and groundwater rankings for the Pistol Range were determined to be moderate. A moderate ranking indicates that there is the potential for lead migration to a receptor, but probably not as an immediate threat to human health and the environment. Actions may be necessary to mitigate future concerns.

Table ES -2: Summary of Five-Year Review Assessment Results for MCAS Beaufort and the Townsend Range

Watershed	Surface Water Screening-Level Analysis Results	Sediment Screening-Level Analysis Results	Groundwater Screening-Level Analysis Results	Conclusion
Snuff Box Canal	Cyclotrimethylene trinitramine (RDX) and perchlorate in runoff at the edge of the EOD and Smokey SAM MC loading areas, respectively, were predicted to be above REVA trigger values. The average annual concentrations of MC in Snuff Box Canal at the Townsend Range boundary were predicted to be below REVA trigger values.	The average annual MC concentrations in sediment at the edge of the MC loading areas were predicted to be below REVA trigger values.	Perchlorate at the Smokey SAM MC loading area was predicted to reach the groundwater at a concentration above the REVA trigger value. The groundwater contribution of this MC was used as one of several input sources for the surface water screening-level analysis that evaluated MC concentration in Snuff Box Canal at the Townsend Range boundary. Drinking water was eliminated as a pathway because the potable water at the Townsend Range is deep, separated by multiple confining units.	MC are predicted to be migrating via surface water and groundwater pathways from MC loading areas; however, the MC are not predicted to reach receptor exposure points at detectable concentrations. Therefore, no further analysis is required at this time. The areas will be evaluated in the next five-year review or sooner if significant changes* at the range warrant reevaluation. Additional actions in the future may include monitoring surface water for MC at the edge of the installation boundary.

* Significant change is defined as an increase in frequency of training, change in munitions activities, or relocation of impacted areas, as determined by subject matter expert working with operations and training personnel.

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1. Introduction

1.1. Purpose

The Range Environmental Vulnerability Assessment (REVA) program is a proactive and comprehensive program designed to support the United States (U.S.) Marine Corps (Marine Corps) environmental range sustainment initiative. The Department of Defense (DoD) has issued several policy, guidance, and planning documents that drive and guide the need to assess operational ranges with respect to potential munitions constituents (MC) migration from operational ranges, including DoD Directive (DoDD) 3200.15, DoDD 4715.11, and specifically, DoD Instruction 4715.14 (*Operational Range Assessments*).

Operational ranges across the Marine Corps were assessed in a baseline review to determine whether a release or substantial threat of a release of MC from operational ranges to off-range areas creates an unacceptable risk to human health and/or the environment. The five-year review assessment will update critical data elements to determine if the results and recommendations from the baseline assessment continue to be a valid representation of the conditions at the installation.

This report presents the five-year review results for the operational ranges and training areas at the Marine Corps Air Station (MCAS) Beaufort, South Carolina (SC), and the Townsend Bombing Range (Townsend Range), Georgia (GA). This report serves as the first five-year review assessment for these installations documenting the period of munitions loading from 2006 through 2011. The baseline assessment completed in 2008 assessed potential impacts from historical munitions use at MCAS Beaufort and Townsend Range from the time of establishment through 2005.

MCAS Beaufort spans 6,909 acres (including Laurel Bay Housing) in Beaufort County, SC, near the southern border with Georgia (**Figure 1-1**). The installation is 4 miles from downtown Beaufort and 70 miles southwest of Charleston, SC. MCAS Beaufort was established in 1943 to serve as a naval air station. Following a deactivation period between 1946 and 1956, MCAS Beaufort was reopened as an air station for the Marine Corps.

MCAS Beaufort operates the Tactical Air Crew Combat Training System (TACTS) Atlantic Ocean Range, which is located approximately 40 miles offshore and is about 80 miles by 40 miles in size (**Figure 1-1**). This combat training range consists of eight towers located within Special Operating Areas 3X (north range) and 4X (south range). These ranges may be combined for large operations. MCAS Beaufort stated that munitions are currently not expended on the

TACTS range and that munitions have not historically been used either. Since the TACTS range does not currently or historically have any munitions use, it is not further evaluated in this REVA five-year review.

The Townsend Range is approximately 130 miles south of MCAS Beaufort in McIntosh County, GA (**Figure 1-1**). The 5,182-acre Townsend Range is used routinely by all services to enhance the bombing and air combat skills of fighter pilots. The U.S. Navy owned the bombing range when it operated Naval Air Station Glynco in Brunswick, GA. The Navy closed the range in 1972 when the air station closed. The Marine Corps reopened the range in 1981 but has an agreement with the Georgia Air National Guard to manage and operate the range.

1.2. Scope and Applicability

The scope of the REVA program includes Marine Corps operational ranges located within the United States and overseas. Operational ranges (as defined in 10 United States Code 101(e)(3)) include, but are not limited to, fixed ranges, live-fire maneuver areas, small arms ranges (SARs), buffer areas, and training areas where military munitions are known or suspected currently to be or historically to have been used. Operational ranges used exclusively for small arms training are evaluated qualitatively under REVA. The Marine Corps (specifically the Training and Education Command [TECOM]) purposely separates operational ranges and training areas. For ease of understanding, in this document, the term "operational range" includes both operational ranges and training areas.

A number of range types are specifically excluded from the DoDD 4715.14 and are not assessed as part of the REVA program. Operational ranges that have a Resource Conservation and Recovery Act (RCRA) Subpart X permit are excluded since these ranges are monitored under a specific regulatory program. Military Munitions Response Program (MMRP) sites are excluded, as they are nonoperational ranges; therefore, they no longer are used for their intended purpose. Additionally, the management and funding of MMRP sites are conducted under a separate DoD program. Skeet/trap ranges used solely for recreation are excluded; these recreational facilities are not deemed operational ranges as defined under Title 10. Any ranges located wholly indoors also are not included, as any munitions constituents (MC) associated with these ranges are assumed to be contained and not available to the environment.

Site-specific environmental conditions and MC loading rates are used in fate and transport models to assess whether the potential exists for a release or substantial threat of a release of MC from an operational range or range complex area to an off-range area.

Modeling is conducted for MC loading areas, which are delineated based on the area in which the majority of MC is deposited within an operational range. Fate and transport modeling in REVA

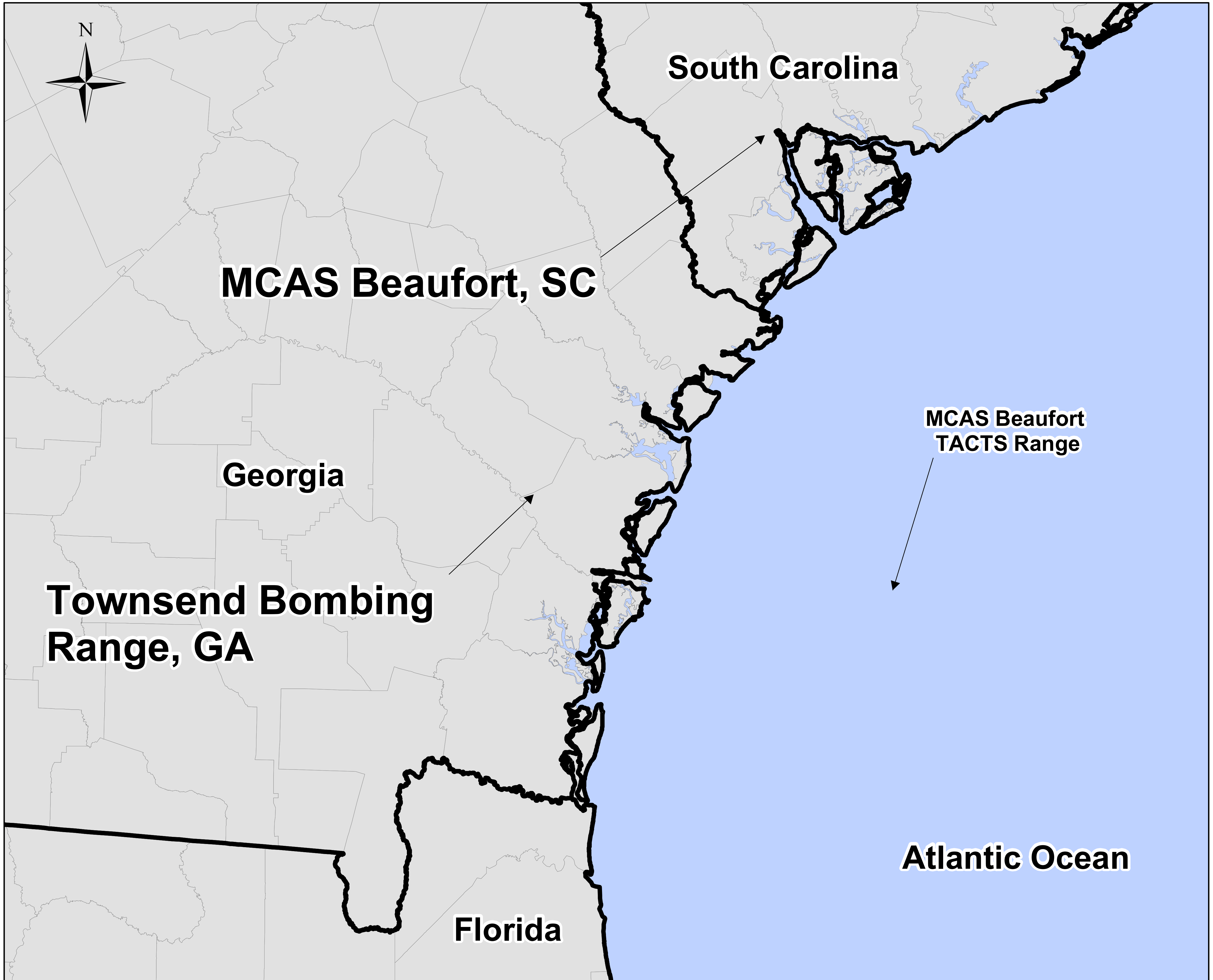

FIGURE 1-1
MCAS BEAUFORT AND
THE TOWNSEND RANGE LOCATIONS

Legend

- State Boundary
- County Boundary

SOURCE: MCAS GIS, 2010

0 10 20 40
Miles

Date: October 2012

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uses screening-level transport analyses that conservatively estimate the concentrations of MC potentially migrating to off-range exposure points. Receptor groups considered in the REVA process include human as well as ecological receptors (defined in the REVA analysis as any threatened or endangered species or species of concern). Human exposure pathways considered include consumption of surface water and groundwater for off-range human receptors, as described in the *REVA Five-Year Review Manual* (HQMC, 2009). Exposure pathways for off-range ecological receptors include direct consumption of surface water and direct exposure to surface water and sediment. Other off-range exposure scenarios (e.g., soil ingestion, incidental dermal contact, bioaccumulation, food chain exposure) currently are not considered in the REVA process unless site-specific considerations warrant an evaluation. Environmental sampling and analysis (i.e., field data collection) is conducted if the results of the screening-level fate and transport modeling suggest an off-range release of MC where receptors may be present. Field data collection activities are conducted to determine whether an off-range release has occurred and whether such a release constitutes an unacceptable risk to human health and the environment.

The MC evaluated in the REVA program include trinitrotoluene (TNT), cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), perchlorate, and lead. TNT, HMX, and RDX are considered indicator MC. Studies have shown that they are detected in a high percentage of samples containing MC because they are common high explosives (HEs) used in a wide variety of military munitions and because of their chemical stability within the environment. Perchlorate is a component of the solid propellants used in some military munitions. Perchlorate also is considered an indicator MC because its high solubility, low sorption potential, and low natural degradation rate make it highly mobile in the environment. Additional information pertaining to the physical and chemical characteristics of the REVA indicator compounds is provided in the *REVA Reference Manual* (HQMC, 2009).

The primary MC of concern at SARs is lead because it is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. Lead is geochemically specific regarding its mobility in the environment; thus, fate and transport modeling of lead requires site-specific geochemical data that usually are unavailable during a REVA assessment. Therefore, instead of modeling lead transport, operational SARs at the installation are qualitatively reviewed and assessed to identify factors that influence the potential for lead migration. These factors include a range's design and layout, the physical and environmental conditions of the area, current and past operation and maintenance practices, and the amount of lead that has been loaded to the operational range.

Lead loading associated with small arms and munitions components at HE ranges was estimated as part of the five-year review process. Lead is present primarily in expenditures at the point of impact as an inert compound and, consequently, does not undergo low-order or high-order detonations. As such, lead loading was estimated based on the total amount of lead content based on the munitions DoD Identification Code (DoDIC) multiplied by the total number of items of each DoDIC fired into the range or MC loading area. The total lead loaded at the site aids in determining if additional actions, such as sampling, are necessary.

The process and assumptions used in estimating the amount of MC deposited onto operational ranges, defined in REVA as MC loading, are discussed in **Section 3**. The screening-level fate and transport modeling and analysis methods and assumptions for surface water and groundwater are discussed in **Section 5**.

This report presents the analysis of the data collected during site visits and the results of screening-level fate and transport modeling for MC loading areas. Additional details of the REVA assessment methods are outlined in the *REVA Reference Manual,* which includes a detailed description of the fate and transport models selected for REVA, the data needed to run those models, and recommended sources for data. In addition, the *REVA Reference Manual* provides a detailed description of the REVA MC Loading Rate Calculator tool used to estimate MC deposition on operational ranges (HQMC, 2009).

This REVA five-year review presents the conditions of the operational ranges at the time the assessment was conducted. The assessment was performed using available data and personnel interviews and is supplemented with information from external sources, including reports and documentation.

1.3. Data Collection Effort

A thorough review of data collected during the baseline assessment was conducted prior to collecting data from the installation for the five-year review. Data required for the operational range assessments were obtained from the installation during a site visit by the REVA assessment team, from the Marine Corps Installations Command (MCI COM), and from external data sources. Data collected include various documents and reports prepared for the installation (e.g., expenditure data, range operating procedures, natural and cultural resource surveys), weather records, and geographic information system (GIS) files.

The REVA assessment team conducted a site visit to MCAS Beaufort and the Townsend Range from 7 to 9 November 2011. MCI COM and TECOM personnel accompanied the team during the site visit. The installation site visit involved a review of various data repositories and interviews with installation personnel from the following offices:

- Environmental Office
- Natural Resource / Cultural Resources Office

- Range Operations and Control
- Explosive Ordnance Disposal (EOD)
- Facilities Management Division
- GIS

Subject matter experts within each of these offices were interviewed to identify areas of interest and specific concerns pertaining to each office. Specific issues relating to operational range use and potential impacts to training were the focus of these discussions.

During the five-year review installation visit, site visits were performed at all of the operational ranges. The REVA assessment team surveyed the physical condition of each range, noting firing points, impact areas, engineered controls, and other environmental factors (e.g., areas of erosion, potential migration routes).

1.4. Report Organization

This REVA five-year review environmental range assessment report for MCAS Beaufort and the Townsend Range is organized into the following sections:

Section 1 – Introduction

Section 2 – Baseline Results and Installation Changes

Section 3 – Munitions Constituents Loading Rate and Assumptions

Section 4 – Conceptual Site Model (CSM)

Section 5 – Modeling Assumptions and Parameters

Section 6 – Screening-Level Assessment Results

Section 7 – Small Arms Range Assessment

Section 8 – References

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2. Baseline Results and Installation Changes

The baseline assessment for MCAS Beaufort and the Townsend Range was conducted using available data through 2005. At the time of the baseline assessment, all identified operational range areas and historical data were used to assess the impact of munitions loading on operational range lands. The results of the baseline assessment are documented in the *Range Environmental Vulnerability Assessment Marine Corps Air Station Beaufort, South Carolina and Townsend Range, Georgia* (Malcolm Pirnie, 2008). Specific details of the methodology implemented in calculating MC loading and determining surface water and groundwater pathways and receptors in the baseline assessment are identified in the report. The following sections provide a brief summary of the baseline assessment results that provide a framework for the structure and areas of focus for the five-year review. **Table 2-1** lists the areas that were evaluated using screening-level modeling and the Small Arms Range Assessment Protocol (SARAP) in the baseline assessment and a summary of results.

Table 2-1: Summary of MC Loading Areas and SARs Evaluated in the Baseline Assessment

MC Loading Area	Screening-Level Modeling Results[a] Predicted to Exceed REVA Trigger Values[b]		Assessing in 5-Year Review
	Surface Water	Groundwater	
TOWNSEND RANGE			
Command Post	Not modeled		Yes
Heavy Weight	Yes	Yes	Yes
Main Bull	Yes	Yes	Yes
Petroleum, Oils, Lubricants (POL) Target	Not modeled		Yes
Surface-to-Air Missile (SAM)	Not modeled		Yes
Scud Site	Not modeled		Yes

Smokey SAM	Not modeled		Yes
SAR	**Surface Water Ranking**	**Groundwater Ranking**	**Assessing in 5-Year Review**
MCAS Beaufort Pistol Range	Moderate	Moderate	Yes
Townsend Range – SAR	Moderate	Moderate	No

Notes:
[a] Result is indicated for downstream receptor.
[b] A REVA trigger value is a median value of method detection limits attained from several laboratories.

The baseline consisted of conducting assessments of two SARs, one at MCAS Beaufort and one at the Townsend Range, and assessing the seven target areas at the Townsend Range for HE and perchlorate. During the baseline, specific munitions expenditure data were not available for the Townsend Range assessment; therefore, conservative assumptions were used to identify potential munitions used at the targets. Also, due to the non-range-specific data available during the baseline, munitions expenditures had to be attributed to target areas based on information from the Townsend Range personnel.

Several operational ranges areas located in operational training areas at MCAS Beaufort were not evaluated during the baseline assessment. These ranges include the EOD Range; TACTS Range; Nuclear, Biological, and Chemical (NBC) Training Area; and the skeet range. The EOD range is operated under RCRA subpart X, so it is excluded from REVA evaluation; the TACTS Range and NBC Training Area did not use munitions containing MC. The skeet range was not assessed since it was used only for recreational purpose2s. Strafing ranges are located at the Townsend Range; however, the assessment was not completed after it was determined that steel munitions were used that did not contain MC.

The Boresight Range was determined to be a historical use area during the baseline. A historical use area refers to formerly used areas that lie within a designated operational range area. The Boresight Range was determined to cause no immediate threat to human health during the baseline since it was a historical use area that had not been used in numerous years and there was no information regarding historical munitions usage or other information about the range.

2.1. Installation Changes since the Baseline

2.1.1. Changes at MCAS Beaufort

Changes identified since the baseline include lead mining and partial berm reconstruction activities at the MCAS Beaufort Pistol. The lead mining activities and partial berm reconstruction at MCAS Beaufort occurred in 2010.

2.1.2. Changes at the Townsend Range

Changes identified since the baseline include the establishment of the Urban Target Area at the Townsend Range. The Urban Target Area is adjacent to the POL Target Area and was constructed to simulate an urban attack scenario based on military operations in recent conflicts. The Urban Target Area at the Townsend Range occurred in 2010.

According to personnel at the Townsend Range, the SAR at the Townsend Range was active from approximately 2002 to 2005, as small arms training operations were transferred to another location. The range has not been used since the baseline assessment and, therefore, does not warrant further evaluation during the five-year review effort. If the SAR status changes in the future, further evaluation may be warranted.

During the baseline, the water supply well at the Townsend Range was not considered a potential pathway of MC migration because of the depth (700 ft bgs) and because bottled water was supplied to range operations personnel because of aesthetics (hydrogen sulfide odor and taste). In March 2007, the bottled water usage was discontinued and the water supply well was put into use. This change in service resulted in an evaluation of the drinking water pathway during the five-year review. This potential drinking water pathway was determined to not be impacted by possible MC migration due to the depth of the water supply well and the presence of confining units and saturated intervals between the surface aquifer and the aquifer used as a drinking water source.

2.1.3. Changes in REVA Assessment

In the baseline, the Smokey SAM MC loading area reflected the launching location for all the inert munitions expended at the Townsend Range. The boundary of the Smokey SAM MC loading area has been changed to better reflect where the munitions are landing. Based on information provided by the Townsend Range personnel and other available sources on the flight characteristics of the munitions used at this site, this loading area has been enlarged to encompass the entire operational range boundary at the Townsend Range.

During the baseline assessment of the Smokey SAM area, only lead was determined to be loaded based on the interviews and data provided by the Townsend Range range personnel. While developing the five-year review, ARCADIS/Malcolm Pirnie staff obtained more detailed information regarding the munitions being used in the Smokey SAM area. Based on this new information, it was determined that perchlorate and lead were components of the munitions used at the range and was therefore, evaluated during the five-year review.

The POL MC loading area and the Scud Site MC loading area had been identified as MC loading areas for the baseline assessment. The munitions use identified for these areas during the baseline assessment was determined to be incorrect through discussions with the Townsend Range Operational Training personnel as part of the five-year review. These areas do not permit munitions containing REVA MC and therefore were not further evaluated.

Lead loading was considered only for SARs in the baseline assessment. However, to provide an initial understanding of the amount of lead deposition on HE ranges and training areas, lead loading was estimated for all ranges, including non-SARs, in the five-year review. The total estimated lead deposition on these ranges was estimated based on installation expenditure records. However, similar to SAR evaluations, the potential for lead migration was not quantitatively assessed because fate and transport parameters for lead are dependent on site-specific geochemical properties, which are generally not available without site-specific investigations.

The Helicopter Door Gunnery MC loading area was not identified in the baseline as an MC loading area. It has been identified as an MC loading area in the five-year review to better account for the lead deposition occurring there.

2.2. Summary

The baseline assessment report identified one SAR at MCAS Beaufort and one SAR and seven target areas at the Townsend Range. Based on the results of the baseline assessment as detailed above and additional data collected for the five-year review effort, seven MC loading areas at the Townsend Range and one SAR at MCAS Beaufort were evaluated during the five-year review effort:

- Command Post MC loading area
- EOD MC loading area
- Heavy Weight MC loading area
- Helicopter Door Gunnery MC loading area
- Main Bull Target MC loading area
- SAM Site Target MC loading area
- Smokey SAM MC loading area
- MCAS Beaufort Pistol Range

3. Munitions Constituents Loading Rates and Assumptions

The conceptual and screening-level analyses conducted under REVA require estimation of the amount of indicator MC deposited on operational ranges over time in order to determine if there is a release or substantial threat of a release of MC. The deposition of indicator MC that is estimated under the REVA program is referred to as MC loading.

Operational range usage, boundaries, and other characteristics typically change over time. The objective of the five-year review is to determine the impact of MC loading since the baseline assessment. For this five-year review of training at MCAS Beaufort and the Townsend Range, MC loading estimates include the period from 2006 to 2011; no further review of historical loading prior to 2006 is required since it was addressed in the baseline assessment.

The MC loading process for a baseline assessment is outlined in the *REVA Reference Manual* (HQMC, 2009), while specifics pertaining to MCAS Beaufort and the Townsend Range are discussed in the baseline REVA Report (Malcolm Pirnie, 2008). This five-year review utilizes and builds upon this process, developing MC loading estimates expressed as the average loading rate (kilograms per square meter [kg/m^2]) deposited annually in the defined area(s) of interest for the most recent time period (from baseline assessment to five-year review). Assumptions were made throughout this MC loading analysis process pertaining to the spatial distribution of the MC on the MC loading areas, as summarized in **Section 3.1** through **Section 3.4**. **Section 3.5** provides a description of the training areas and ranges at MCAS Beaufort and the Townsend Range and defines the specific MC loading areas identified as well as the overall assumptions for MC loading on the operational ranges. The range-specific assumptions used in the process and the results of the MC loading are provided in **Section 5**.

3.1. Munitions Constituents Loading Process

The MC loading was estimated based on mass-loading principles. One key consideration for MC loading estimates is the MC content of each type or specific item(s) used at a given MC loading area. Information on the types and amounts of energetic fillers associated with military munitions was developed primarily through the use of Internet-based sources, such as the Defense Ammunition Center's Munitions Items Disposition Action System (MIDAS) Web site and the ORDATA database (2012), which is hosted on the Mine Action Information Center Web site of James Madison University.

Additional key considerations for MC loading estimates are dud, low-order, and high-order detonation rates. Studies have shown that MC are deposited on operational ranges through low- and high-order detonations, as well as the leaching of corroded unexploded ordnance (UXO). MC loading estimates are based upon the sum of the MC deposition associated with each outcome (i.e., high order, low order, UXO) for a given MC loading area. Details on this process are included in the MCAS Beaufort baseline report and the *REVA Reference Manual* (Malcolm Pirnie, 2008; HQMC, 2009).

When calculating MC loading for a range/training area that is determined to be managed regularly and intensely for explosive hazards (e.g., demolition or engineering range), dud and low-order rates were set to zero. Dud/UXO rates associated with DoDICs that were reported in the expenditure data were not used in place of the standard dud assumptions used in the REVA MC Loading Rate Calculator because these data were not reported for a long enough period to develop meaningful dud rates, and the data may not have been reported consistently. As such, the standard REVA methodology and dud rate assumptions were used in order to maintain a higher level of conservatism in the estimates.

Deposition of metals, specifically lead, was further considered during this review. Small arms are presumed to be the most significant contributor to lead deposition at operational ranges and training areas, though the metal may also be part of other HE munitions components to varying degrees. Using a similar MC loading methodology, the annual areal deposition of lead for any given MC loading area was estimated; the results are included in **Section 6**. Deposition rates may provide an initial measure of potential impact from lead on training ranges; however, it is important to note such rates differ from other MC loading rates due to key considerations. Given the nature of metals, lead deposition estimates assume no consumption from impact of this REVA indicator MC (e.g., no loss due to detonation of the munitions) and that all of the lead contained within the munitions is deposited in the MC loading area. However, the amount of lead that is deposited in a form that is exposed to the environment and available for transport (e.g., small particles and dust separated from the munitions body upon impact) cannot be estimated without site-specific measurements. This is complicated further at demolition or other ranges where management practices may involve collection of scrap metals, which would reduce the overall lead presence at that location. In such instances, unless information indicates otherwise, it is conservatively assumed that lead deposition is 5% of the munitions' lead content. Finally, as described in other sections, fate and transport parameters for lead are dependent on site-specific geochemical properties, which may vary across a designated MC loading area and cannot be determined solely by physical observation. For these reasons, the lead loading estimates developed for this assessment are intended to serve as a general indicator of the total lead deposited rather than an estimate of the fraction of lead that is environmentally available for transport and exposure to receptors. In the case of a SAR, range design typically concentrates the impact point to a small, restricted area, and the SARAP may be used to qualitatively assess it, as summarized in **Section 7**.

Additional specifics regarding how these data were incorporated are explored in the aforementioned *REVA Reference Manual* and baseline *REVA Report for MCAS Beaufort and Townsend Range*.

3.2. Expenditure Data

3.2.1. Expenditure Data for MCAS Beaufort

Range Control is responsible for the administration and oversight of the training operations conducted at MCAS Beaufort. Range Control coordinates primary recordkeeping for munitions expenditures at an operational range by maintaining expenditure reports completed following each training session. Summaries of current munitions expenditures at MCAS Beaufort Pistol Range were based upon the expenditure report data produced by the MCAS Beaufort Range Safety Officer. The records incorporated into this assessment for the MCAS Beaufort Pistol Range are from October 2009 through September 2011, which corresponds to the Federal Government's Fiscal Years 2010 (FY10) through FY11. No Range Facility Management Support System (RFMSS) data were available from the MCAS Beaufort Pistol Range.

The use of documented expenditure data is preferred in the REVA program as opposed to the use of assumptions based on training and potential munitions use. A quality review of the expenditure data provided by the installation resulted in the following assumptions applicable across operational training areas at MCAS Beaufort:

- The expenditure summaries provided by the installation contained an expenditure type with a description that did not match the corresponding DoDIC. A surrogate DoDIC matching that of the description in the expenditure report was selected to represent this expenditure type.
- The average expenditure counts generated from the available FY10–FY11 expenditure data were assumed to reflect training operations for the entire five-year review period.

Based on information from Range Control personnel and other sources at MCAS Beaufort, it was determined that no significant changes in training patterns had occurred during the five-year review period.

3.2.2. Expenditure Data for the Townsend Range

The Georgia Air National Guard is responsible for the administration and oversight of the training operations conducted at the Townsend Range. They coordinate the primary recordkeeping for munitions expenditures at the operational range by internally tracking the numbers and types of munitions expended by the various users at the Townsend Range using

Air Force protocol. The dates of the records incorporated into this five-year assessment for the Townsend Range cover the period from October 2006 through September 2011 (FY07–FY11). No RFMSS data were available from the Townsend Range.

A quality review of the expenditure data provided by the Townsend Range personnel resulted in a series of assumptions applicable across operational training areas at the Townsend Range:

- The expenditure data provided by the installation were not recorded per DoDIC. Surrogate DoDIC information was selected based on the descriptions provided in the recorded expenditure data and information provided by the Townsend Range personnel.
- The expenditure data were not tracked to individual target areas within the Townsend Range. Based on range use information provided by the Townsend Range personnel, the various expenditure types were attributed to the appropriate target areas where they are permitted. In the cases where expenditure types were permitted in multiple target areas, the expenditure counts were distributed according to guidance from the Townsend Range personnel.
- The expenditure data contained some practice bomb munitions with no bomb type descriptions. These unspecified practice bomb munitions totals were distributed proportionately among the other known practice bomb types.
- Smokey SAM rocket expenditures were not included in the expenditure data provided by the installation. Townsend Range personnel indicated that approximately 100 of these munitions are expended per year; therefore, this number was used as the annual expenditure total.
- The Smokey SAM MC loading area used in the baseline assessment was altered to reflect the likely depositional area of the inert munitions used at the site. This adjustment enlarged the MC loading area to encompass the entire operational range area at the Townsend Range based on the information provided by Townsend Range personnel. Due to the construction and usage of these munitions and unpredictable variables like wind direction and wind speed at the time of launch, the distribution pattern for these munitions is quite large and hard to predict. In an effort to maintain conservative MC loading calculations, only 10% of the surface area of this MC loading area was used in the loading process.
- Expenditure data totals were not FY specific. Therefore, the total munitions expenditures were divided by the total number of years of data (5 years) to generate a single-year average expenditure count for each munitions.
- According to Townsend Range personnel, rockets with two types of warheads are permitted at the Townsend Range: an inert warhead and a spotting charge. The expenditure data did not distinguish between the two warheads. Townsend Range personnel indicated that 60% of the rockets fired were equipped with the inert warhead and 40% were equipped with the spotting charge warhead. These percentages were applied to the total rocket expenditure counts to estimate the total number of each warhead type.

Key assumptions also were developed with regard to EOD activities at the Townsend Range. MCAS Beaufort EOD personnel provided expenditure reports covering the period from March 3, 2011, through December 8, 2011. These reports were used to develop a single year of averages using the following assumption:

> The data captured demolition expenditure counts from the calendar year 2011 operational range clearance events. According to EOD personnel, only three operational range clearance events were conducted during this period as opposed to the typical four events. Therefore, the EOD expenditure counts were increased proportionately to reflect expenditure counts for four operational clearance events to ensure conservative MC loading calculations. According to Townsend Range personnel, the training patterns were consistent throughout the five-year review period. Based on this information, it was assumed that the calculated expenditure counts accurately reflect yearly EOD expenditures in connection with the operational range clearance activities.

Given these considerations, data spanning approximately 6 years (October 2006 through September 2011) were used for MC loading calculations associated with current MC loading areas at MCAS Beaufort and the Townsend Range, as well as to determine lead loading estimates. Other general assumptions regarding application of these expenditure data to calculate MC loading are discussed in **Section 3.5**. Assumptions and data specific to individual MC loading areas or ranges are discussed as appropriate in **Section 6**.

3.3. REVA Munitions Constituents Loading Rate Calculator

The REVA MC Loading Rate Calculator is used to provide an automated method to calculate the overall loading of the operational range area in the units needed for the fate and transport analysis (kg/m^2). It utilizes information regarding the size of MC loading areas, the military munitions expenditure data obtained from the installation, and information and assumptions related to duds, low-order, and high-order detonations. Additionally, it utilizes training factors to account for fluctuations in training during periods of use where no expenditure data are available. During the baseline assessment, the potential influence of historical MC loading was assessed through the use of training factors in the MC Loading Calculator for Periods A through E (1914–baseline) (Malcolm Pirnie, 2008). A Period F was established to represent the time period covered by this five-year review. Since no additional historical MC loading was identified during this five-year review and actual expenditure data were obtained from MCAS Beaufort and the Townsend Range, training factors were unnecessary for MC loading calculations.

Further explanation regarding the REVA MC Loading Rate Calculator may be found in the *REVA Reference Manual* (HQMC, 2009). All known data and assumptions input into the MC Loading Rate Calculator for each operational range area assessed are documented in **Section 3** and **Section 6**.

3.4. Munitions Constituents Loading at MCAS Beaufort and the Townsend Range

MCAS Beaufort is located in Beaufort County, along the coast of southeastern South Carolina, as seen in **Figure 1-1**. It was established in 1943 as a Naval Air Station and has grown to currently encompassing over 5,841 acres on the station proper (Tidewater, 2006). This area contains core administrative buildings, training facilities and centers, and Merritt Field, which contains 3.9 million square yards of runways and taxiways (USACE, 2007). MCAS Beaufort hosts all active duty Marine Corps F/A-18 air operations on the East Coast, assigned to Marine Air Group 31 (MAG-31). The mission of MCAS Beaufort is to provide support as an operation base for MAG-31 and its supporting units.

The Townsend Range is located in McIntosh County, GA near the town of Townsend, as seen in **Figure 1-1**. It is a Class A controlled range covering 5,182 acres, most of which are forested. Though the Marine Corps owns the Townsend Range, it is operated and staffed by the Georgia Air National Guard. The Townsend Range is equipped with scorable targets for practice bombs, inert rockets, and strafing and is utilized by the Navy, Marine Corps, Air Force, Army, and Georgia Air National Guard (USACE, 2007).

3.4.1. MCAS Beaufort Ranges and Training Areas

One historical use area and three operational ranges located on operational training land were identified at MCAS Beaufort during the five-year review, as seen in **Figure 3-1**: Boresight Range, EOD Range, NBC Training Area, and the Pistol Range.

The Boresight Range historically was used to sight in exterior mounted gun pods for F-4 and A-4 aircraft. It was assessed during the baseline assessment indicating no immediate threat to human health and the environment. This range is inactive but not closed; it is in an operational training area and is used as a gun jam clearing area. Since this historical use area has been inactive for over 15 years and there was no new information regarding the area during the five-year review, no further evaluation was conducted. Should historical use information come to light in the future, the site may be evaluated in future REVA efforts.

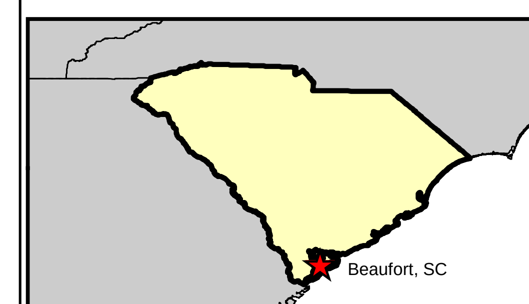
The EOD Range occupies approximately 20 acres in the northernmost portion of the installation. It is utilized for open burning and open detonation of waste military munitions (CH2M HILL, 2011). This range is regulated as a RCRA-permitted facility and, as such, is not evaluated in this REVA five-year review.

The NBC Training Area is utilized to train Marines in the proper use of gas masks. O-chlorobenzalmalonitrile (CS agent) is used as a training tool to help the Marines gain confidence

FIGURE 3-1
MCAS BEAUFORT OPERATIONAL AND HISTORICAL USE AREA LOCATIONS
MCAS BEAUFORT
BEAUFORT, SC

Legend

Installation Boundary



SOURCE: MCAS GIS, 2010

0 1,500 3,000 6,000
Feet

Date: October 2012

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in their equipment. The area initially was evaluated in the baseline assessment; at that time, it was determined that no munitions containing REVA indicator MC had been expended in that area. Data collected during the five-year review indicate training operations in this area have not changed. Therefore, no further evaluation is required during this five-year review.

The Pistol Range commenced operations in 1959 and was refurbished in 2003. It is equipped with 12 firing lanes and an earthen backstop berm. Concrete walls and overhead baffles with a ballistic canopy keep projectiles from escaping the range (Aerostar, 2010). According to the range safety officer, the Pistol Range impact berm is mined as needed (typically once every 5 to 6 years); the most recent such event occurred in 2010 and included a reconstruction of the berm. This is the only MC loading area at MCAS Beaufort evaluated in the five-year review. Additional details regarding the qualitative analysis of the Pistol Range are provided in **Section 7**.

Should the status and/or use of the Boresight Range, EOD Range, or NBC Training Area change in the future, further REVA evaluation may be warranted.

3.4.2. Townsend Range

The Townsend Range occupies approximately 5,182 acres of mostly forested land (**Figure 3-2**). The developed area of the Townsend Range, which includes the target areas and associated range support facilities, occupies approximately 410 acres (MCAS Beaufort, 2008). It facilitates approximately 2,200–2,400 sorties per year carried out primarily by F/A-18 fighter aircraft along with A-10, F-16, various rotary, and occasionally B-2 bomber aircraft.

The range contains 12 target areas designed for use of various types of inert munitions. These include the Command Post Target; Heavy Weight Target; Helicopter Door Gunnery Target; Main Bull Target; POL Target; SAM Site Target; Scud Target; Smokey SAM; three Strafe Targets; and Urban Target. According to Townsend Range personnel, the Helicopter Door Gunnery Target is seldom used, as door gunnery sorties frequently are called off due to various scheduling priorities and range traffic issues. The Helicopter Door Gunnery Target is a MC loading area for lead due to the small arms used at the range. The Urban Target Area is a new target constructed in 2010. The site is adjacent to the POL Target and was constructed to simulate an urban attack scenario based on military operations in recent conflicts.

The Townsend Range is a 100% inert bombing range facility. These are composed of steel bomb casings and contain concrete instead of HE to match the exact weight and flight characteristics of their live counterparts. The most common inert munitions utilized at the Townsend Range is 25-pound (lb) inert munitions which simulates the flight characteristics of HE bombs and is made of cast-iron and steel. Since the practice bombs contain no REVA indicator MC, no further evaluation is required.

In addition to practice bomb munitions, certain target areas permit the use of inert rockets. These include the Command Post Target, Heavy Weight Target, Main Bull Target, and the SAM Site Target. These areas are MC loading areas for lead that is associated with these rockets, however, lead is not carried through the screening-level transport analysis process but is evaluated qualitatively.

Munitions permitted at the Townsend Range, though inert, may be equipped with various types of small spotting charges to better enable the pilot's accuracy to be scored during training. These spotting charges typically contain very little or no REVA indicator MC; therefore, they are not considered in the MC loading process.

A further enhancement of training at the Townsend Range is the capability to simulate anti-aircraft fire. The Smokey SAM is a loading area because the inert munitions contain small amounts of perchlorate.

All strafing operations training at the Townsend Range is conducted using steel ammunition. Weekly, an electromagnet is used to extract the expended steel projectiles from each of the strafing targets; the projectiles are recycled. The strafing ranges were not carried through the REVA assessment because MC are not used.

The EOD personnel stationed at MCAS Beaufort conduct quarterly operational range clearance activities at the Townsend Range. During these clearances, the practice munitions that are visible on the ground surface are recovered. EOD stages the expended munitions in the Heavy Weight Target area and removes the wing attachment lugs. A small amount of explosive material, which may contribute to MC loading at the range, is used to expose the inert material within the practice bomb casings in order to be turned over to a recycling contractor. According to the Townsend Range personnel, a recent study was performed at the Townsend Range concluding the installation is recovering and recycling approximately 80% of the munitions expended at the range as a result of these range management practices. The EOD is a MC loading area for HE, perchlorate, and lead.

FIGURE 3-2
TOWNSEND BOMBING RANGE BOUNDARY

TOWNSEND BOMBING RANGE
TOWNSEND, GA

Legend

Installation Boundary

SOURCE: MCAS GIS, 2010

0 750 1,500 3,000
Feet

Date: October 2012

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Should the status and/or use of the targets at the Townsend Range change in the future, further REVA evaluation may be warranted.

3.5. Munitions Constituents Loading Assumptions

3.5.1. Selection of MC Loading Areas

During the five-year review, MC loading areas listed in **Table 3-1** and shown in **Figure 3-4** were identified for analysis using the MC loading process.

Table 3-1: MC Loading Areas (all at the Townsend Range)

MC Loading Area	HE	Perchlorate	Lead
Command Post			X
EOD	X	X	X
Heavy Weight			X
Helicopter Door Gunnery			X
Main Bull			X
SAM Site			X
Smokey SAM		X	X

The Helicopter Door Gunnery MC loading area was not identified in the baseline as an MC loading area. It has been identified as an MC loading area in the five-year review to better account for the lead deposition occurring there. Lead is not carried through the screening-level transport analysis process but is evaluated qualitatively.

During the baseline assessment, a rocket was identified to have been used at the POL and the Scud Site targets that contained HE, perchlorate and lead. These areas were then assessed for these MCs in the baseline report. Through discussions with the Townsend Range range personnel as part of the five-year review, ARCADIS/Malcolm Pirnie learned that this rocket was not used at either of these ranges. Thus, it was determined that these ranges did not permit munitions containing REVA MC and therefore were not further assessed in the five-year review.

The remainder of the aerial gunnery and strafing operations at the Townsend Range are conducted with steel ammunition. As steel ammunition does not contain REVA indicator MC, MC loading is not required for this type of training.

According to Townsend Range personnel, these targets along with the newly constructed Urban Target Area only permit the use of inert munitions that do not contain REVA indicator MC.

Seven MC loading areas (Command Post, Heavy Weight, Main Bull, SAM Site, Smokey SAM, Helicopter Door Gunnery Range, and the EOD) have been identified at the Townsend Range. Each the seven areas have been identified as having lead loading while HE and/or perchlorate is also loaded at only the EOD and Smokey SAM areas. The lead loading at the Command Post, Heavy Weight, Main Bull, and SAM Site MC loading areas is attributed to the use of rockets while perchlorate and lead are associated with the Smokey SAM rockets in the Smokey SAM MC loading area. The Helicopter Door Gunnery Range has lead loading from the small arms used. The EOD MC loading area located in the Heavy Weight Target area is the only MC loading area associated with HE due to the EOD operations described in **Section 3.4.2**. Based on information provided by MCAS Beaufort EOD personnel, the MC loading area boundary reflects the staging area utilized by the EOD personnel during the inerting phase of the quarterly operational range clearance activities. This boundary represents only a portion of the Heavy Weight Target area, as HE use is focused in this specific area rather than across the entire target.

In the baseline, the Smokey SAM MC loading area was located adjacent to the equipment storage building and reflected the launching location for all the Smokey SAMs expended at the Townsend Range. The launch point of these munitions has not changed since the baseline; however, the boundary of the Smokey SAM MC loading area has been changed to better reflect where the munitions are landing. Based on information provided by Townsend Range personnel and other available sources on the flight characteristics of the Smokey SAM rocket, the boundary for this loading area has been enlarged to encompass the entire operational range boundary at the Townsend Range, as seen in **Figure 3-3**. Based upon baseline assessment assumption that no HE or perchlorate was contained within the Smokey SAM rocket, no MC loading was conducted for this MC loading area. However, improved data sources obtained since the baseline assessment have indicated that perchlorate and lead are components of the rockets. As such, MC loading was conducted during the five-year review.

The baseline assessment assumptions for perchlorate loading were reviewed; it was noted that, due to the lack of specific expenditure data, estimates of the types and numbers of munitions loaded as well as where they were primarily loaded to had to be made. One estimation used assigned a rocket type that contained over 100 lb of perchlorate to the Main Bull and Heavy Weight Targets. Preliminary assessment of the HE and perchlorate found that perchlorate was loaded onto these two areas at a higher rate than the other targets based on the rocket type selected. The assessment continued for the Main Bull and Heavy Weight because of the loading of perchlorate and the characteristics of perchlorate in the soils (most soluble indicator MC and does not tend to attenuate by sorption to soil particles). The assessments estimated that perchlorate would reach the off-range Churchill Swamp via surface water and groundwater pathways exceeding the REVA trigger values for perchlorate but not the ecological risk-based freshwater chronic water quality criterion (Dean et al., 2004). During the five-year review,

FIGURE 3-3
TOWNSEND BOMBING RANGE
MC LOADING AREAS

TOWNSEND BOMBING RANGE
TOWNSEND, GA

Legend

Installation Boundary

MC Loading Area

AREAS:

Command Post MC Loading Area = 3,220 meters^2

EOD MC Loading Area = 1,802 meters^2

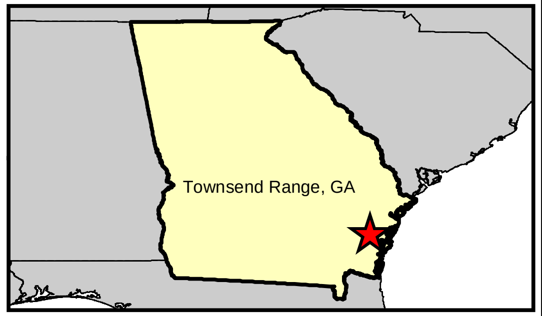
Heavy Weight MC Loading Area = 9,039 meters^2

Helicoptor Door Gunnery MC Loading Area = 23,572 meters^2

Main Bull MC Loading Area = 24,467 meters^2

SAM Site MC Loading Area = 2,636 meters^2

Smokey SAM MC Loading Area = 1,231,068 meters^2



SOURCE: MCAS GIS, 2010

0 250 500 1,000
Feet

Date: October 2012

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improved expenditure data were available and the surrogate assumption chosen for the rockets was reviewed. The REVA team concluded that a better surrogate exists; it contains no perchlorate. Therefore, in the five-year review, perchlorate loading was determined not to be occurring at these targets areas.

The only active fixed range at MCAS Beaufort requiring assessment for this five-year review is the Pistol Range. This SAR is evaluated using the SARAP, as summarized in **Section 7**. The SAR at the Townsend Range evaluated during the baseline assessment does not require evaluation during the five-year review as has not been used since 2005.

3.5.2. Overarching Assumptions

To estimate MC loading for operational ranges, assumptions were developed to apply to data collected during the five-year review. Complete details and background of these assumptions and data are available in the *REVA Reference Manual* (HQMC, 2009). The following bullets represent the primary assumptions used in the MC loading assessment.

- Only the main fillers and perchlorate components (REVA indicator MC) are included in the estimates. The amount of MC in fuzes, boosters, and other components is not considered significant enough, by comparison, to impact the MC loading amounts.
- All REVA indicator MC are considered 100% pure and, therefore, more readily transported in the environment.
- Dud and low-order detonation rate estimates are from the *Report of Findings for: Study of Ammunition Dud and Low Order Detonation Rates, United States Army Defense Ammunition Center* (DAC, 2000). In the event rate estimates are not available, the default values listed in the referenced report of 3.45% (dud rate) and 0.028% (low-order detonation rate) are used.
- One hundred percent of all UXO result in exposed MC. Following deposition of UXO, 1% of the total MC mass within the UXO is considered exposed and available for transport.
- For low-order detonations, it is assumed that 50% of the total MC per item is consumed, resulting in deposition of the other 50% of the MC mass on the loading area (DAC, 2000). For high-order detonations, it is assumed 99.9% of the total MC per item is consumed, resulting in deposition of 0.1% of the MC mass on the loading area, as detailed in the *REVA Reference Manual* (HQMC, 2009).
- In the event that data are unavailable for the entire training period identified, other methods or assumptions for estimating MC loading are implemented.
- Calculations incorporating expenditures at EOD and demolition ranges are adjusted to reflect an assumed 100% high-order detonation.

HE and perchlorate were evaluated at MC loading areas where significant HE use has been documented, and lead was evaluated at all operational ranges. Calculation of representative annual values of expenditures at the ranges was performed to help characterize respective MC and lead loading; the recorded totals by DoDIC for applicable years were averaged together, with all fractional values conservatively rounded up to the next whole number. The specific methodologies and assumptions used to conduct the MC loading at each MC loading area are detailed in **Section 6**, as applicable.

4. Conceptual Site Model

Predicting off-range migration of MC requires the evaluation of potential exposure pathways, such as surface water and groundwater flow characteristics, and possible receptors (human and ecological) that might be affected. To this end, the REVA assessment team developed CSMs to characterize the dynamics at MCAS Beaufort and the Townsend Range that can affect MC migration. The primary components of these CSMs include:

- delineation of the MC loading areas;
- identification of REVA indicator MC at individual MC loading areas;
- a synthesis and interpretation of various environmental data to identify potential MC migration pathways and receptors; and
- identification of data gaps.

The CSM was developed using information obtained during the site visit, environmental reports obtained from MCAS Beaufort and the Townsend Range, and local geologic field studies. Documents obtained from the Environmental Department and Facilities Management Division at MCAS Beaufort and the Townsend Range included information on the site geology and hydrology, the water supply system, cultural resource studies, natural resource studies, range operating procedures, EOD commitments, and operational range clearances. In addition, the REVA team used spatial data provided by the Facilities Management Division to map site characteristics.

The site-specific CSMs for the MC loading areas are provided in **Section 6**.

4.1. Installation Profile

CSM Information Profiles – Installation Profile	
Information Needs	**Preliminary Information**
Installation location	MCAS Beaufort spans approximately 6,909 acres (including Laurel Bay Housing) in Beaufort County, SC, near the southern border with Georgia. The installation is 4 miles from downtown Beaufort, 70 miles southwest of Charleston, SC, and 40 miles northeast of Savannah, GA. The Townsend Range spans 5,182 acres and is approximately 130 miles south of MCAS Beaufort in McIntosh County, GA, near the town of Townsend, GA. The Townsend Range is located approximately 60 miles south of Savannah, GA and 15 miles north of Darien, GA.
Date of Installation establishment	MCAS Beaufort was established in 1943 to serve as a naval air station during World War II. Following a deactivation period between 1946 and 1956, MCAS Beaufort was reopened as an air station for the Marine Corps. The area that would become Laurel Bay Housing was acquired in 1957 (MCAS Beaufort, 2009). The Townsend Range was established in 1942 and owned by the U.S. Navy when it operated Naval Air Station Glynco in Brunswick, GA. During this time, it was known as "Glynco Bombing Range." The Navy closed the range in 1972 with the closure of the Naval Air Station Glynco. The range reopened in 1981 as Townsend Air-to-Ground Gunnery Range and currently is owned by the Marine Corps but operated by the Georgia Air National Guard (MCAS Beaufort, 2009).
Installation area and layout	MCAS Beaufort is divided into two areas, the air station and the Laurel Bay Housing. The majority of the air station, 5,841 acres, is located east of U.S. Highway 21. The area contains a core administrative building, training facilities and centers, and Merritt Field (3.9 million square yards of runways and taxiways). The Pine Grove Housing Area also is located on the air station. The Laurel Bay Housing Area consists of 1,068 acres of housing area located 3 miles west of the MCAS Beaufort. This area contains approximately 1,500 family housing units. The housing area also includes community support facilities, two elementary schools, two middle schools, and a recreation center (MCAS Beaufort, 2009). Approximately 383 of the 5,182 acres of the Townsend Range are cleared for placement of targets and instrumentation. The majority of the property

CSM Information Profiles – Installation Profile	
Information Needs	**Preliminary Information**
	is forested and undeveloped. The range contains operation and maintenance facilities, which consist of a main office complex, main control tower, pole shed for vehicles, equipment shed, pump house, explosive storage sheds, and two observation towers.
Installation mission	MCAS Beaufort hosts all active duty Marine Corps F/A-18 air operations on the East Coast, assigned to MAG-31. The mission of MCAS Beaufort is to provide support as an operation base for MAG-31 and the support units. MAG-31 is one of the largest aircraft groups and includes approximately 4,200 Marines and Sailors. The mission of the MAG-31 is to conduct anti-air-warfare and offensive air support operation in support of Fleet Marine Forces from advanced bases, expeditionary airfields, and aircraft carriers and conduct such other air operations as directed (MCAS Beaufort, 2009). Military aircraft from the Air Force, Navy, Marine Corps, and Georgia Air National Guard use the Townsend Range in order to meet training requirements. The mission of the Townsend Range is to provide a realistic target and hostile threat environment to train combat aircrews from all services; provide an environment for ground forces to conduct training; and facilitate command and control, information, surveillance, and reconnaissance training (MCAS Beaufort, 2008).

4.2. Operational Range Profile

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
MC loading areas	One SAR is present at MCAS Beaufort (Pistol Range). Seven MC loading areas were delineated on the Townsend Range, focused on specific target areas: • Command Post • EOD

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
	• Heavy Weight • Helicopter Door Gunnery • Main Bull • SAM Site • Smokey SAM
Range names	Three operational ranges are present at MCAS Beaufort: the EOD Range, the NBC Training Area, and the Pistol Range. The Boresight Range is a historical use area presently located on operationally active land; this range has not been used in more than 10 years. The Townsend Range contains the following targets: the Command Post Target, Heavy Weight Target, Helicopter Door Gunnery Target, Main Bull Target, POL Target, SAM Target, Scud Target, multiple Strafe Targets, and Urban Target Area. MCAS Beaufort EOD personnel use a portion of the Heavy Weight Target during range clearance activities. A SAR was used between 2002 and 2005 but is now considered a historical use area.
Date of range establishment	The Pistol Range at MCAS Beaufort has been in use from 1959 to the present, with the exception of the period from 1999 to 2003. The Townsend Range has been in use from 1942 to the present, with the exception of the period from 1972 to 1981. Current configuration of the range was completed in 1982 with the Urban Target Area added in 2010.
Range design and use	The Pistol Range at MCAS Beaufort is used for pistol marksmanship training. The range was redeveloped in 2003. The berm was refurbished with the slope of the berm modified in late 2010. The Townsend Range is a 100% inert bombing range facility that supports fixed wing and rotary aircraft. Munitions types used at the range include practice bombs, rockets, and small arms ammunition. Ten targets are used for a variety of bombing engagement training, and strafe runs are conducted in three areas. Each of the targets was constructed in 1982, with the exception of the Urban Target Area, which was constructed in 2010.

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
Range security	All of the operational ranges are located within the MCAS Beaufort and Townsend Range boundaries. Both installations are fenced along their perimeter, with various access points with locked gates. Access to the installations is limited to installation personnel and contractors with escorts. MCAS Beaufort has guards stationed at the gates. The gate at Townsend Range is only opened after notifying range personnel of your presence and reason to be on range.
Military munitions usage	Small arms ammunition is used at the MCAS Beaufort Pistol Range. Authorized military munitions at the Townsend Range include inert munitions with only smoke or marker charges for the location of impact points.
Munitions constituents	Lead is the only REVA indicator MC used at the MCAS Beaufort Pistol Range. The principal MC potentially present at the Townsend Range include lead and perchlorate. EOD activities associated with operational range clearance may result in the deposition of small volumes of HE.
Maintenance	Regular maintenance activities of the ranges at MCAS Beaufort and the Townsend Range generally include vegetation removal to prevent overgrowth of the ranges. The Facilities Department is responsible for this type of maintenance of ranges at MCAS Beaufort. A grounds maintenance program at the Townsend Range provides for regular mowing of the grass at the operation and maintenance facilities. A controlled burn of the range area is completed annually. The berm at the Pistol Range at MCAS Beaufort was redeveloped in 2010. Refurbishing the range included sifting and lead mining of the berm, replenishment and reconstruction of the backstop, and construction of baffles and wing walls to capture projectiles within the range. The range typically is mined every 5 to 6 years based on use. MCAS Beaufort EOD personnel conduct operational range clearance at the Townsend Range approximately quarterly. During these clearances, the practice munitions that are visible on the ground surface are recovered. EOD stages the expended munitions in the Heavy Weight

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
	Target area and removes the wing attachment lugs. A small amount of explosives is used to expose the inert material within the practice bomb casings in order to be turned over to a recycling contractor. The strafing ranges at the Townsend Range are maintained weekly by using an electromagnet to extract the expended steel projectiles from each of the strafing targets. The recovered projectiles are recycled.
Engineered controls	At the MCAS Beaufort Pistol Range, concrete walls approximately 15 feet tall are present on each side of the range and an earthen berm backstop is present at the northern end of the range. The berm is approximately 17 feet tall and has a 2:1 slope on both sides. Five rows of overhead baffles at various increments downrange and a ballistic canopy directly above the firing line keep projectiles from escaping the range. There are no engineering controls at the Townsend Range.

4.3. Physical Profile

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Climate	MCAS Beaufort is located in the Atlantic Lower Coastal Plain, where the climate is milder than anywhere else in South Carolina. The average temperature is 70 degrees Fahrenheit (°F) for Beaufort, SC. The summer is hot and humid, with inland high temperatures reaching 90°F to 100°F, but the coastal areas are cooled by sea breezes. Winter is cool, with occasional brief cold spells with lows reaching 20°F. Rain occurs throughout the year and is fairly heavy at times. Average annual rainfall is about 49 inches, with the highest rate of precipitation in July and the lowest in November. The prevailing wind is southwesterly at average speeds of about 8 miles per hour (mph) (MCAS Beaufort, 2010a). The average temperature for the Townsend Range is around 70°F.

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	Winters are mild, averaging in the low 50s °F, with occasional brief cold spells where lows reach the 20s °F. Rain occurs throughout the year and is fairly heavy at times. Average annual rainfall is about 51 inches (MCAS Beaufort, 2008). July and August typically are the wettest months (greater than 7 inches), whereas April and May are the driest (less than 3 inches) (MCAS Beaufort, 2010b). It should be noted that tropical storms and hurricanes are not unusual to Beaufort, SC and Townsend, GA. The hurricane season generally is considered to be the period from June through November. Tropical storms occur an average of about every 2 or 3 years and can bring winds up to 50 mph. While hurricanes are less frequent to the area, they have caused severe flooding and damage in low-lying areas near the ocean, sounds, bays, rivers, and creeks. According to Beaufort USA (2008), seven hurricanes and 14 tropical storms passed across or close by the Beaufort, SC area between 1910 and 1989. Hurricane Gracie, a Category 3 hurricane, caused major damage to the Beaufort area in 1959. Moderate damage was noted in the area from an unnamed hurricane in 1947 and David (a Category 1 hurricane) in 1979.
Elevation	The area around MCAS Beaufort is generally of low relief with elevations ranging from sea level to 35 ft above mean sea level (msl), with an average elevation of 20 ft. Elevations at Laurel Bay Housing Area range from 0 to 40 ft above msl. The area is gently rising in elevation from the Broad River (MCAS Beaufort, 2009). Land elevations near the Townsend Range vary from 15 to 25 ft above msl. The Townsend Range itself is generally flat with little elevation change (MCAS Beaufort, 2010b).
Topography and geologic features	MCAS Beaufort is located on Port Royal Island in the Atlantic Coastal Plain within the Lower Coastal Plain physiographic province. This area is characterized by a series of parallel coastal terraces, about 5 to 35 ft above msl, separated by lower areas of marsh. The topography of MCAS Beaufort is relatively flat and incised by numerous tidal marshes and creeks. The base is bounded by Brickyard Creek and adjacent tidal marshes to the east and Albergottie Creek and tidal wetlands to the

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	south. Water drains from the marshes into the Beaufort River, which is east of Albergottie Creek. The Beaufort River flows into Port Royal Sound about 12 miles to the south (Malcolm Pirnie, 2008). Geologic units at MCAS Beaufort ranging from the youngest (Pleistocene age) to oldest (Eocene age) include the Pleistocene/Holocene sands and clay, Hawthorn Formation from the Miocene Age, and Ocala Limestone. The Townsend Range is located between the Altamaha and South Newport Rivers in McIntosh County. The Townsend Range is predominantly low and flat and locally is referred to as the "flatwoods." It lies within the Lower Coastal Plain. This division consists of limestone, shell, sand, and clay. Most of the dry land in McIntosh County lies between the Pamlico terrace to the east and the Talbot terrace to the west (MCAS Beaufort, 2009). According to U.S. Geological Survey (USGS) topographic maps, the topography of the Townsend Range generally slopes gently downward from the northwest to the southeast. There are only slight depressions that may hold water during particularly wet weather on the Townsend Range. The surface water runoff from the majority of the Townsend Range discharges in a southeasterly direction (Malcolm Pirnie, 2005). The following are the geologic units from the youngest (Pleistocene age and younger) to the oldest (Eocene age) found at the Townsend Range: Pliocene and younger sands and clays, Ebenezer Formation, Coosawatchie Formation, Marks Head Formation, Parachucla Formation, Tiger Leap Formation, Lazaretto Formation, and Suwannee Limestone / Ocala Limestone.
Stratigraphy	MCAS Beaufort MCAS Beaufort and its surrounding area fall within the Lower Coastal Plain of southeast South Carolina. The coastal area of South Carolina is underlain by a thick sequence of unconsolidated to semi-consolidated layers of sand and clay and poorly indurated to very dense layers of limestone and dolomite. These rocks and sediments range in age from Paleocene (oldest) to recent. **Sediments of Pleistocene to Holocene Age:** Approximately 40 to 60 ft of Pleistocene to Holocene sediments overlie the Ocala Limestone, or

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	Hawthorn Formation where present. These materials include the coastal barrier island and marine near shore deposits of the late Pleistocene and Holocene and are predominantly fine- to medium-grained sand and silty sand with thin clay layers and sparse shell fragments. As a result of sea-level fluctuations, the Pleistocene sediments are in many cases reworked, deposited as beach ridges and barrier islands, cut by erosional channels, and interbedded with alluvium. **Hawthorn Formation of Miocene Age:** The Hawthorn Formation primarily consists of a thin (5 to 15 ft thick) Lower Miocene limestone known as the Tampa Limestone. The Tampa Limestone is composed of phosphatic sand, sandy marl, or sandy clay in southwestern Beaufort County. Wells screened in the Tampa Limestone have a noticeably high content of hydrogen sulfide, which imparts a rotten-egg odor to the water. The Hawthorn Formation is locally discontinuous in coastal Beaufort County. Where present in the study area, the Hawthorn Formation (in conjunction with the Cooper Marl Formation) serves as a confining unit to the underlying Santee Limestone. **Cooper Marl of Oligocene Age:** The Cooper Marl of Oligocene age consists of phosphatic, greenish-gray clay and fine-grained sand with a moderate to very abundant amount of shells and serves as a confining unit to the underlying Santee Limestone. The thickness of the Cooper Marl ranges from 0 to 15 ft in the area. Within the region of MCAS Beaufort, the top of the unit is 20 to 120 ft bgs. **Ocala Limestone of Eocene Age:** The Ocala Limestone of Upper Eocene age is primarily a calcitized, fossiliferius limestone. The Ocala Limestone comprises the highly permeable upper portion of the Floridan aquifer and supplies most of the groundwater extracted from the Floridan aquifer. **Santee Limestone of Eocene Age:** The Santee Limestone of Middle Eocene age is composed primarily of relatively pure to impure limestone containing clay, shale, or relatively thick marls. In the Low Country area, the Santee Limestone is 430 to 830 ft thick. The Santee Limestone corresponds to the lower Floridan aquifer.

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	The hydrogeologically important structural feature at MCAS Beaufort is the Beaufort Arch, a structural high with a northeast-trending axis located in central Beaufort County. This structural arch influences the extent of direct hydraulic communication between saturated portions of the Pleistocene/Holocene sediments and the Santee Limestone. Townsend Range The coastal area of Georgia also is underlain by a thick sequence of unconsolidated to semiconsolidated layers of sand and clay. These rocks and sediments at the Townsend Range vary in age from Paleocene (oldest) to recent. **Sediments of Post-Miocene Age:** The undifferentiated sediments consist of interbedded sand, clay, and thin limestone beds of Miocene and younger age. **Coosawhatchie, Marks Head, and Tiger Leap Formations:** These formations are composed primarily of poorly sorted, fine to coarse, slightly phosphatic and calcareous or dolomitic quartz sand of Miocene age (Clarke, 2003). Near Townsend, GA, the Miocene unit consists of, in descending order, Coosawhatchie, Marks Head, and Tiger Leap Formations (Williams, 2010). The Coosawhatchie Formation serves as the confining unit for the underlying Brunswick aquifer, while the Marks Head and Tiger Leap Formations correspond to the lower Brunswick aquifer. **Lazaretto Creek Formation:** At the base of the lower Brunswick aquifer is the Oligocene fossiliferous limestone of the Lazaretto Creek Formation. This formation acts as a confining unit between the Brunswick and Floridan aquifers. **Ocala Limestone**: The Ocala limestones comprise the highly permeable upper portion of the Floridan aquifer and supply most of the groundwater extracted from the Floridan aquifer. A major structural feature that affects the hydrogeology of coastal Georgia is the southeast Georgia embayment. Within the southeast Georgia embayment, Coastal Plain sediments are thicker, resulting in

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	thicker and more abundant aquifer layers (MCAS Beaufort, 2008). The Townsend Range is located just west of the southeast Georgia embayment.
Soil and vadose zone characteristics	Soils at MCAS Beaufort tend to be dominated by fine sands, sandy loams, and loams. Soils with a clay layer greater than 21 inches thick (up to 62 inches thick) reside in the southern part of MCAS Beaufort and wrap around the southernmost MCAS Beaufort runway heading north and then northeast. Clayey soils, in general, tend to inhibit the downward flow of percolating rainwater. However, the clayey soils at MCAS Beaufort may support a shallow water table during wet periods or they may crack during drier periods, thus creating preferential flow paths for infiltrated rainwater. Therefore, the clayey soils at MCAS Beaufort do not prevent recharge to the shallow water table. Non-clayey soils mostly occur in the western and northwestern portions of MCAS Beaufort where elevations are higher. Soils in this area tend to be better drained and are very sandy throughout their profiles (Malcolm Pirnie, 2005). According to the U.S. Department of Agriculture (USDA) Soil Conservation Service maps, Brookman is the dominant soil composition in the area of the Townsend Range. Brookman soils are very deep, very poorly drained, slow permeable soils. Water runs off the surface very slowly. These soils consist of a black, clay loam surface layer over dark gray, plastic-like clay that is mottled in places. These soils are very acidic. The following soils are associated with Brookman series soils: Bayboro, Ellabell, and Stockade series and the Argent, Bladen, Grifton, Meggett, Okeetee and Yonges series. The following soil types may be present within the general area of the Townsend Range: surface soils with a fine sandy loam to loam and deeper soils with a sandy loam to clay loam (Malcolm Pirnie, 2005).
Erosion potential	The natural erosion potential for upland impact areas at MCAS Beaufort is low due to the flat topography and low slopes. However, this may not be true for highly disturbed range areas or stream valleys. The soils characterized at the Townsend Range have a low to moderate

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	inherent soil erodibility. The overall site erosion potential, as quantified in the Revised Universal Soil Loss Equation (RUSLE) and described in **Section 5.**1, indicates low to high potential for soil erosion at the loading areas depending on slope, vegetative cover, and soil/sediment disturbances specific to each area.
Potential MC release mechanisms	Potential MC release mechanisms include mobilization in surface water runoff or groundwater. Precipitation at both MCAS Beaufort and the Townsend Range averages approximately 50 inches per year. Flat topography results in slow runoff and low-level ponding. Personnel at the Townsend Range stated that the range floods after a heavy rainfall. Surface water runoff can transport MC in soil through dissolution in runoff water or erosion of soil and sediments transported in storm water runoff. MC in surface water runoff potentially can be released into streams, ponds, wetlands, and ultimately to the Atlantic Ocean. A portion of the precipitation infiltrates through the surface soil.

4.4. Surface Water Profile

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water drainage	MCAS Beaufort is bounded by Brickyard Creek and adjacent tidal marshes to the east and Albergottie Creek and tidal wetlands to the south. Water drains from the marshes into the Beaufort River, which is east of Albergottie Creek. The Beaufort River flows into Port Royal Sound about 12 miles to the south (Malcolm Pirnie, 2005). The Townsend Range is located in the Ogeechee Coastal subbasin of the Ogeechee River Basin. Surface water features on the range include Snuff Box Canal (which traverses the Townsend Range), freshwater marshes/swamps and streams, and isolated depressions that hold water seasonally (MCAS Beaufort, 2008). Drainage on the range occurs in a

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
	southwesterly direction through a series of low ditches, some of which are regularly maintained, into the Snuff Box Swamp and Snuff Box Canal. Snuff Box Canal drains into Cathead Creek, which drains into the Darien River. The Darien River flows into the Rockdedundy River, which empties into Doboy Sound (MCAS Beaufort, 2008).
Hydrological unit & watershed areas	MCAS Beaufort is located entirely in the Broad St. Helena Watershed (USGS Cataloging Unit 03050208) (MCAS Beaufort, 2001a). This watershed is approximately 8,772 square kilometers in size and encompasses portions of southeast South Carolina and northeast Georgia. All of the Townsend Range is located in the Ogeechee Coastal subbasin watershed (USGS Cataloging Unit 03060204) (MCAS Beaufort, 2010b). This watershed is approximately 9,273 square kilometers in southeast Georgia.
Surface water uses	At MCAS Beaufort, surface water features (such as the fish ponds, the Broad River, and Albergottie Creek) are used for recreational use by active duty and retired military personnel and their dependents (MCAS Beaufort, 2010a). Several surface water features on and adjacent to MCAS Beaufort also are available for nonmotorized and motorized boating. Surface water down gradient of the site is not used as a drinking source at MCAS Beaufort or for municipal supply. Surface water in the general area of the Townsend Range includes freshwater marshes, swamps, ponds, and streams. Surface waters down gradient of the Townsend Range are not used for recreational activities and are not used for municipal or domestic drinking water supply.
Supported habitats/ ecosystems	A variety of wildlife species, including amphibians, reptiles, mammals, and birds, inhabit MCAS Beaufort and the Townsend Range (Malcolm Pirnie, 2008). There are various designated wildlife management areas throughout MCAS Beaufort. The vegetation at MCAS Beaufort largely consists of freshwater and estuarine wetlands as well as forestland. The air station has approximately 505 acres of palustrine-forested wetlands, 16 acres of palustrine emergent wetlands, 260 acres of estuarine

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
	emergent wetlands, and 15 acres of excavated, freshwater ponds. MCAS Beaufort has approximately 2,000 acres of forestland. The predominant forest cover is loblolly pine, with lesser amounts of forest cover in slash pine, pine/hardwood, longleaf pine, and hardwood. The vegetation at the Townsend Range consists of largely forestland and wetlands. Most of the upland portion of the Townsend Range is an uneven-aged pine forest community. This community is characterized by a slash and loblolly pine overstory, with occasional longleaf on the higher, drier sites and pond pine on the lower, wetter sites. The understory and shrub layer is extensive and composed of saw palmetto (*Serenoa repens)* and members of the heath family (Ericaceae) (MCAS Beaufort, 2010b). Seven upland community types have been identified on the Townsend Range, including planted pine, natural mixed pine, longleaf pine, cut-over pine, pine-mixed hardwood, mixed hardwood, and open/maintained. Approximately 30% of the Townsend Range is wetlands. These wetlands are of the palustrine system (MCAS Beaufort, 2010b). Federally threatened and endangered (T/E) species that are known to occur at MCAS Beaufort include the American alligator *(Alligator mississippiensis*), the bald eagle (*Haliaeetus leucocephalus*), the wood stork (*Mycteria Americana*), and the southeastern myotis (*Myotis austroriparius*). The final is a plant species, Pondberry *(Lindera melissifolia*). The only resident federally protected species known to occur on the Townsend Range is the flatwood salamander (*Ambystoma cingulatum*). Wood stork (*Mycteria americana*) occasionally has been observed flying over or feeding on the Townsend Range but is not a resident. American alligator (*Alligator mississippiensis*) also may occur on the Townsend Range but is not abundant. Additional information of T/E and species of special concern is provided in the Natural Resources Profile.
Gaining or losing streams	Surface waters at MCAS Beaufort flow primarily eastward to Beaufort River and southward to Albergottie Creek and Brickyard Creek. These surface waters are tidal creeks, and flow direction changes with the tides

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
	four times a day. Groundwater flowing beneath MCAS Beaufort discharges primarily into Brickyard Creek and Albergottie Creek and its minor tributaries. Shallow groundwater may discharge locally into smaller streams and other surface water features. As a result, streams at MCAS Beaufort generally are gaining. Surface waters at Townsend Range will either migrate to on-site wetlands or the Snuff Box Canal. The canal flows in a southeasterly direction off the range. Wetlands at MCAS Beaufort and the Townsend Range serve as a valuable resource for groundwater discharge within the region. Wetlands make up approximately 30% of the Townsend Range. Even when surface water is absent, the water table is usually at or very near land surface. Shallow groundwater from the wetlands may discharge locally into smaller streams and other surface water features.
Surface water collection points	At MCAS Beaufort, two managed ponds and two storm water retention basins are the only permanent surface water features on the base. The other remaining surface water features on MCAS Beaufort are not considered perennial. The major surface water drainage feature at the Townsend Range is Snuff Box Canal, which runs northwest-southeast through the center of the range. This canal is a channelized stream that flows perennially. One tributary of the Snuff Box Canal located within the Townsend Range is perennial. Other water bodies within the range boundary are not perennial.
Known water quality characteristics	Surface water sampling occurs annually at the EOD Range at MCAS Beaufort (CH2M HILL, 2011). In 2011, surface water samples were collected from nearby wetlands considered to be brackish. No metals were detected above the screening criteria in 2009 or 2010. Only lead was detected above screening criteria of 15 µg/L in 2011.

4.5. Groundwater Profile

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Groundwater aquifers	MCAS Beaufort The primary groundwater aquifers at MCAS Beaufort are the surficial and upper Floridan. Neither of these aquifers is used as a drinking water source by the installation, which obtains its water from the Beaufort-Jasper Water & Sewer Authority (BJWSA). The BJWSA was formed in 1954 due to saltwater intrusion issues in the upper Floridan aquifer and began providing treated water from the Savannah River in 1965. **Surficial aquifer:** The surficial aquifer that underlies the coastal part of South Carolina, including MCAS Beaufort, is about 50 ft thick. These materials give rise to a thin, shallow, unconfined aquifer supported by local precipitation, with the water table typically within 4 to 6 ft of land surface. A review of water level data by George Siple (1960) determined that the surficial aquifer in areas at/near MCAS Beaufort is recharging the Floridan aquifer. **Upper Floridan aquifer**: The upper Floridan aquifer is the primary source of groundwater supply for residential wells in Beaufort County, SC because of its good water quality and high productivity (Hughes et al., 1989). In Beaufort County, the Ocala Limestone comprises the highly permeable upper portion of the Floridan aquifer and supplies most of the groundwater extracted from the Floridan aquifer. Groundwater in the upper zone occurs in solutionally enlarged openings or cavities in the limestone. The upper Floridan aquifer is approximately 30 to 40 ft thick near Beaufort, SC. As discussed above, MCAS Beaufort obtains its drinking water from the Savannah River through the BJWSA. In an effort to mitigate the effects of saltwater intrusion, the South Carolina Department of Health and Environmental Control (SCDHEC) regulates the groundwater withdrawals from the upper Floridan aquifer in Beaufort County, SC. The SCDHEC requires a permit for all upper Floridan aquifer wells that withdraw 3 million gallons or more

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	groundwater in any month. They also monitor water quality in the upper Floridan for saltwater intrusion. <u>Townsend Range</u> The Townsend Range has three primary aquifers: the surficial saturated deposits, the lower Brunswick aquifer, and the Floridan aquifer. These aquifers generally are separated by confining units of the Coosawhatchie Formation (between the surficial and the Brunswick aquifers) and the Lazaretto Creek Formation (between the Brunswick and the Floridan aquifers). **Surficial aquifer:** The surficial aquifer system consists of interbedded sand, clay, and thin limestone beds of Miocene and younger age. The surficial aquifer has been subdivided into three zones—the water-table zone and the confined upper and lower water-bearing zones (Leeth, 1999). The surficial aquifer is used primarily for domestic supply and livestock operations in rural areas. **Lower Brunswick aquifer:** This aquifer consists of poorly sorted, fine to coarse, slightly phosphatic and calcareous or dolomitic quartz sand of Miocene age (Clarke, 2003). At Townsend, the lower Brunswick aquifer is approximately 50 ft thick. The Brunswick aquifer is not a major source of water in coastal Georgia but is being considered a supplemental water supply to the upper Floridan aquifer because of restrictions instituted by the Georgia Environmental Protection Division (GEPD) on the Floridan aquifer. **Upper Floridan aquifer:** The Floridan aquifer is a principal source of groundwater supply in Georgia. The Suwannee and Ocala limestones comprise the highly permeable upper portion of the Floridan aquifer and supply most of the groundwater extracted from the Floridan aquifer. At Townsend, GA, the top of the upper Floridan aquifer is approximately 350 ft thick. The water supply well at the Townsend Range draws water from the Floridan aquifer at a depth of approximately 700 ft bgs. The GEPD requires withdrawal permits for quantities of 100,000 gallons

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	per day or more. The GEPD also evaluates if the proposed withdrawal will affect saltwater intrusion.
Groundwater uses	The Floridan aquifer is one of the most productive aquifers in the world. The aquifer system supplies water for several large cities, including Savannah, GA and Jacksonville, Florida (Miller, 1990). The Floridan aquifer is also intensively pumped for industrial and irrigation supplies. The BJWSA, from which MCAS Beaufort receives its drinking water, uses water from the Floridan aquifer to supplement the water obtained from the Savannah River. Wells, which pump water from the aquifer, are used during times of high water demand in the summer months. Drinking water for the Townsend Range is supplied from a groundwater supply well that also withdraws water from the Floridian aquifer.
Groundwater supply wells	MCAS Beaufort originally obtained its water supply from wells located on the installation. After the BJWSA was established over concerns with saltwater intrusion in the Floridan aquifer, the installation connected to the authority's water supply. This water supply is treated surface water from the Savannah River. All drinking water production wells at MCAS Beaufort were closed in September 2008. Properties are required to connect to the BJWSA if water lines are in the area. The Townsend Range has a water supply well on site to provide drinking water. The well was installed in the late 1970s or early 1980s. This well is approximately 700 ft deep and screens the Floridan aquifer. The well is sampled monthly for bacteria. A geologic log of this well was not available. There are no known domestic water supply wells located within the immediate vicinity of the Townsend Range. A local water well driller stated that domestic water supply wells in the Townsend area are screened in the Floridan aquifer. The GEPD also requires withdrawal permits for quantities of 100,000 gallons per day or more. The GEPD also evaluates if the proposed withdrawal will affect saltwater intrusion.

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Recharge source(s)	The surficial aquifer at MCAS Beaufort is unconfined and recharged by local precipitation (CH2M HILL, 2011). Areas in the surficial aquifer in which a confining unit is not present may be recharging areas for the Floridan aquifer. This is true in the northern portions of Port Royal Island and Lady's Island, on which MCAS Beaufort is located (CH2M HILL, 2011). The surficial aquifer at the Townsend Range is recharged by local precipitation; however, due to various confining layers between the surficial aquifer and the underlying Brunswick and Floridan aquifers in the Townsend area, it is not likely that the surficial aquifer will directly recharge the Brunswick and Floridan aquifers in this region.
Porous or fracture flow	Groundwater flow through the water-bearing units at MCAS Beaufort and the Townsend Range is generally porous-media flow. The water-bearing units are composed of a thick sequence of unconsolidated to semiconsolidated layers of sand and clay. These materials give rise to an unconfined surficial aquifer with the water table typically less than 10 ft bgs.
Depth to groundwater	Depth to water in the surficial aquifer at MCAS Beaufort and the Townsend Range is less than 10 ft bgs. The water table often can be found at or very near land surface.
Gradient and flow velocity	The hydraulic gradients are nearly flat at MCAS Beaufort and the Townsend Range. The rate of groundwater flow in the surficial aquifer generally ranges from 0.2 to 1.2 ft per day with an average hydraulic conductivity of 7.1 x 10^{-3} ft per minute for MCAS Beaufort (CH2M HILL, 2011). Hydraulic gradients and flow velocity were not obtained for the Townsend Range.
Known water quality characteristics	Water quality at MCAS Beaufort is dependent on the types of soil and rock the water moves through. In the Beaufort area, the surficial aquifer is comprised of limestone and marl. Water from this aquifer may have a high mineral content (hard water) and contain high

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	concentrations of iron and hydrogen sulfide (CH2M HILL, 2011). Near the coast, the water from the surficial aquifer may be brackish. The top of the Floridan aquifer is greater than 500 ft bgs at the Townsend Range. Water quality is good, containing low concentrations of silica, iron, and dissolved solids. The presence of sulfur gives the water a distinctive odor and taste (MCAS Beaufort, 2010b).
Discharge location(s)	Discharge from the Floridan aquifer occurs naturally by upward seepage through the overlying or confining beds over a wide area and by submarine discharge under the estuaries and bays in the Beaufort area (Siple, 1960). A significant amount of groundwater also is removed from the Floridan aquifer through water supply wells. The surficial aquifers at both MCAS Beaufort and the Townsend Range discharge to the nearby surface water bodies.

4.6. Human Land Use and Exposure Profile

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
Land use	The natural areas surrounding MCAS Beaufort contain freshwater and estuarine wetlands and forested areas. Most of the large wetlands are estuarine and occur along Brickyard and Albergottie Creeks. The smaller freshwater wetlands consist of both the forested and nonforested types. MCAS Beaufort has approximately 505 acres of palustrine-forested wetlands, 16 acres of palustrine emergent wetlands, 260 acres of estuarine emergent wetlands, and 15 acres of excavated, freshwater ponds. MCAS Beaufort has approximately 2,000 acres of forestland. The predominant forest cover is loblolly pine, with lesser amounts of forest cover in slash pine, pine/hardwood, longleaf pine, and hardwood. The maintained areas at MCAS Beaufort consist primarily of the airfield and

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
	the urban/production area. The airfield contains the aircraft landing strips and surrounding graded clean zone areas. The urban/production area contains administrative buildings, facility maintenance structures, aircraft hangers, other operational structures, and personnel housing. Outdoor recreation areas include hunting, fishing, boating, picnic and camping areas, and horseback riding. The area around the Townsend Range is used extensively for timber harvesting as well as animal husbandry and agriculture (MCAS Beaufort, 2009). The Townsend Range and lands adjacent to the Townsend Range boundaries in McIntosh County are zoned General Agriculture-Forestry. Land use within the Agriculture-Forestry District includes forestry and allows structures to include housing, agricultural-forestry buildings, churches, cemeteries, riding stables, home business offices, playgrounds/parks, country clubs, lodges, kennels, and public buildings for utilities (MCAS Beaufort, 2008). Approximately 30% of the Townsend Range is wetlands. These wetlands are of the palustrine system (MCAS Beaufort, 2010b). The maintained areas at the Townsend Range, approximately 383 acres, consist primarily of the cleared target areas and operation and maintenance facilities. Limited outdoor recreation is available at the Townsend Range in the form of deer hunting.
Current human receptors	**Surface water:** At MCAS Beaufort, the MC loading area is located near Brickyard Creek, which is tidally influenced and receives surface water runoff and groundwater discharge from the MC loading area. There are no current users or potential off-site human receptors that are likely to be adversely affected from potential contaminant migration in surface water. At the Townsend Range, surface water runoff and shallow groundwater discharges into the Snuff Box Canal and associated wetlands before flowing southeasterly off the range. There are no current users or potential off-site human receptors that are likely to be adversely affected by the range impacts or potential impact from off-site migration. **Drinking water:** MCAS Beaufort obtains its drinking water from the BJWSA,

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
	which obtains its water from the Savannah River. Therefore, there are likely no direct human receptors for groundwater potentially impacted by MCAS Beaufort ranges. Additionally, the BJWSA requires connection to their system, if it is located in the area. A water supply well screened in the Floridan aquifer is present at the Townsend Range for drinking water use by installation personnel. Since this well is screened in the Floridan aquifer at a depth of 700 ft bgs, human contact with the surficial aquifer should be limited at the Townsend Range. The State of Georgia considers all groundwater to be a source of drinking water. There is potential for future residential land use, beyond the installation boundary, that may use the surficial aquifer for drinking water. Discharge is currently into Snuff Box Canal and associated wetlands and does not serve as a drinking water source.
Land use restrictions	No land use restrictions are known to be in place at MCAS Beaufort or the Townsend Range.

4.7. Natural Resources Profile

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
Ecosystems	MCAS Beaufort lies in the Coastal Plain physiographic province, surrounded by tidal features such as marshes, sounds, and river systems. The MCAS Beaufort region can be described as a transitional zone, with fresh water from the main Broad River and lesser Beaufort River watersheds entering the saline Port Royal Sound. The extensive salt marshes and tidal creeks form complex estuary systems, which support a rich diversity of habitats. There are five types of wetlands present on MCAS Beaufort, two of which are estuarine (saltwater) communities and three are palustrine (freshwater) (MCAS Beaufort, 2009). MCAS Beaufort

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
	has approximately 2,000 acres of forestland. The predominant forest cover is loblolly pine, with lesser amounts of forest cover in slash pine, pine/hardwood, longleaf pine, and hardwood. The Townsend Range lies in the Coastal Plain physiographic province. The Townsend Range is predominantly low and flat and is referred to locally as the "flatwoods." The vegetation at the Townsend Range consists of largely forestland and wetlands. Most of the upland portion of the Townsend Range is an uneven-aged pine forest community. Approximately 30% of the Townsend Range is wetlands. Wetlands at the Townsend Range are of the palustrine system, which are wetlands dominated by trees, shrubs, and persistent emergent herbaceous plants. Four classes of palustrine wetlands occur at the Townsend Range: palustrine forested, palustrine scrub-shrub, palustrine emergent, and palustrine open water/canal.
Vegetation	The dominant habitat found at MCAS Beaufort is managed pine forest, which comprises approximately 58% of the forested acreage on the installation. Slash and loblolly pines are the major species present, but longleaf pine occurs in some areas. Rows of hardwood trees (mostly sweet gum, red maple, and black cherry) are being established in the planted pine stands. The pure hardwood habitat comprises about 330 acres of the forested acres. These areas harbor many invasive plants, such as Chinese privet, Chinese tallowtree, and Chinaberry. About 25% (493 acres) of MCAS Beaufort are mixed pine-hardwood types, which have neither hardwoods nor pines dominating the crown (MCAS Beaufort, 2010a). Most of the upland portion of the Townsend Range is an even-aged pine forest community. This community is characterized by a slash and loblolly pine overstory, with occasional longleaf on the higher, drier sites and pond pine on the lower, wetter sites. The understory and shrub layer is extensive and composed of saw palmetto (*Serenoa repens)* and members of the heath family (Ericaceae) (MCAS Beaufort, 2010b). Portions of the site are remnant sandhill community converted to commercial pine tree production. Seven upland community types have

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
	been identified on the Townsend Range, including planted pine, natural mixed pine, longleaf pine, cut-over pine, pine-mixed hardwood, mixed hardwood, and open/maintained (MCAS Beaufort, 2008).
Fauna	MCAS Beaufort's wildlife is typical of South Carolina's outer coastal plain. The most common large mammal on the installation is the white-tailed deer. Common mammals found at MCAS Beaufort include the shrew, mole, red bat, evening bat, gray squirrel, mice, rat, gray fox, river otter, bobcat, and white-tailed deer. Common birds found at MCAS Beaufort include pied-billed grebe, double-crested cormorant, heron, egret, wood duck, osprey, red-tailed hawk, American kestrel, clapper rail, killdeer, laughing gull, ring-billed gull, mourning dove, chimney swift, belted kingfisher, red-bellied woodpecker, downy woodpecker, Northern flicker, Eastern wood-peewee, great-crested flycatcher, Eastern kingbird, white-eyed vireo, red-eyed vireo, blue jay, American crow, fish crow, purple martin, tree swallow, barn swallow, Carolina chickadee, tufted titmouse, brown-headed nuthatch, Carolina wren, wood thrush, hermit thrush, brown thrasher, Northern mockingbird, European starling, American pipit, yellow-rumped warbler, yellow-throated warbler, pine warbler, summer tanager, Eastern towhee, white-throated sparrow, northern cardinal, red-winged blackbird, and common grackle. Common amphibians found at MCAS Beaufort include slimy, dwarf, and mole salamanders; green, pinewoods, and squirrel, treefrogs; spring peeper; ornate chorus frog; Southern, Eastern spadefoot, and Eastern narrowmouth toads; and Southern leopard frog. Common reptiles found at MCAS Beaufort include turtle; green anole; Southeastern five-lined, broad head, and ground skink; Eastern glass lizard; black racer; and banded water snake. The wildlife at the Townsend Range is typical of Georgia's lower coastal plain. Common amphibians expected and/or observed include slimy, dwarf, and mole salamanders; two-toed amphiuma; greater, lesser, and dwarf siren; green, pinewoods, and squirrel treefrogs; spring pepper; ornate, least, and southern chorus frogs; southern cricket frog; oak, southern, eastern spadefoot, and eastern narrowmouth toads; bronze

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
	and southern leopard frogs; and bullfrog. The Townsend Range includes yellow-bellied slider; Florida cooter; spotted, eastern mud, striped mud, chicken, and box turtles; green anole; southeastern five-lined, broad-headed, and ground skink; southern fence, eastern, and mimic glass lizards; southern black racer; eastern and scarlet kingsnakes; yellow rat, corn, southern ringneck, eastern garter, and eastern ribbon snakes; cottonmouth; copperhead; canebrake, pigmy, and eastern diamondback rattlesnakes; glossy crayfish snake; eastern mud snake; and red-bellied and banded water snakes.
Special status species	Five rare, T/E species have been confirmed to occur on MCAS Beaufort. They include the American alligator (*Alligator mississippiensis*), the bald eagle (*Haliaeetus leucocephalus*), the wood stork (*Mycteria Americana*), and the southeastern myotis (*Myotis austroriparius*). The final is a plant species, Pondberry (*Lindera melissifolia*). There are no areas designated as critical habitat for T/E species on MCAS Beaufort. The only resident federally protected species known to occur on the Townsend Range is the flatwood salamander (*Ambystoma cingulatum*). Wood stork (*Mycteria americana*) occasionally has been observed flying over or feeding on the range but is not a resident. American alligator (*Alligator mississippiensis*) may also occur on the range but is not abundant. Flatwoods salamander was found on the range in 1994 in a seasonally inundated pond cypress depression on the northeastern edge of the target area. A second larval flatwoods salamander was found in a small borrow pit located approximately 200 ft east of Pond 1 in April 2003.

4.8. Potential Pathways and Receptors

MC accumulated in the MC loading areas could migrate to potential receptors via the following exposure pathways:

- Surface water runoff, including sediment transport during storm events discharging to surface water bodies

- Leaching to groundwater and subsequent groundwater flow with discharge to surface water

Exposure pathways considered in the REVA process include consumption of surface water and groundwater by off-range human receptors, as described in the *REVA Reference Manual* (HQMC, 2009). For groundwater, water supply wells located within the installation boundaries are considered receptor locations because the water is distributed to consumers within the installation area. Exposure pathways for off-range ecological receptors (defined in the REVA analysis as any T/E species or species of concern) also are considered, including direct consumption of surface water and direct exposure to surface water and exposure to sediment. Other off-range exposure scenarios (e.g., soil ingestion, incidental dermal contact, bioaccumulation and food chain exposure) are not considered in the REVA process. Potential receptors at the MCAS Beaufort and the Townsend Range include the following:

- T/E special concern ecological receptors, such as the flatwood salamander, which has habitat at the Townsend Range
- Human receptors (through contact and noncontact recreation) at the major streams, creek mouths, and wetlands

4.8.1. Surface Water and Sediment Pathway

Surface water runoff is a potential MC transport mechanism at both MCAS Beaufort and the Townsend Range. Both areas experience an average of approximately 50 inches of precipitation per year. The topography is relatively flat, but wetlands and creeks/drains are located throughout both ranges. Dissolved and associated MC could be transported by way of surface drainage to habitats containing ecological and human recreational receptors.

4.8.2. Groundwater Pathway

Due to the high water table and permeable soil in the MCAS Beaufort area, the surficial aquifer is recharged through local precipitation. The groundwater from the surficial aquifer then is able to recharge the Floridan aquifer where the confining layer between the two aquifers is absent. Saltwater intrusion has been documented to occur in the Floridan aquifer underlying MCAS Beaufort; therefore, the City of Beaufort and MCAS Beaufort obtain their drinking water from the Savannah River. The BJWSA provides water obtained from the Savannah River in the MCAS Beaufort area, and the authority requires connection to their system, if present. Water supply wells that were formerly used at MCAS Beaufort were closed in 2008. Therefore, the relevant groundwater receptor pathway would be the discharge of groundwater from the surficial aquifer into the surface water bodies in the area of MCAS Beaufort. Since the drinking water consumed at the base in not obtained from the underlying aquifers, the drinking water pathway is not complete and ensures no immediate to human health and the environment via this pathway.

The State of Georgia considers all groundwater to be a source of drinking water. There is a potential for future residential land use, beyond the installation boundary, that may use the surficial aquifer for drinking water. The surficial aquifer discharges locally into Snuff Box Canal and associated wetlands and currently does not serve as a drinking water source.

The Floridan aquifer is used as a drinking water source in the Townsend Range area. During the baseline, the water supply well on site was not considered a potential pathway of MC migration because of the depth (700 ft bgs) and intervening aquifers and confining units separating it from the surficial aquifer. Additionally, at the time of the baseline evaluation, bottled water was supplied because of aesthetics of the water (hydrogen sulfide odor and taste). Approximately 2 years ago, the bottled water was discontinued and drinking water at the range was provided by the water supply well when water fountains were installed in March 2007. Even though the water supply well is now used at the Townsend Range, the depth of the well screen and the presence of intervening aquifers and confining units between the surficial aquifer and the Floridan Aquifer should prevent the vertical migration of MC. There are no other known domestic wells located in the immediate vicinity of the Townsend Range. Therefore, the relevant groundwater receptor pathway would be the discharge of groundwater from the surficial aquifer into the surface water bodies in the area of the Townsend Range.

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5. Modeling Assumptions and Parameters

As part of the REVA five-year review effort, fate and transport screening-level modeling analyses were conducted at the Townsend Range for the EOD and the Smokey SAM MC loading areas. These MC loading areas were selected for quantitative transport modeling based on their current use of munitions containing HE and/or perchlorate and their proximity to potential down gradient receptor locations. Other identified MC loading areas either were estimated to have negligible MC loading or are associated with lead munitions only that are assessed qualitatively.

The purpose of the fate and transport screening-level analyses was to determine the potential for MC release in surface water, sediment, and groundwater from the identified MC loading areas. If the results of the screening-level analyses indicate a potential release of MC, additional assessments, such as sampling, would be conducted. Otherwise, no further assessment would be conducted at this time, but the identified MC loading areas would be reassessed in the next five-year review to ensure that continued loading at the sites is not impacting surface water, sediment, and groundwater. The surface water, sediment, and groundwater screening-level modeling analyses methods and assumptions are presented in this section.

5.1. Surface Water and Sediment Modeling Assumptions

The analyses of potential surface water and sediment impacts for MCAS Beaufort and the Townsend Range were conducted following the REVA process described in the *REVA Reference Manual* and the *REVA Five-Year Review Manual* (HQMC, 2009; HQMC, 2010). The initial step is a qualitative analysis of the surface water and sediment conditions based on the CSM, described in detail in **Section 4**, including the identification of potential exposure pathways, migration routes, and potential receptors (human and ecological). When these qualitative analyses indicate a potential for MC migration from MC loading areas to surface water receptors, screening-level MC transport analyses are performed to quantitatively estimate potential concentrations of indicator MC (RDX, HMX, TNT, and perchlorate) that can migrate in surface water and sediment.

Under REVA, screening-level transport analyses are used first to estimate the MC concentrations in surface water runoff and sediment at the edge of the identified MC loading areas. If these analyses predict potential impacts at the edge of the loading area, then additional calculations are performed to estimate the potential MC concentrations at a downstream receptor location. Average annual surface water and sediment concentrations of the indicator MC are estimated based on the average annual MC loading of each indicator MC to each MC loading area.

All parameters used in the screening-level analysis are provided in **Appendix A**.

The mass loading of the indicator MC on the operational ranges was estimated as described in **Section 3**. In accordance with the REVA Part I surface water and sediment screening-level methodology, the entire annual MC load was converted to an average daily loading rate. This average daily loading rate was assumed to be loaded to the ground surface soil. The screening-level analyses were conducted for the 2006–2011 time period.

A conservative, screening-level modeling approach was taken to estimate the annual average concentrations of MC in surface water runoff and sediment from the identified MC loading areas.

Results of the surface water and sediment screening-level analyses were compared to the REVA trigger values (**Table 5-1**) to evaluate the potential for MC releases to off-range receptors. The screening-level analyses methods are described briefly in the following sections. Additional details on the method are provided in the *REVA Reference Manual* and the *REVA Five-Year Review Manual* (HQMC, 2009; HQMC, 2010).

Table 5-1: REVA Trigger Values for MC

MC	Trigger Value (µg/L)	Trigger Value for Sediment (µg/kg)
RDX	0.11	32.5
TNT	0.113	25
HMX	0.114	51
Perchlorate	0.021	0.18

Note:

µg/kg – micrograms per kilogram

5.1.1. Surface Water Screening-Level Approach at MC Loading Areas

This subsection discusses the methods used in estimating MC entering surface water through (1) erosion of particulate or adsorbed MC in soil and transport in surface water runoff and (2) direct dissolution of MC in surface water runoff.

The MC at loading areas were assumed to be loaded to the ground surface soil.

5.1.1.1. Estimation of the Annual Average Munitions Constituent Concentrations Leaving MC Loading Areas

The following three calculations were carried out in order to estimate average annual MC concentrations in surface water runoff leaving MC loading areas.

Estimation of Soil Erosion

Estimates of soil erosion were required for subsequent calculation of the mass of MC transported from MC loading areas. Estimation of the soil erosion to calculate transported MC mass is especially important for MC that strongly adsorb to soil (e.g., TNT). Annual soil erosion rates were estimated using the RUSLE, which incorporates the major factors affecting erosion to predict the rate of soil loss in mass per area per year. The RUSLE is expressed as follows:

A = RKLSCP

Where: A = Predicted soil loss
R = Rainfall energy factor
K = Soil erodibility factor
LS = Topographic factor (factor influenced by length and steepness of slope)
C = Cover and management factor
P = Erosion control practice factor

These factors were estimated for the MC loading areas at MCAS Beaufort and the Townsend Range using available information, such as soil types, land use / land cover, and digital elevation data (MCAS Beaufort, 2011; USDA NRCS, 2004). **Appendix A** lists parameter values used in estimating soil erosion for the MC loading areas.

Estimation of Surface Water Runoff Rate

The annual surface water runoff rate from each loading area was estimated simply as the product of the average annual precipitation, the loading area, and a runoff coefficient. The average annual precipitation of 51 inches per year was obtained from MCAS Beaufort (2008). Runoff coefficients were selected from published tabular data based on soil hydrologic group, slope, and land cover of the MC loading areas being analyzed (McCuen, 1998) (**Appendix A**).

Estimation of MC Mass and Concentration in Surface Water Runoff

A multimedia partitioning model, CalTOX, was used to estimate the mass of MC transported from surface soil to surface water runoff. This model has the capability of simulating the major transport mechanisms that are likely to affect MC from their point of origin in surface soils to their release into surface water runoff. CalTOX was used to simulate the partitioning of MC loaded into various media (soil, air, and water) over time. The rate at which MC will partition among these media is dependent on both the chemical properties of the MC and the physical/hydrological properties of the site. CalTOX requires the input of landscape properties of the MC loading areas and chemical properties of the MC (**Appendix A**). Values of landscape and chemical properties were selected based on local reports, soil surveys, mapping information, and the scientific literature. Estimates of soil erosion and surface water runoff were calculated as described above and entered into CalTOX. An estimated recharge rate also was entered into CalTOX as one of the input parameters.

The chemical parameter values used in the model were selected as the most recent available at the time the modeling was carried out. It was noted that some of the parameter values have variability in the literature, such as MC decay rate and MC organic carbon partition coefficient (K_{oc}). In general, variability of many of the chemical parameters in the literature is not wide enough to cause significant variations in model results.

The CalTOX output of interest for the surface water analysis was the MC mass transferred from surface soil to surface water, which CalTOX expresses as an average daily load in grams per day. This daily mass transfer rate was divided by the daily runoff volume to estimate the MC concentration in surface water runoff at the edge of the MC loading area, prior to down gradient mixing/dilution in streams.

Temporal and spatial resolution of the analysis is limited by the basic input parameter, the loading rate, which is defined on an annual basis and to a fixed area. Therefore, the screening analysis inherently results in annual average concentrations.

5.1.1.2. Estimation of Munitions Constituents Concentrations Entering Snuff Box Canal at the Southern Townsend Range Boundary

MC loading areas within the Townsend Range drain to the tributary streams of Snuff Box Canal or drain directly into Snuff Box Canal itself. Snuff Box Canal flows southeasterly off the Townsend Range boundary. MC concentrations in surface water entering the identified downstream receptor location (Snuff Box Canal at the southern Townsend Range boundary) were estimated by the application of a conservative mixing calculation. The total drainage area upstream of the canal at the southern Townsend Range boundary was estimated (**Figure 5-1**). Both MC loading areas analyzed entirely drain within the delineated drainage area of Snuff Box Canal. The estimated concentrations at the edge of the MC loading areas then were multiplied by the ratio of the loading area to the total drainage area of the receptor location in Snuff Box Canal at the southern Townsend Range boundary. The down gradient, mixed MC concentrations entering the receptor location in Snuff Box Canal at the southern Townsend Range boundary were estimated as area-weighted sums of the concentrations from the individual loading areas draining to the canal:

Figure 5-1
Surface Water and Groundwater Features and MC Loading Areas Modeled

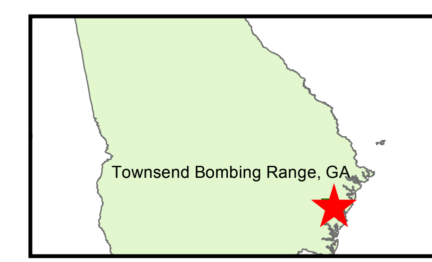
Townsend Range
Townsend, GA

Legend

- Installation Boundary
- MC Loading Area
- Snuffbox Canal Watershed
- Wetlands
- Flatwood Salamander Habitat

Stream

- Intermittent
- Perennial
- Surface Water Flow Direction
- Shallow Groundwater Flow Direction



0 550 1,100 2,200 3,300
Feet

Coordinate System: UTM
Zone: 17N
Datum: NAD83
Units: Meters

Date: October 2012

Source: MCAS Beaufort GIS

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$$C_{mixed} = [\sum (C_{runoff} \times A_{LA})] / A_{DA}$$

Where:

C_{mixed} = Concentration entering the receptor location in Snuff Box Canal at the southern Townsend Range boundary (µg/L)
C_{runoff} = Concentration in runoff from loading areas (µg/L)
A_{LA} = Area receiving MC loading (square meters [m^2])
A_{DA} = Total drainage area of receptor location (Snuff Box Canal at the southern Townsend Range boundary) (m^2)

An inherent assumption of this method is that all areas other than MC loading areas contribute runoff that has negligible MC concentrations. This provides an estimate of the potential for estimated concentrations to be reduced by mixing with other runoff prior to entry into Snuff Box Canal at the southern Townsend Range boundary. This approach conservatively assumes no reduction of MC through MC decay in surface water.

In addition to direct surface water runoff sources, shallow groundwater is a known source of baseflow to streams at the Townsend Range. MC concentrations in groundwater potentially discharging into the nearest surface water receptor location from MC loading areas were estimated in the groundwater screening-level analysis that is discussed in **Section 5.2**. From the groundwater screening-level analysis, MC concentrations that were predicted to discharge into surface water receptor locations above REVA trigger values were considered for a mixing calculation with runoff sources. The following steps were followed in the mixing calculation:

1. The MC load in groundwater from the loading area was estimated by multiplying the predicted concentration (result of the groundwater screening analysis from **Section 5.2.2.2**) with a baseflow rate of 3.52 inches per year (estimated from 46% of recharge based on study conducted by Faye and Mayer, 1990) and the loading area.
2. The mixed runoff and baseflow concentration leaving the MC loading area was estimated by dividing the total MC load leaving the MC loading area (the sum of the MC load from groundwater calculated in step 1 and MC load from runoff estimated from CalTOX) by the total volume of runoff and baseflow.

The mixed runoff and baseflow concentration from step 2 was used as the input concentration (instead of the C_{runoff}) in the downstream mixing calculation described above to estimate downstream mixed concentrations entering identified receptor location in Snuff Box Canal. In order to take a conservative approach, if the mixed runoff and baseflow concentration from step 2 was lower than the C_{runoff}, then C_{runoff} was used as the input concentration in the downstream mixing calculation.

5.1.2. Sediment Screening-Level Approach at MC Loading Areas

The CalTOX partitioning model was used to estimate MC concentrations in sediment leaving MC loading areas. The input variables used are similar to the input variables used for the surface water analysis as described in **Section 5.1.1.1**. CalTOX was used to estimate the MC mass transferred to surface water through partitioning into the soil/sediment eroding from the site and transported in storm water runoff. The MC concentrations in eroded soil/sediment leaving the MC loading areas then were estimated by dividing the MC mass in eroded soil (obtained from CalTOX) by the estimated total soil erosion (obtained from RUSLE).

If MC concentrations in sediment at the edge of the MC loading area were predicted to exceed REVA trigger values, additional screening analysis was carried out to estimate the MC concentration in sediment at a downstream receptor location in Snuff Box Canal at the southern Townsend Range boundary. This involves using RUSLE to estimate the total annual mass of sediment transported to the downstream receptor location from areas upstream of the receptor location (the total mass of sediment eroded within the drainage area of the receptor location). The sediment MC concentration at the downstream receptor location in Snuff Box Canal will be equivalent to the MC mass leaving the MC loading area divided by the total sediment mass from the drainage area transported to the downstream receptor location. The cumulative sediment MC concentration from different MC loading areas draining to the same receptor location will be equivalent to the sum of the MC mass in sediment leaving the individual MC loading areas divided by the sediment mass eroding into the receptor location as follows:

$$C_{sed,mixed} = \sum M_{MC,LA} / M_{sed,DA}$$

Where:

$C_{sed,mixed}$ = MC concentration in sediment entering receptor locations in Snuff Box Canal at the southern Townsend Range boundary (µg/kg)

$M_{MC,LA}$ = MC mass in sediment entering Snuff Box Canal at the southern Townsend Range boundary from the individual MC loading areas (micrograms per day)

$M_{sed,DA}$ = Sediment mass eroded within the drainage area to the receptor location in Snuff Box Canal at the southern Townsend Range boundary (kilograms per day)

This method conservatively assumes that 100 % of the sediment leaving the loading areas is deposited into downstream surface water (the downstream receptor location). This is a conservative approach because typical sediment yields in surface water range from 30% to 50%.

5.2. Groundwater Modeling Assumptions

The purpose of the groundwater analysis in the REVA program is to make best use of the available information to infer whether indicator MC (RDX, HMX, TNT, and perchlorate) can be transported in groundwater from MC loading areas to receptors. Both conceptual and quantitative methods are used. The initial step is a qualitative analysis of the groundwater conditions based on the CSM, described in detail in **Section 4**, including the identification of potential exposure pathways, migration routes, and potential receptors (human and ecological). When this qualitative analysis indicates there is potential for MC migration from MC loading areas to groundwater receptors, a screening-level MC transport analysis is performed to quantitatively estimate potential concentrations of indicator MC in groundwater migrating to a receptor or beyond the installation boundaries. This quantitative screening-level analysis method uses multiple conservative assumptions, is more likely to overestimate than underestimate MC concentrations, and is used to determine whether particular MC loading areas merit additional investigation. The groundwater screening-level analysis methods employed for Townsend Range follow the approach described in the *REVA Reference Manual* and the *Assessment of Models for Evaluating Fate and Transport of Munitions on Operational Ranges* and are discussed in this section (HQMC, 2009; Malcolm Pirnie, 2005).

5.2.1. Qualitative Analysis

The qualitative groundwater analysis looked at multiple data sources, which are detailed in the CSM. The following key information sources were used in the qualitative assessment:

- Military munitions expenditure data
- GIS data (MCAS Beaufort GIS data)
- Integrated Natural Resources Management Plan
- USGS topographic maps and regional groundwater resource reports
- USDA Natural Resources Conservation Service (NRCS) soil survey
- Precipitation data

The groundwater conditions, the potential for MC migration in vadose zone and saturated zones, and the presence of potential groundwater receptors at off-range locations are described in more detail in **Section 4.3**, **Section 4.5**, and **Section 4.8.2**, respectively.

5.2.2. REVA Groundwater Analysis Procedure

A screening-level fate and transport analysis of potential MC migration via groundwater was conducted as part of the vulnerability assessment for the Townsend Range. The analysis was conducted for two MC loading areas that were selected for groundwater modeling based on their current use of munitions containing HE and their proximity to a potential surface water receptor location where the shallow groundwater discharges. The modeled areas include EOD and Smokey SAM MC loading areas. The screening-level analysis was accomplished in two main steps:

1. *Initial groundwater screening analysis*: MC concentrations are estimated in the portion of the precipitation water that infiltrates to the groundwater and assumed to arrive at the groundwater at that concentration.
2. *Vadose zone modeling*: A screening-level vadose zone model was used to evaluate the potential for MC to migrate through the vadose zone to the groundwater at concentrations greater than the REVA trigger value.

An additional step involving saturated zone groundwater modeling typically is carried out as part of the screening-level analysis to assess the migration potential of MC in groundwater to potential receptor locations. The saturated zone groundwater modeling was not conducted as part of this analysis. Instead, the concentration of the MC that was predicted to reach the water table above the REVA trigger value from the vadose zone modeling (step 2 of the analysis) was used to conservatively estimate the groundwater concentration reaching the nearest surface water receptor location. This is because the nearest surface water receptor location is within the MC loading area where the MC was predicted to reach the water table at a concentration above the REVA trigger value.

The above two steps executed for the screening-level analysis are discussed in the following subsections.

5.2.2.1. Initial Groundwater Screening Analysis

The first step in analyzing groundwater transport is an initial analysis of the MC loading rate and the annual groundwater recharge rate to determine a maximum MC concentration in infiltrating water. This approach produces a highly conservative concentration because the majority of the MC (with the exception of perchlorate) is not completely soluble in water and their effective solubilities decrease when in mixtures. Further, most MC have a high rate of decay and some of the MC (TNT and RDX) can have a relatively strong affinity to the soil particles and, thus, can readily sorb to the soil from the aqueous phase. Perchlorate is the only recalcitrant (persistent) indicator MC that does not readily degrade, is miscible (completely soluble) in water, and does not sorb to solid soil particles. This analysis also assumes that there is no removal of MC in the surface water runoff or decay as a result of biotic and abiotic transformations. If this initial, highly conservative analysis indicates the potential for MC to have a concentration in the infiltrating water above the REVA trigger value (**Table 5-1**), a more detailed screening-level modeling analysis is done for that MC using the models outlined in the *REVA Reference Manual* and the *Assessment of Models for Evaluating Fate and Transport of Munitions on Operational Ranges* (HQMC, 2009; Malcolm Pirnie, 2005).

The initial groundwater analysis is performed as a spreadsheet-based mass balance calculation. The basic input data are the estimated average annual MC loading rates at the MC loading areas (presented in **Section 6**) and the estimated infiltration rate (recharge) of 0.64 feet per year (ft/yr) at the Townsend Range (Heath, 1994). The estimated recharge rate value of 0.64 ft/yr includes the estimated evapotranspiration rate, which significantly reduces recharge.

The maximum possible concentrations of MC in the infiltrating water were calculated by dividing the MC loading rates by the volume of the infiltrating water. The MC estimated to have concentrations above the REVA trigger values at MC loading areas were analyzed further for transport through the vadose zone using a screening-level vadose zone model. MC estimated to have concentrations below REVA trigger values at MC loading areas were eliminated from additional analysis.

5.2.2.2. Vadose Zone Modeling

When the results from the initial groundwater analysis (**Section 5.2.2.1**) indicate a need for further evaluation, the Environmental Protection Agency VLEACH Model was used to simulate fate and transport of MC through the unsaturated zone to the groundwater table. VLEACH is a one-dimensional finite difference vadose zone leaching model that simulates the movement of organic contaminants within and between three phases: 1) as a solute dissolved in water, 2) as a gas in the vapor phase, and 3) as an adsorbed compound in the solid phase (Ravi and Johnson, 1997). Partitioning between phases occurs according to the contaminant distribution coefficient. Vertical transport in VLEACH is simulated by advection in the liquid phase and by gaseous diffusion in the vapor phase. Since VLEACH does not include decay as a mechanism of environmental fate and transport, a post-processing step that included decay was performed on the VLEACH results. The MC decay rate was applied to the VLEACH output concentrations based on the elapsed time.

Results obtained from the initial groundwater screening analysis (**Section 5.2.2.1**) were used to simulate MC transport to the water table. RDX and perchlorate were modeled for migration through the vadose zone at the EOD and the Smokey SAM MC loading areas.

Local soils generally consist of clay loam, loam, fine sandy loam, loamy sand, and very coarse sand. The relevant physical and chemical properties of the vadose zone soils, MC, and climate that were used as input parameters to VLEACH are presented in **Appendix A**. **Figure 5-1** presents groundwater features and locations of the modeled MC loading areas.

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6. Screening-Level Assessment Results

MC loading areas, listed in **Table 6-1**, were assessed qualitatively through the development of site-specific CSMs and, if necessary, quantitatively through screening-level transport assessments. All of the MC loading areas identified during the MCAS Beaufort and the Townsend Range REVA five-year review are located within the Townsend Range. The MCAS Beaufort Pistol Range is associated only with small arms ammunition and is assessed qualitatively (presented in **Section 7**). The assessment results for the MC loading areas within the Townsend Range are presented within this section based on the hydrologic watershed area within which they are located. All the MC loading areas are located within the Snuff Box Canal watershed, which was delineated upstream of the Townsend Range boundary.

The seven MC loading areas identified in the REVA five-year review are presented in **Table 6-1**.

Table 6-1: MC Loading Areas in Snuff Box Canal Watershed

MC Loading Area	Size of MC Loading Area	
	Acres	m^2
Command Post	0.80	3,220
EOD	0.45	1,802
Heavy Weight	2.23	9,039
Helicopter Door Gunnery	5.82	23,572
Main Bull	6.05	24,468
SAM Site	0.65	2,636
Smokey SAM	304.20	1,231,068

Only the EOD and Smokey SAM MC loading areas underwent screening-level modeling during the five-year review as they are the only MC loading areas where HE or perchlorate was deposited during the five-year review period.

Section 6.1 contains discussions on the operational range areas identified, the site-specific CSM, MC deposition estimates, screening-level modeling results, and additional range information within the Snuff Box Canal watershed.

Surface Water and Sediment Analyses Summary

The screening-level analyses of MC fate and transport in surface water and sediment were conducted for two MC loading areas located within the Snuff Box Canal watershed. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing REVA indicator MC and surface drainages to a potential receptor location. Annual average MC concentrations in surface water runoff and sediment at the edge of each MC loading area were estimated. Additionally, MC concentrations in surface water (including surface water runoff and base flow contributions) entering the identified downstream receptor location (Snuff Box Canal at the Townsend Range boundary) were estimated.

MC concentrations in surface water runoff at the edge of both MC loading areas analyzed were estimated to be above REVA trigger values, while MC concentrations in sediment at the edge of both MC loading areas analyzed were estimated to be below REVA trigger values. Annual average MC concentrations in surface water (including surface water runoff and base flow contributions) entering Snuff Box Canal at the Townsend Range boundary were predicted to be below REVA trigger values. The results of the surface water and sediment screening-level analyses for the two MC loading areas are discussed in detail in **Section 6.1.2**.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for two MC loading areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing REVA indicator MC and their proximity to a potential receptor location in surface water where the shallow groundwater discharges. The initial groundwater screening-level analysis predicted MC concentrations at the MC loading areas leaching into the vadose zone above REVA trigger values. Therefore, vadose zone modeling was conducted at the MC loading areas. MC at one of the MC loading areas modeled was predicted to reach the groundwater at a concentration above the REVA trigger value. The groundwater contribution of this MC was used as one of several input sources for the surface water screening-level analysis that evaluated MC concentration in Snuff Box Canal at the Townsend Range boundary. The results of the groundwater screening-level analysis for the two MC loading areas are discussed in detail in **Section 6.1.3**.

6.1. Snuff Box Canal Watershed

The Snuff Box Canal watershed is located throughout almost the entire area of the Townsend Range; it is approximately 5,787 acres and includes the entire area in which targets are located at the range (**Figure 6-1**). The watershed area encompasses the upper portions of the Snuff Box Canal and its tributary streams. The canal itself flows perennially. With the exception of the tributary stream that enters the canal south of the Smokey Sam MC loading area, all tributary streams are non-perennial. All seven MC loading areas where the majority of MC deposition is anticipated to occur are listed in **Table 6-2**.

Table 6-2: MC Loading Areas in the Snuff Box Canal Watershed

MC Loading Area	Size (acres)
Command Post	0.80
EOD	0.45
Heavy Weight	2.23
Helicopter Door Gunnery	5.82
Main Bull	6.05
SAM Site	0.65
Smokey SAM	304.20

Military Munitions

Military munitions authorized for use within the MC loading areas located in the Snuff Box Canal watershed are listed in **Table 3-1**.

6.1.1. Conceptual Site Model

6.1.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the Snuff Box Canal watershed are shown in **Figure 6-1**. The boundaries of each MC loading area were selected based on training-specific information (e.g., operational range boundaries, target locations, personnel interviews, GIS data), which does not necessarily capture the complete potential spatial distribution of MC loading.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within this MC loading area over time (**Table 6-3**); the assumptions used to guide the estimates are detailed in **Section 3**. Since some of the MC loading areas have been altered since the baseline and others were not assessed during the five-year review, MC loading calculations for all of the MC loading areas within the Townsend Range were aggregated so that a generalized comparison of the baseline and five-year review MC loading rates could be conducted. Based on this overall comparison in **Table 6-3**, the MC loading rates calculated for the five-year review are lower than the rates calculated during the baseline assessment.

Notably, estimated perchlorate decreased by five orders of magnitude across the MC loading areas in this watershed. The baseline evaluation conducted at the Townsend Range identified perchlorate as a significant contributor to MC loading rates. Upon review of the baseline report and comparison to the findings of the five-year review, it was noted that overly conservative assumptions were used for the baseline assessment due to a lack of specific munitions information. In the absence of actual DoDIC information, the baseline team selected rocket motors that contained a large amount of perchlorate. The new, more detailed information obtained from Townsend Range personnel in the five-year review indicates that the baseline conservative assumption no longer serves as the best estimation for munitions loading. A different DoDIC was selected based on the description of munitions use and additional MIDAS data. This resulted in a significant decrease in perchlorate loading for the five-year review period in comparison to the baseline.

Estimated RDX loading decreased by three orders of magnitude, and estimated TNT loading was found to no longer be occurring at the Townsend Range during the five-year review based on the available expenditure data and information provided by personnel interviews. Similar to the baseline results, no HMX loading occurred during the five-year review period. The most concentrated MC loading in the watershed during the review period is RDX at the EOD MC loading area with an estimated loading rate of 7.50E-06 kg/m^2. Calculations also indicate that perchlorate is the MC with the highest aggregate loading rate during the five-year review period with an estimated rate of 1.83E-07 kg/m^2, as seen in **Table 6-3**.

Annual lead deposition for the MC loading areas in the Snuff Box Canal watershed was estimated during this five-year review (**Table 6-4**). The baseline assessment did not include lead loading estimates. Calculations indicate the Helicopter Door Gunnery MC loading area has the most significant lead deposition rates estimated at 6.35E+02 lb of lead annually. Based on the sampling conducted in 2010, lead and copper are accumulating in the surface soils, but vertical migration is being restricted by a clay unit at 1.5 ft bgs.

FIGURE 6-1
MC LOADING AREAS WITHIN
THE SNUFF BOX CANAL WATERSHED

TOWNSEND BOMBING RANGE
TOWNSEND, GA

Legend

Stream

- Intermittent
- Perennial
- MC Loading Area
- Townsend Range Boundary
- Snuff Box Canal Watershed

SOURCE: MCAS GIS, 2010

0 750 1,500 3,000
Feet

Date: October 2012

ARCADIS MALCOLM PIRNIE

Table 6-3: Estimated MC Loading Rates for the Snuff Box Canal Watershed

Assessment	MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)			
			HMX	RDX	TNT	Perchlorate
Baseline (Period E 1989–2005)	Target #1: Main Bull (Conventional Circle)	1.79E+04	0.00E+00	8.33E-05	2.14E-05	1.60E-02
	Target #2: SAM Site	2.92E+03	0.00E+00	7.86E-06	4.06E-06	2.68E-07
	Scud Site	2.92E+03	0.00E+00	7.86E-06	4.06E-06	2.68E-07
	Target #3: Command Post (Control Tower)	2.92E+03	0.00E+00	7.86E-06	4.06E-06	2.68E-07
	Target #4: Heavy Weight Target	1.29E+04	0.00E+00	1.15E-04	2.96E-05	2.20E-02
	POL Target	2.92E+03	0.00E+00	7.86E-06	4.06E-06	2.68E-07
	Smokey SAM Site	2.22E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total Estimated Loading (Period E)	**4.54E+04**	**0.00E+00**	**6.75E-05**	**1.79E-05**	**1.26E-02**
Five-Year Review (Period F 2006–2011)	Command Post	3.22E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	EOD	1.80E+03	0.00E+00	7.50E-06	0.00E+00	0.00E+00
	Heavy Weight	9.04E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Helicopter Door Gunnery	2.36E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Main Bull	2.45E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	SAM Site	2.64E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Assessment	MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)			
			HMX	RDX	TNT	Perchlorate
	Smokey SAM	1.23E+05*	0.00E+00	0.00E+00	0.00E+00	2.80E-07
	Total Estimated Loading (Period F)	**1.88E+05**	**0.00E+00**	**7.20E-08**	**0.00E+00**	**1.83E-07**

Note:

Estimated baseline MC loading rates are based on Period E values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping. Five-year review values cover 2006 to 2011.

* To maintain conservative MC loading calculations, only 10% of the total surface area of this MC loading area was used in the loading process.

Table 6-4: Estimated Annual Lead Deposition for the Snuff Box Canal Watershed

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
Command Post	3,220	4.73E-05	8.72E-05	3.36E-01
EOD	1,802	1.26E-09	2.32E-09	5.00E-06
Heavy Weight	9,039	1.69E-05	3.11E-05	3.36E-01
Helicopter Door Gunnery	23,572	1.22E-02	2.25E-02	6.35E+02
Main Bull	24,468	6.23E-06	1.15E-05	3.36E-01
SAM Site	2,636	5.78E-05	1.07E-04	3.36E-01
Smokey SAM	123,107*	3.98E-10	7.34E-10	1.08E-04

Total Estimated Lead Loading (Period F)	**187,844**	**1.54E-03**	**2.83E-03**	**6.36E+02**

Note:
lb/yd^2 – pounds per square yard
*To maintain conservative MC loading calculations, only 10% of the total surface area of this MC loading area was used in the loading process.

6.1.1.2. Geography and Topography

The Snuff Box Canal watershed lies within the Lower Coastal Plain, and the area is predominantly low and flat. The topography of the area generally slopes gently from north to south. Available contour data indicate the elevation of the watershed area ranges from approximately 15 ft above msl at a point in the southwestern part of the Smokey SAM MC loading area to approximately 28 ft above msl in the part of the watershed approximately 3,700 ft north of the northern Townsend Range boundary (MCAS Beaufort, 2011). Based on available spatial data, the slope within the installation boundary of the watershed area can range from nearly level to approximately 30%; however, the majority of the watershed area has slope ranging from nearly level to approximately 3% (MCAS Beaufort, 2011).

6.1.1.3. Surface Water Features

The Snuff Box Canal watershed includes Snuff Box Canal, its unnamed tributary streams, and wetlands associated with the canal. With the exception of the tributary stream that flows to the canal south of the MC loading area, all tributary streams are non-perennial. The Snuff Box Canal originates approximately 4,200 ft north of the Townsend Range boundary and flows southeasterly through the range and off the southern range boundary into Cathead Creek and, ultimately, the Darien River. Tributaries of the Snuff Box Canal flow west, southwest, and southeast into the canal. All of the identified MC loading areas (Command Post, EOD, Heavy Weight, Helicopter Door Gunnery, Main Bull, SAM Site, and Smokey SAM) drain within the Snuff Box Canal watershed.

Table 6-5 describes the drainage characteristics of the seven MC loading areas within the Snuff Box Canal watershed.

Table 6-5: Drainage Description for the MC Loading Areas within the Snuff Box Canal Watershed

MC Loading Area	Drainage Description
Command Post	There are no surface water features within the MC loading area. Snuff Box Canal, which is the closest stream, flows southerly approximately 1,500 ft west of the MC loading area.

MC Loading Area	Drainage Description
EOD	There are no surface water features within the MC loading area. Snuff Box Canal, which is the closest stream, flows southerly approximately 2,100 ft west of the MC loading area.
Heavy Weight	There are no surface water features within the MC loading area. Snuff Box Canal, which is the closest stream, flows southerly approximately 2,100 ft west of the MC loading area.
Helicopter Door Gunnery	There are no surface water features within the MC loading area. The closest tributary stream flows westerly to Snuff Box Canal approximately 740 ft northwest of the MC loading area.
Main Bull	There are no surface water features within the MC loading area. A perennial tributary stream flows southwesterly to Snuff Box Canal approximately 2,600 ft east of the MC loading area, and Snuff Box Canal flows southeasterly approximately 2,500 ft west of the MC loading area.
SAM Site	There are no surface water features within the MC loading area. The closest tributary stream flows westerly to Snuff Box Canal approximately 1,700 ft north of the MC loading area.
Smokey SAM	The MC loading area is close to a tributary stream on the north, Snuff Box Canal on the west, and another tributary stream on the east and south of the area that flows perennially. The perennial unnamed tributary stream flows partially within the MC loading area; it flows southwesterly within the southeastern tip of the MC loading area to Snuff Box Canal.

6.1.1.4. Soil Characteristics and Land Cover

The USDA Natural Resources Conservation Service has not mapped in detail the soil types within a majority of the Snuff Box Canal watershed area inside the Townsend Range boundary. However, soils on the Townsend Range can be categorized as belonging to the Weston-Bayboro-Bladen-Coxville association (USDA, 1961). These soils comprise clay loam, loam, fine sandy loam, loamy fine sand, loamy sand, and very coarse sand. The soils are poorly to very poorly drained with an acidic pH ranging from 4 to 6. The Bladen-Coxville soil complex, which comprises 75% of the Weston-Bayboro-Bladen-Coxville association, consists of a gray to black surface layer over a mottled, structures clay layer (MCAS Beaufort, 2001b). Bladen-Coxville soils have slow to very slow permeability and can generally be found to a depth of 57 inches below the soil surface. Weston and Bayboro soils are very poorly drained and consist of a black, mucky surface layer over gray, plastic-like clay that is mottled in places; these soils account for approximately 15% of the Weston-Bayboro-Bladen-Coxville association. The Weston and Bayboro soils are very acidic and are classified as hydria soils; they occur primarily where the level of groundwater fluctuates but is generally very high. These soils are generally found in wetlands. The soils have a relatively low soil erodibility factor of 0.18 and relatively low runoff potential (hydrologic soil group B) (USDA NRCS, 2004).

Based on the measured soil organic carbon content at nine sample locations in the northwestern area of the Smokey SAM MC loading area, the soil organic carbon content ranged from 0.63% to 6.5% and had an average value of 4.1%.

The area within the Snuff Box Canal watershed outside of the identified MC loading areas is covered with dense vegetation. The vegetation can consist of pine forest, native and non-native grass, sedges and wetlands dominated by trees, shrubs, and persistent emergent herbaceous plants (MCAS Beaufort, 2001b). The identified MC loading areas are either unvegetated or sparsely vegetated (MCAS Beaufort, 2011).

6.1.1.5. Erosion Potential

Based on the overall site characteristics, as quantified in the RUSLE, the estimated soil erosion potential of the EOD and the Smokey SAM MC loading areas analyzed within the Snuff Box Canal watershed were low and moderate. The estimated low soil erosion potential at the EOD MC loading area is attributable to the flat topography and low inherent soil erodibility factor. The moderate soil erosion potential estimated at the Smokey SAM MC loading area is attributable to the slight slope, sparse vegetation, and the high rainfall and runoff factor common to the area.

6.1.1.6. Groundwater Characteristics

The major aquifers and confining units underlying the Snuff Box Canal watershed within the Townsend Range boundary are discussed in **Section 4.5**. The surficial aquifer consists of interbedded sand, clay, and thin limestone beds of Miocene and younger age and is divided into three zones (the unconfined water table zone and upper and lower confined water-bearing zones). This aquifer is recharged from rainfall and is the source of recharge to underlying confined aquifers as well as the source baseflow to streams. The Lower Brunswick aquifer that underlies the surficial aquifer is confined by the Coosawhatchie Formation. This aquifer is estimated to have a thickness of 50 ft at the Townsend Range. The upper Floridan aquifer underlies the Lower Brunswick aquifer, and this aquifer is confined by the Lazaretto Creek Formation. The upper Floridan aquifer is the principal source of groundwater supply in Georgia and is where the Townsend Range supply well draws water from at a depth of 700 feet bgs. The water table at the Townsend Range often can be found at or near land surface, but the average depth to water at the Townsend Range is approximately 3 ft bgs (Malcolm Pirnie, 2008).

6.1.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Snuff Box Canal watershed. Runoff coefficients at the EOD and the Smokey SAM MC loading areas were estimated to be 0.34 (**Appendix A**). Although the MC loading areas have flat topographies and have soil types that have fairly low runoff potential (soil hydrologic group B), the unvegetated and sparsely vegetated land covers at the MC loading areas resulted in the moderate runoff potential value estimated at the MC loading areas.

As indicated in **Section 6.1.1.5**, the EOD and the Smokey SAM MC loading areas within the watershed have low and moderate soil erosion potential. The moderate soil erosion potential at the Smokey SAM MC loading area can indicate that land surface erosion is an important mechanism for MC mobilization into surface water runoff. MC transported through surface water runoff and sediment from the MC loading areas could reach the surface water receptor location Snuff Box Canal at the installation boundary. Surface water runoff from the EOD MC loading area drains west and southwest into Snuff Box Canal. Surface water runoff from the Smokey SAM MC loading area drains north or south into tributary streams or west into Snuff Box Canal. The unnamed tributary streams receiving drainage from the Smokey SAM MC loading area drain westward and southwestward into Snuff Box Canal.

Groundwater Pathways

MC at MC loading areas within the Snuff Box Canal watershed may migrate to the surficial aquifer via infiltration of rainwater. Water levels in the surficial aquifer are assumed to follow ground surface elevations. As a result, the potential shallow groundwater pathway at MC loading areas is toward the tributary streams of Snuff Box Canal and toward Snuff Box Canal itself (**Figure 5-1**). Deeper groundwater, in the upper Floridan aquifer, generally flows toward the drinking water supply well located at the southeastern boundary of the Smokey SAM MC loading area. MC pathway through connection between the surficial and the upper Floridan aquifers is highly unlikely because of the presence of several continuous thick confining units between the aquifers.

6.1.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

Snuff Box Canal flows off the Townsend Range boundary, and the sediments within the water potentially support federally and state protected ecological species, including mammals, birds, fish, reptiles, amphibians, and plants outside of the range boundary (Malcolm Pirnie, 2008). Additionally, sensitive wetland habitats are present adjacent to streams within the Snuff Box Canal watershed. Surface water is not a drinking water source down gradient of the Townsend Range, and a human exposure pathway has not been identified for water and sediment within the Snuff Box Canal watershed.

Groundwater Receptors

The groundwater in the upper Floridan aquifer is used for drinking water at the Townsend Range; however, the upper Floridan aquifer is overlain by multiple continuous thick confining units and there is likely no significant groundwater pathway between the surficial and the upper Floridan aquifers. Therefore, the drinking water pathway was eliminated. Potential receptors in surface water features where shallow groundwater from the surficial aquifer discharges include federally and state protected ecological species and sensitive wetland habitats (as discussed in the surface water and sediment receptors section above).

6.1.2. Surface Water and Sediment Screening-Level Assessment Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from the EOD and the Smokey SAM MC loading areas, which drain to Snuff Box Canal at the southern Townsend Range boundary. The EOD and the Smokey SAM MC loading areas were selected for quantitative transport analysis based of their current use of munitions containing HE and/or perchlorate and surface drainages that lead to the potential receptor location in Snuff Box Canal at the southern Townsend Range boundary. Other identified MC loading areas within the Snuff Box Canal watershed (Command Post, Heavy Weight, Helicopter Door Gunnery, Main Bull, and SAM Site) were not included in the screening-level analysis because these MC loading areas were estimated to have negligible MC loading.

The EOD MC loading area was modeled for RDX transport, and the Smokey SAM MC loading area MC loading area was modeled for perchlorate transport. Other MC (HMX, TNT, and perchlorate at the EOD MC loading area and HMX, TNT, and RDX at the Smokey SAM MC loading area) were estimated to have negligible MC loading rates (**Table 6-3**). The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**, respectively.

The surface water and sediment screening-level analyses were conducted for the time period matching the estimated MC loading period (2006–2011 [Period F]). The EOD and the Smokey SAM MC loading areas drain to Snuff Box Canal at the southern Townsend Range boundary. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Snuff Box Canal watershed.

It is important to note that even though the EOD MC loading area is contained within the Smokey SAM MC loading area, the two areas were considered as separate, individual areas for the purpose of developing the loading estimates and conducting the screening-level analysis. The loading within the Smokey SAM MC loading area was assumed to occur in 10% of the surface area of the range (as discussed in **Section 3.2.2**). As a result, only 10% of the loading area was used in the screening-level analysis. This assumption leads to conservative estimates of MC in surface water runoff and sediment leaving the MC loading area (edge of loading area concentration) as the MC loaded are concentrated in runoff and eroded sediment within a much smaller area. However, this assumption does not impact the estimated concentrations entering into the Snuff Box Canal at the Townsend Range boundary.

All of the RDX mass within the Snuff Box Canal watershed is contributed by the EOD MC loading area, and all of the perchlorate mass within the Snuff Box Canal watershed area is contributed by the Smokey SAM MC loading area. **Table 6-6** presents the estimated annual average edge-of-loading-area concentrations in surface water runoff from the EOD and the Smokey SAM MC loading areas draining within the Snuff Box Canal watershed. Based on the screening-level calculations, concentrations of RDX and perchlorate were predicted to exceed the REVA trigger values at the edge of the EOD and the Smokey SAM MC loading areas, respectively, modeled within the Snuff Box Canal watershed.

Table 6-6: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Snuff Box Canal Watershed

MC Loading Area	Estimated MC Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
EOD	N/A	**6.10**	N/A	N/A
Smokey SAM	N/A	N/A	N/A	**0.195**
REVA Trigger Value for Water	0.114	0.110	0.113	0.021

Note:
N/A – not modeled because the MC loading rate was estimated to be negligible
Shading and bold indicate concentration exceeds the REVA trigger value.

Additional analysis was conducted to estimate the annual average MC concentrations in surface water (including surface water runoff and base flow contributions) entering Snuff Box Canal at the southern Townsend Range boundary (as described in **Section 5.1.1.2**). The average annual concentrations of RDX and perchlorate in surface water (including surface water runoff and base flow contributions) entering Snuff Box Canal at the southern Townsend Range boundary were predicted to be below REVA trigger values (**Table 6-7**).

Table 6-7: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water (including surface water and base flow contributions) Entering Snuff Box Canal at the Southern Townsend Range Boundary

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	N/A

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
RDX	0.110	~0
TNT	0.113	N/A
Perchlorate	0.021	0.002

Note:
N/A – not modeled because the MC loading rate was estimated to be negligible

Table 6-8 presents the estimated annual average edge-of-loading-area concentrations in sediment from the EOD and the Smokey SAM MC loading areas draining within the Snuff Box Canal watershed. Based on the screening-level calculations, the average annual concentrations of MC in sediment at the edge of the EOD and the Smokey SAM MC loading areas were predicted to be below REVA trigger values (**Table 6-8**).

Table 6-8: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Snuff Box Canal Watershed

MC Loading Area	MC Concentration (µg/kg)			
	HMX	RDX	TNT	Perchlorate
EOD	N/A	1.93	N/A	N/A
Smokey SAM	N/A	N/A	N/A	~0
REVA Trigger Value for Sediment	51	32.5	25	0.18

Note:
N/A – not modeled because the MC loading rate was estimated to be negligible

Based on the surface water and sediment screening-level analyses results, no additional assessment is required at this time for the MC loading areas identified within the Snuff Box Canal watershed. However, additional actions such as field monitoring for MC in surface water at the edge of Townsend Bombing Range property may be conducted as necessary in the future.

6.1.3. Groundwater Analysis Results

The screening-level analysis was conducted for the EOD and the Smokey SAM MC loading areas, which were selected for quantitative transport modeling based on their current use of munitions containing HE and their proximity to a potential ecological receptor location in surface water where the shallow groundwater discharges. RDX was evaluated at the EOD MC loading area, and perchlorate was evaluated at the Smokey SAM MC loading area. Similar to the surface water and sediment screening analysis (**Section 6.1.2**), the EOD and the Smokey SAM MC loading areas were considered as separate, individual areas for the purpose of conducting the screening-level analysis. Also, only 10% of the Smokey SAM MC loading area was used in the screening-level analysis. This assumption leads to conservative estimates of MC in the infiltrating water at the MC loading area as the MC loaded are concentrated in groundwater infiltration within a much smaller area.

The initial step of the Part I groundwater screening-level analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the EOD and the Smokey SAM MC loading areas assessed within the Snuff Box Canal watershed. In doing this, the estimated MC loading rates (**Table 6-3**) were divided by a recharge rate of 0.64 ft/yr estimated for the Townsend Range based on land cover at the MC loading areas (Heath, 1994; MCAS Beaufort, 2011). **Table 6-9** shows the estimated MC concentrations in infiltrating water at the EOD and the Smokey SAM MC loading areas. Concentrations of RDX at the EOD MC loading area and perchlorate at the Smokey SAM MC loading area were estimated to exceed respective REVA trigger values. As a result, these two constituents were modeled for migration through the vadose zone at the EOD and Smokey SAM MC loading areas.

Table 6-9: Estimated Maximum MC Concentrations in Infiltrating Water at the EOD and the Smokey SAM MC Loading Areas within the Snuff Box Canal Watershed

MC Loading Area	Estimated Maximum Infiltration Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
EOD	N/A	**38.6**	N/A	N/A
Smokey SAM	N/A	N/A	N/A	**1.44**
REVA Trigger Value for Water	0.114	0.110	0.113	0.021

Note:
N/A – not modeled because the MC loading rate was estimated to be negligible
Shading and bold indicate concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model with a post-processing step that included decay. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Appendix A**. The model was run for a simulation time of 200 years.

Modeling results including decay are presented in **Table 6-10** for comparison. Based on the estimated infiltration rate of 0.64 ft/yr and a depth to groundwater of approximately 3 ft bgs, the minimum travel time for MC to reach the water table at concentrations equal to the respective MC trigger value is less than 1 year. When decay is included, RDX from the EOD MC loading area is predicted to degrade to a concentration below the REVA trigger value before reaching the water table. The perchlorate concentration at the Smokey SAM MC loading area is estimated to exceed the REVA trigger at a travel time of less than 1 year (**Figure 6-2**). The perchlorate concentration is estimated to reach a steady-state concentration of 1.44 µg/L, which exceeds its REVA trigger value of 0.021 µg/L.

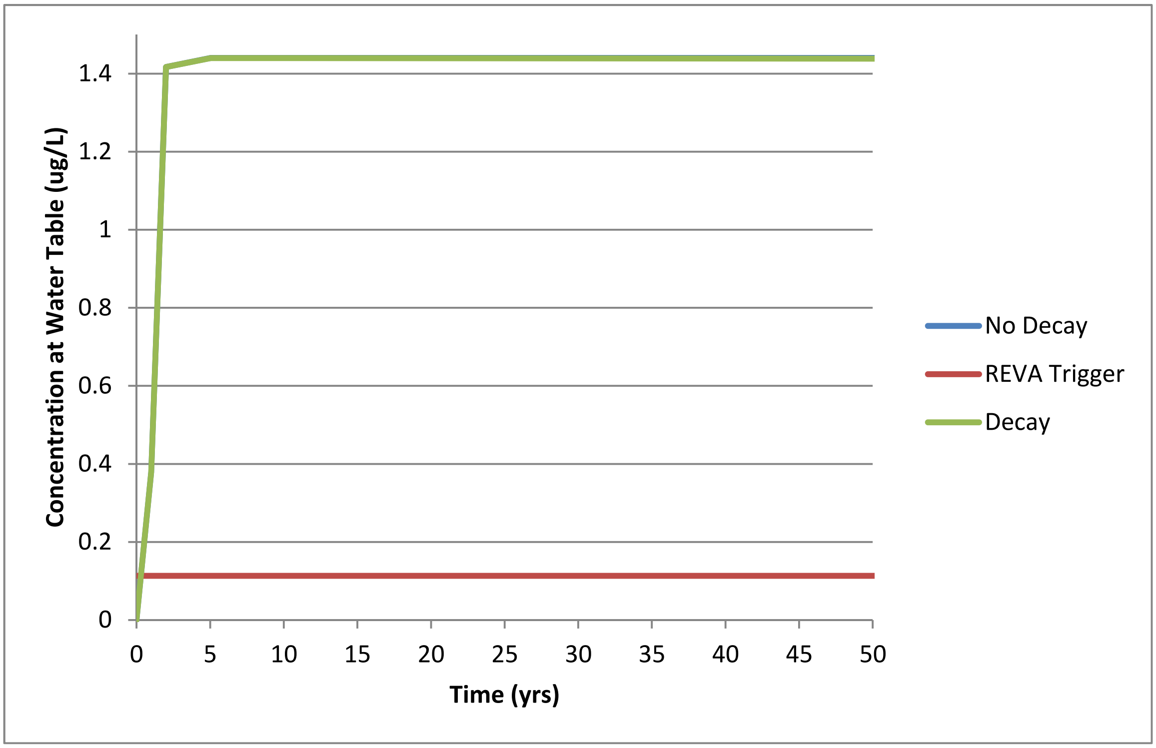
Table 6-10: Estimated MC Concentrations Reaching the Water Table at the EOD and the Smokey SAM MC Loading Areas within the Snuff Box Canal Watershed

MC Loading Area	MC	REVA Trigger Value (µg/L)	VLEACH (No Decay)		VLEACH (Decay)	
			Steady-State Concentration at Water Table (µg/L)	Time to Exceed Trigger Value (yr)	Steady-State Concentration at Water Table (µg/L)	Time to Exceed Trigger Value (yr)
EOD	RDX	0.110	**38.6**	~ 0.5	~0	--
Smokey SAM	Perchlorate	0.021	**1.44**	< 1	**1.44**	< 1

Note:
yr – years
-- denotes that the MC degrades before reaching the water table.
Shading and bold indicate concentration exceeds the REVA trigger value

Because the tributary stream of Snuff Box Canal flows within the Smokey SAM MC loading area (**Figure 5-1** and **Figure 6-1**), it was conservatively assumed that the perchlorate concentration reaching the water table at the MC loading area would discharge directly into the tributary stream. As a result, additional saturated zone modeling with BIOCHLOR was not conducted. Instead, the output from the vadose zone modeling was used as an input to the surface water screening-level analysis that evaluated MC concentration in Snuff Box Canal at the Townsend Range boundary, taking into account MC contributions from surface water runoff and base flow sources (**Section 6.1.2**). The resulting concentrations are presented in **Table 6-7**.

Figure 6-2: VLEACH Vadose Zone Model Perchlorate Result for the Smokey SAM MC Loading Area



7. Small Arms Range Assessment

The REVA indicator MC for SARs is lead because it is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. As described in previous sections, fate and transport parameters for lead at SARs are dependent on site-specific geochemical properties, which cannot be determined solely by physical observation. Therefore, ranges that solely use small arms ammunition (defined as nonexplosive ammunition, .50-caliber or smaller) for training purposes are qualitatively assessed under the REVA program. Ranges that perform joint small arms and live-fire training with HE munitions are not assessed through this process; rather, they are assessed through the MC loading estimation and modeling processes previously described. Only operational SARs are addressed in this protocol; historical use SARs that are no longer used are not assessed due to lack of information to adequately perform an assessment.

The SARAP was developed as a qualitative approach to identify and assess factors that influence the potential for lead to migrate from an operational range. These factors include the following:

- Range design and layout, including any best management practices
- Physical and chemical characteristics of the area
- Past and present operation and maintenance practices

In addition, potential receptors and pathways are identified relative to the SAR being assessed. The potential for an identified receptor to be impacted by MC migration through an identified pathway is evaluated.

7.1. Summary of the Small Arms Range Assessment Protocol

The SARAP produces two scores: the sum of surface water elements and the sum of groundwater elements. These determine the overall rankings for surface water and groundwater conditions. The scoring system assigns minimal, moderate, and high values for each category:

- Minimal (0 to 29 points) – SAR has minimal or no potential for lead migration to a receptor, but actions may be necessary to ensure that continuing training activity at the range does not pose a future threat to human health and the environment.
- Moderate (30 to 49 points) – The SAR may have the potential for lead migration to a receptor, most likely indicating no immediate threat to human health and the environment, but actions may be necessary to mitigate future concerns.

- High (50 to 65 points) – The SAR most likely has the potential for lead migration to an identified receptor and requires additional action(s).

Additional documentation describing the purpose, requirements, and supporting drivers for the performance of the SAR assessment is provided with the range-specific assessment in **Appendix B**, which contains the assessment of the single operational SAR identified during this five-year review located at MCAS Beaufort. Where warranted, key range-specific considerations not captured by the SARAP were taken into account during the assessment, and rankings were modified accordingly.

The location of the range is shown in **Figure 7-1**. **Table 7-1** provides a summary of the assessment of the SAR at MCAS Beaufort. These results are discussed in **Section 7.2**.

Table 7-1: Summary of SAR Prioritizations

Range Name	Range Type	Surface Water Score	Groundwater Score
Pistol Range	Known distance pistol range	Moderate	Moderate

As discussed in **Section 3.2.1**, estimation of average annual lead loading at this SAR was based upon 2 fiscal years of expenditure data (FY10 to FY11); key assumptions are discussed in that section.

7.2. Pistol Range at MCAS Beaufort

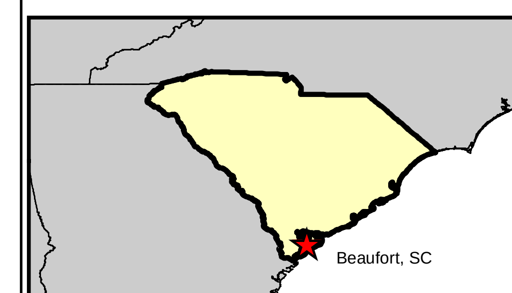
7.2.1. Site Background

As previously mentioned, the only operational SAR identified during the five-year review of MCAS Beaufort and the Townsend Range is the Pistol Range located at MCAS Beaufort, as shown in **Figure 7-1**. The Pistol Range is located in the northeastern portion of MCAS Beaufort near the historical use Boresight Range. It is equipped with 12 firing points, an overhead track system for suspending targets, two 15ft concrete side walls on each side of the range, five rows of overhead baffles, a ballistic canopy directly above the firing line, and an earthen berm that is approximately 17 ft tall with an approximate slope of 2:1. The concrete side walls have two 3-inch openings on each side to allow water to drain from the range to the north and south.

This range has been operational since 1959 and was refurbished in 2003. According to the range safety officer, the Pistol Range is mined for lead on an as-needed basis, which typically equates to once every 5 to 6 years depending on the usage. The most recent such event occurred in 2010 and included a reconstruction of the slope of the berm from 1.5:1 to 2:1. During the five-year review period, this range had a lead loading rate of approximately 3,598 lb/year based on

FIGURE 7-1
MCAS BEAUFORT PISTOL RANGE

MCAS BEAUFORT
BEAUFORT, SC



SOURCE: MCAS GIS, 2010

0 60 120 240
Feet

Date: October 2012

ARCADIS MALCOLM PIRNIE

the available expenditure data. Firing on the newly constructed berm commenced at the start of FY11.

7.2.2. Assessment Results

The surface water and groundwater rankings both resulted in Moderate scores (30 points for surface water and 45 points for groundwater). The primary drivers in the baseline and five year review rankings include the significant lead loading at the range, high precipitation levels recorded by MCAS Beaufort, shallow groundwater (less than 20 ft bgs), and pH less than 6.5 in the soil and groundwater. The surface water ranking increased from minimal to moderate. The change to moderate was by one scoring point and can be attributed to the range use duration. The baseline assessment based the range use after the refurbishment in 2003 whereas the five-year review assessment conservatively used 1959, the date the range opened. The groundwater ranking remained the same (moderate) as the baseline.

Additional site-specific data used to complete the qualitative evaluations of the SAR are provided in the site-specific SARAP in **Appendix B**

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Appendix A

Screening-Level Analysis Parameters

Table A-1: Climate Data used in the CalTOX Model

Data Type	Value	Reference(s)
Annual Average Precipitation (in/yr)	51	MCAS Beaufort, 2008
Recharge Rate for SW transport (% ppt)[a]	15	Heath, 1994
Annual Average Wind Speed (mph)[b]	8	NOAA, 1998
Annual Average Ambient Environmental Temperature (^{0}F)	70	MCAS Beaufort, 2008

Note:

in/yr = inches per year

% ppt = percent precipitation

mph = miles per hour

^{0}F = degrees Fahrenheit

[a] Conservatively assumed based on values for the Coastal Plain area and land cover of the loading areas

[b] Average wind speed at Savannah, GA that is approximately 60 miles south of Townsend Range

Table A-2: Soil Types and Hydrologic Properties at Identified MC Loading Areas

MC Loading Area	Land Cover[a]	Slope (%)[b]	Predominant Soil Type Name and Map Symbol[b,c]	Soil Description[c]	Soil Water Content[d]	Soil Air Content[e]	Hydrologic Soil Group[c]	Soil Organic Carbon Content (%)[f]	Soil Bulk Density (kg/m^3)[c]	Runoff Coefficient[g]
EOD	Unvegetated	< 1	Bayborow clay loam (BhA), Bladen loam and clay loam (BjA), Bladen-Coxville fine sandy loam (BkA), Weston loamy fine sand (Wes), Weston very coarse sand (Wet), Weston loamy sand, thick surface (Wst)	Clay loam, loam, fine sandy loam, loamy fine sand, loamy sand, and very coarse sand	0.24	0.18	B	4.1	1422	0.34
Smokey SAM	Sparsely vegetated	1.3	Bayborow clay loam (BhA), Bladen loam and clay loam (BjA), Bladen-Coxville fine sandy loam (BkA), Weston loamy fine sand (Wes), Weston very coarse sand (Wet), Weston loamy sand, thick surface (Wst)	Clay loam, loam, fine sandy loam, loamy fine sand, loamy sand, and very coarse sand	0.24	0.18	B	4.1	1422	0.34

Note:

kg/m^3 = kilograms per cubic meter

[a] Spatial data (MCAS Beaufort, 2011)

[b] Soil survey was not completed for areas near the MC loading areas within the Townsend Range; the soil map symbols listed apply to the general area within Townsend Range

[c] USDA NRCS, 2004

[d] Estimated field capacity value for soil types (Fetter, 1994)

[e] Estimated from soil porosity (McWhorter and Sunada, 1997) and water content (Fetter, 1994)

[f] Average measured value near MC loading areas (Malcolm Pirnie, 2010)

[g] Selected from reference (McCuen, 1998) based on slope soil type and land cover

Table A-3: Parameter Values used to Estimate Soil Erosion

MC Loading Area/Watershed Area	Area (m^2)	R[a]	K[b]	LS[c]	C[d]	P[e]	A ($kg/m^2/d$)
EOD	1,802	300	0.18	0.12	0.37	1	1.65E-03
Smokey SAM	123,107	300	0.18	1.59	0.37	1	2.19E-02

A = predicted soil loss
C = cover and management factor
K = soil erodibility factor
$kg/m^2/d$= kilogram per cubic meter per day
LS = topographic factor (influence of length and steepness of slope)
P = erosion control practice factor
R = rainfall and runoff factor

[a] Brady, 1984
[b] USDA NRCS, 2004
[c] Slope length and gradient were used to select LS (USDA ARS, 1997).
[d] Estimated based on vegetation cover (USDA ARS, 1997)
[e] Factor selected based on conservative assumption

Table A-4: Chemical Properties of TNT

Installation name:	MCAS Beaufort Townsend Range
Date:	July, 2012
Munitions Constituent:	TNT

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result	Units	Necessary Actions / Data Gaps
1	Molecular weight	Molecular weight of TNT	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	227.1	g/mol	
2	Solubility	Water solubility of TNT	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum: Average: 5.72E-01 Maximum:	mol/m^3	
3	Vapor pressure	Vapor pressure of TNT	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum: Average: 1.47E-04 Maximum:	Pa	
4	Henry's law constant	Henry's law constant of TNT	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum: Average: 1.10E-08 Maximum:	atm-m^3/mol	
5	Kow	Octanol-water partition coefficient for TNT			HQMC, 2009	Minimum: Average: 72.4 Maximum:	unitless	
6	Koc	Organic carbon partition coefficient for TNT	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum: Average: 525 Maximum:	mL/g	
7	K_D	Equilibrium distribution coefficient	☑ Literature ☐ Site Data ☐ Assumption	Evaluated from the product of organic carbon partition coefficient and soil organic carbon fraction	Malcolm Pirnie, 2008; HQMC, 2009	Minimum: Average: 21.53 Maximum:	mL/g	
8	Diffusion coefficient in air	Diffusion coefficient of TNT in air	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum: Average: 6.40E-02 Maximum:	cm^2/sec	
9	Diffusion coefficient in water	Diffusion coefficient of TNT in water	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum: Average: 6.71E-06 Maximum:	cm^2/sec	
10	Half-life in soil	Reaction half-life of TNT in soil	☑ Literature ☐ Site Data ☐ Assumption	A representative value selected by subjuect matter expert based on a compilation of academic, industrial and government references	HQMC, 2009	Minimum: Most likey: 23.1 Maximum:	days	

Table A-5: Chemical Properties of HMX

Installation name:	MCAS Beaufort Townsend Range
Date:	July, 2012
Munitions Constituent:	HMX

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil per unit MC loading area (from MC loading analysis)				Minimum:	3.26E-09		
						Average:			
						Maximum:	4.89E-09	Kg/m^2	
2	Molecular weight	Molecular weight of HMX	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995		296.2	g/mol	
3	Solubility	Water solubility of HMX	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum:			
						Average:	1.69E-02		
						Maximum:		mol/m^3	
4	Vapor pressure	Vapor pressure of HMX	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum:			
						Average:	4.40E-12	Pa	
						Maximum:			
5	Henry's law constant	Henry's law constant of HMX	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	2.63E-15		
						Maximum:		atm-m^3/mol	
6	Kow	Octanol-water partition coefficient for HMX	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	1.15	unitless	
						Maximum:			
7	Koc	Organic carbon partition coefficient for HMX	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	3.47	mL/g	
						Maximum:			
8	K_D	Equilibrium distribution coefficient	☑ Literature ☐ Site Data ☐ Assumption	Evaluated from the product of organic carbon partition coefficient and soil organic carbon fraction	Malcolm Pirnie, 2008; HQMC, 2009	Minimum:			
						Average:	0.142	mL/g	
						Maximum:			
9	Diffusion coefficient in air	Diffusion coefficient of HMX in air	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	6.30E-02	cm^2/sec	
						Maximum:			
10	Diffusion coefficient in water	Diffusion coefficient of HMX in water	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	6.02E-06	cm^2/sec	
						Maximum:			
11	Half-life in soil	Reaction half-life of HMX in soil	☑ Literature ☐ Site Data ☐ Assumption	A representative value selected by subjuect matter expert based on a compilation of academic, industrial and government references	HQMC, 2009	Minimum:			
						Most likely:	51.3	days	
						Maximum:			

Table A-6: Chemical Properties of RDX

Installation name:	MCAS Beaufort Townsend Range
Date:	July, 2012
Munitions Constituent:	RDX

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil per unit MC loading area (from MC loading analysis)				Minimum:	2.12E-07		
						Average:			
						Maximum:	3.18E-07	Kg/m^2	
2	Molecular weight	Molecular weight of RDX	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995		222.1	g/mol	
3	Solubility	Water solubility of RDX	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum:			
						Average:	1.90E-01		
						Maximum:		mol/m^3	
4	Vapor pressure	Vapor pressure of RDX	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum:			
						Average:	5.47E-07	Pa	
						Maximum:			
5	Henry's law constant	Henry's law constant of RDX	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	1.20E-05		
						Maximum:		$atm\text{-}m^3/mol$	
6	Kow	Octanol-water partition coefficient for RDX	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	6.45	unitless	
						Maximum:			
7	Koc	Organic carbon partition coefficient for RDX	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	7.76E+00	mL/g	
						Maximum:			
8	K_D	Equilibrium distribution coefficient	☑ Literature ☐ Site Data ☐ Assumption	Evaluated from the product of organic carbon partition coefficient and soil organic carbon fraction	Malcolm Pirnie, 2008; HQMC, 2009	Minimum:			
						Average:	0.318	mL/g	
						Maximum:			
9	Diffusion coefficient in air	Diffusion coefficient of RDX in air	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	7.40E-02	cm^2/sec	
						Maximum:			
10	Diffusion coefficient in water	Diffusion coefficient of RDX in water	☑ Literature ☐ Site Data ☐ Assumption		HQMC, 2009	Minimum:			
						Average:	7.15E-06	cm^2/sec	
						Maximum:			
11	Half-life in soil	Reaction half-life of RDX in soil	☑ Literature ☐ Site Data ☐ Assumption	A representative value selected by subjuect matter expert based on a compilation of academic, industrial and government references	HQMC, 2009	Minimum:			
						Average:	14.2	days	
						Maximum:			

Table A-7: Chemical Properties of Perchlorate

Installation name:	MCAS Beaufort Townsend Range
Date:	July, 2012
Munitions Constituent:	Perchlorate

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil per unit MC loading area (from MC loading analysis)				Minimum:	1.42E-09		
						Average:			
						Maximum:	2.13E-09	Kg/m^2	
2	Molecular weight	Molecular weight of perchlorate	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995		99.45	g/mol	
3	Solubility	Water solubility of perchlorate	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum:			
						Average:	2.01E+03		
						Maximum:		mol/m^3	
4	Vapor pressure	Vapor pressure of perchlorate	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995	Minimum:			
						Average:	3.75E-09	Pa	
						Maximum:			
5	Henry's law constant	Henry's law constant of perchlorate	☑ Literature ☐ Site Data ☐ Assumption	No reported values available; Estmated by CalTOX from vapor pressure and solubility values		Minimum:			
						Most Likely:	1.85E-17	$atm\text{-}m^3/mol$	
						Maximum:			
6	Kow	Octanol-water partition coefficient for Perchlorate	☑ Literature ☐ Site Data ☐ Assumption		Walsh et al., 1995 Meylan and Howard, 1995	Minimum:			
						Average:	1.40E-06	unitless	
						Maximum:			
7	Koc	Organic carbon partition coefficient for Perchlorate	☑ Literature ☐ Site Data ☐ Assumption	Estimated by the CalTOX model based on the Kow for perchlorate		Minimum:			
						Average:	6.94E-07	mL/g	
						Maximum:			
8	K_D	Equilibrium distribution coefficient	☑ Literature ☐ Site Data ☐ Assumption	Evaluated from the product of organic carbon partition coefficient and soil organic carbon fraction		Minimum:			
						Average:	2.85E-08	L/Kg	
						Maximum:			
9	Diffusion coefficient in air	Diffusion coefficient of perchlorate in air	☑ Literature ☐ Site Data ☐ Assumption	No reported values available, input variables used are based on conservative assumptions		Minimum:			
						Average:	7.00E-10	cm^2/sec	
						Maximum:			
10	Diffusion coefficient in water	Reaction half-life of perchlorate in water	☑ Literature ☐ Site Data ☐ Assumption	No reported values available, input variables used are based on conservative assumptions		Minimum:			
						Average:	1.90E-12	cm^2/sec	
						Maximum:			
11	Half-life in soil	Reaction half-life of perchlorate in soil	☑ Literature ☐ Site Data ☐ Assumption	No reported values available, input variables used are based on conservative assumptions		Minimum:			
						Average:	1.00E+07	days	
						Maximum:			

Table A-8: Groundwater Modeling Parameters - Vadose Zone Properties for MC Loading Areas

VLEACH Parameters	**MC Loading Area**		**Rationale**	**Reference(s)**
1) Polygon Data				
Parameter	**EOD**	**Smokey SAM**		
Area ($feet^2$)	19,387	1,324,434		
Vertical Cell Dimension (feet)	0.328	0.328		
Number of Cells (-)	10	10		
Height of Polygon (feet)	3.28	3.28	Approximate average depth to water	Malcolm Pirnie, 2008
2) Soil Parameter				
Parameter	**EOD**	**Smokey SAM**		
Dry Bulk Density (g/cm^2)	1.42	1.42		USDA NRCS, 2004
Effective Porosity (-)	0.28	0.28	Estimated based on the vadose zone material	McWhorter and Sundada, 1977
Volumetric Water Content (-)	0.24	0.24	Estimated field capacity value the vadose zone material	Fetter, 1994
Soil Organic Carbon Content (-)	0.041	0.041	Measured organic carbon content of surface soil near MC loading areas	Malcolm Pirnie, 2010
3a) Boundary Condition				
Parameter	**EOD**	**Smokey SAM**		
Recharge Rate (feet/year)	0.64	0.64	Estimated based on values for the Coastal Plain area and land cover for the loading areas	Heath, 1994
Concentration of HMX in Recharge Water (mg/L)	N/A	N/A	Not modeled; Loading negligible	
Concentration of RDX in Recharge Water (mg/L)	0.0386	N/A	Concentration for EOD is the Result from the initial groundwater screening analysis; Smokey SAM is not modeled as loading is negligible	
Concentration of TNT in Recharge Water (mg/L)	N/A	N/A	Not modeled; Loading negligible	
Concentration of Perchlorate in Recharge Water (mg/L)	N/A	0.00144	Concentration for Smokey SAM is the results from the initial groundwater screening analysis; EOD is not modeled as loading is negligible	
Upper Boundary Vapor Condition (mg/L)	0	0		
Lower Boundary Vapor Condition (mg/L)	0	0		
Upper Cell Number (-)	1	1		
Lower Cell Number (-)	10	10		
Initial Contaminant Concentration in Cells (µg/Kg)	0	0		

Table A-9: Chemical Properties of MC used in the VLEACH Vadose zone Model

CHEMICAL PARAMETER	HMX	RDX	TNT	PERCHLORATE	Rationale	Reference(s)
Organic Carbon Distribution Coefficient (mL/g)	3.47	7.76	525	6.91E-07	HQMC, 2009	HQMC, 2009
Henry's Constant (-)	1.09E-13	4.97E-04	4.56E-07	7.64E-16	equivalent to the Henry's constant divided by the ideal gas constant multiplied by the ambient temperature	HQMC, 2009
Water Solubility (mg/L)	5	42.2	130	200,000	Walsh et al., 1995	Walsh et al., 1995
Free Air Diffusion Coefficient (m^2/day)	0.544	0.639	0.553	7.00E-10	HQMC, 2009	HQMC, 2009
Molecular Weight (g/mol)	296.2	222.1	227.1	99.45		

Appendix B

Small Arms Range Assessment Protocol Tables

SMALL ARMS RANGE ASSESSMENT

Appendix Table of Contents

Introduction

The purpose of the Range Environmental Vulnerability Assessment (REVA) is to identify whether there has been a release or there is a substantial threat of a release of munitions constituents (MC) of concern from the operational range or range complex areas to off-range areas. This is accomplished through the use of fate and transport modeling and analysis of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas at an installation.

Lead is the primary REVA indicator MC for small arms ranges. The fate and transport parameters for lead are based entirely on site-specific geochemical properties, which cannot be determined solely by physical observation. Therefore, small arms ranges associated with the installation are qualitatively reviewed and assessed to identify factors that influence the potential for lead migration at the operational range, including:

- design and layout,
- the physical and chemical characteristics of the area, and
- current and past operation and maintenance practices.

In addition, potential receptors and pathways must be identified relative to the small arms range being assessed. The potential for an identified receptor to be impacted by MC migration through an identified pathway will be evaluated.

MC associated with small arms ammunition commonly used at operational ranges include lead, antimony, copper, and zinc. REVA focuses on lead as the MC indicator for small arms ranges because lead is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike any other MC. Lead is geochemically specific regarding its mobility in the environment. Site-specific conditions must be known (i.e., geochemical properties) in order to quantitatively assess lead migration. Site-specific geochemical properties are only identified via sampling and cannot be observed physically. Without site-specific physical and chemical characterization, lead cannot effectively be modeled using fate and transport modeling like the other indicator MC in REVA. The scientific community has established that metallic lead (such as recently fired, unweathered bullets and shot) generally has low chemical reactivity and low solubility in water and is relatively inactive in the environment under most ambient or everyday conditions. However, a portion of lead deposited on a range may become environmentally active if the right combination of conditions exists.

This Small Arms Range Assessment Protocol was developed in lieu of collecting site-specific information for every small arms range. The protocol will help to determine which ranges necessitate data collection of site-specific geochemical properties or further assessment based the range’s overall prioritization regarding the potential for an identified receptor to be impacted by potential lead migration through an identified pathway.

Purpose

This protocol is to be used for:

1) Identifying the small arms ranges within the Marine Corps that have the greatest potential for lead migration and impact to identified receptors, and
2) Assessing the need for implementing further actions. Recommended further actions may include, but are not limited to, the following:
   - Sampling surface water, groundwater, and/or soil
   - Conducting additional studies
   - Implementing best management practices (BMPs)

Data Collection and Documentation

The qualitative assessment process for a small arms range involves first defining and documenting its physical and environmental conditions, as well as how the range is utilized and maintained (including dates of use and types and amounts of small arms ammunition expended). The small arms range data collection form within Section 3 of the REVA Reference Manual is a guide to collecting and documenting the necessary information in order to complete the evaluation forms presented later in this protocol (Tables 1 through 6). It includes a comprehensive list of data elements that are useful in establishing the historical and current physical and environmental conditions, as well as capturing the types of information on conditions that influence lead's potential to migrate from the range. The data collection form is organized by major topics or information areas associated with the operational range, including the following:

- Basic range information
- Current range layout
- Current range operations
- Historical range operations
- Amount of lead potentially deposited
- Environmental characteristics
- Potential receptors
- Surrounding land use

- Environmental activities conducted on the range
- Summary

The data collection form in the REVA Reference Manual can be modified, where needed, to fully capture the major factors that can potentially influence lead's ability to migrate from each specific small arms range.

Qualitative Assessment

The small arms range can be qualitatively assessed once the conditions of the range have been fully understood and documented. The assessment process involves a discussion of possible factors that can influence the potential for lead to migrate off range. Several of these factors are listed below, followed by a detailed discussion:

- Range use and range management (source)
- Surface water conditions
- Groundwater and soil conditions
- Pathways
- Receptors

Range Use and Range Management (Source)

The amount of lead and other MC deposited on a range is a combination of the following factors:

- Duration of use
- Current and historical frequency of range usage
- Amount and types of small arms ammunition expended on the range
- Scope and frequency of any range maintenance activities involving the removal of lead from the range
- Presence and duration of bullet-capturing technologies

Surface Water Conditions

Under specific pH conditions, lead from shot or bullets can slowly dissolve in water. Runoff and groundwater recharge could transport this dissolved lead off range. In addition, lead adsorbed onto sediment can be transported off range in surface runoff. The primary factors influencing the potential for lead to migrate via surface water include, but are not limited to, the following:

- pH of the water
- Duration of water contact with the lead
- Intensity and frequency of rainfall
- Steepness of the slope containing lead
- Amount and type of vegetation on the slope
- Infiltration rate of surface soils
- Presence of engineering controls or BMPs to modify or control surface water runoff

Groundwater and Soil Conditions

The amount of lead that dissolves in water is primarily influenced by the pH of the water and the duration of water contact with the lead. Once lead is dissolved in water, the amount of lead that attaches to the soil and/or enters the groundwater is determined by several factors, including the following:

- Organic carbon content of the soil
- pH of the soil
- Properties of the soil, including porosity, irreducible water content, and hydraulic conductivity
- Amount of recharge percolating through the vadose zone
- Clay content of the soil (lead attaches to clay minerals more than other soil fractions)
- Depth to groundwater

Pathways

The REVA Small Arms Range Assessment Protocol involves developing a conceptual site model (CSM) for the range to identify the range's physical and environmental conditions. The CSM's purpose is to identify if a potential for source-receptor-pathway interaction may exist. Factors that influence the potential for a source-receptor-pathway interaction (e.g., heavy range use, potable water supply wells in proximity to the range), as well as factors that decrease the potential for such interactions, should be discussed in the assessment.

Potential pathways include:

- groundwater used as a source of potable or agricultural water,
- the use of surface water downstream of a range as a source of potable or agricultural water, and
- the use of the soil, surface water, or groundwater by sensitive species.

Receptors

Receptors in REVA can include on-range and off-range personnel and sensitive species and ecosystem areas. Factors considered when assessing the potentially complete exposure pathways for receptors include, but are not limited to, the following:

- The number and proximity of water supply wells relative to the range
- The characteristics of nearby water supply wells (e.g., depth to groundwater, well construction details)
- The uses of the surface water or groundwater (e.g., agriculture, drinking water)
- The locations of nearby sensitive species areas, such as endangered species habitats (i.e., within proximity to the range)

Small Arms Range Assessment Protocol

This Small Arms Range Assessment Protocol is based on evaluating the potential for exposure to receptors by MC. Evaluation rankings for surface water and groundwater conditions are established for each small arms range. The rankings range between high (indicating the highest potential for lead to migrate toward identified receptors) and minimal (indicating the lowest potential for lead to migrate toward identified receptors). Possible recommended actions are based on the relative evaluation rankings assigned by the protocol. High rankings necessitate further actions. Further actions may included sampling, additional site-specific studies, and/or BMPs. These actions will be evaluated based on site conditions for each range.

Protocol Instructions

1. For Tables 1 through 5:
    a. Enter the appropriate score for each criteria in the site score column. Use the highest (i.e., most conservative) value if no information is known to complete the score. A designated score may be overridden if it is determined that the value does not adequately represent the site based on site characteristics and constituent loading estimates, mark the score column appropriately (*) and fill in the notes section at the bottom of the table with text detailing why the score was adjusted. Sum the site scores in the last row.
2. Transfer the scores from Tables 1 through 5 onto Table 6 in the appropriate rows.
3. Use the scores in Table 6 to determine the surface water and groundwater evaluation rankings.

Evaluation Ranking Designation

Once Table 6 is complete, the protocol finishes with two scores: the sum of surface water elements and the sum of groundwater elements. These scores are used to identify the appropriate evaluation ranking (High, Moderate, Minimal) for surface water and groundwater (as mentioned in step 3 of the protocol instructions).

The surface water evaluation ranking and the groundwater evaluation ranking identify the potential impact for lead migration for each of those pathways at the small arms range. The ranking designations and their descriptions follow:

- High = Small arms range most likely has the potential for lead migration to an identified receptor and requires additional action(s).
- Moderate = Small arms range may have the potential for lead migration to a receptor, most likely indicating that there is no immediate threat to human health and the environment, but actions may be necessary to mitigate future concerns..
- Minimal = Small arms range has minimal or no potential for lead migration, but actions may be necessary to ensure that continuing training activity at the range does not pose a future threat to human health and the environment.

These rankings are used to determine whether additional actions are appropriate. The evaluation ranking (surface water or groundwater), as determined in Table 6, is used to evaluate if further actions are suggested, based on the guidelines for recommended actions (Table 7, provided on Page A-9).

The overall range evaluation rankings should be compared to each range within the installation and to the overall rankings of all ranges across the Marine Corps. These rankings will assist in determining how funding should best be allocated across the Marine Corps to prevent environmental concerns due to small arms ranges.

Assessment Report

Once the Small Arms Range Assessment Protocol has been completed and appropriate actions have been designated and implemented, the assessment should be written into a report that describes the process taken, details the information used to score Tables 1 through 5, outlines the scores and evaluation rankings, and identifies the additional actions taken. The report should detail whether an identified receptor is or is not impacted by lead migration through the identified pathway(s). The completed protocol tables should be included as an appendix to the report.

Best Management Practices for Small Arms Ranges

BMPs are important for all ranges and should be used appropriately to maintain the sustainability of operational ranges. However, this protocol prioritizes which small arms ranges may need BMPs to address specific possibilities of lead migration.

Following the Small Arms Range Assessment Protocol, BMPs may be recommended based on the evaluation ranking. Prior to selecting and implementing BMPs, the management objectives must be established. Depending on the range-specific site conditions and the management objectives, the following BMPs should be considered:

- Bullet and shot containment techniques (e.g., berms, backstops, traps)
- Prevention of soil erosion from berms, aprons, and other range areas
- Soil amendments
- Recovery and/or recycling of lead

Negative impacts of implementation should also be considered when selecting a BMP. For example, using soil amendments may affect water quality of nearby water bodies or modifying surface water runoff may impact nearby habitats.

The prevention of soil erosion can be achieved by implementing one or several of the following practices:

- Maintaining vegetation on berms and drainageways
- Reducing runoff rates by adjusting site drainage patterns
- Providing sediment traps such as a vegetated detention basin or infiltration area
- Preventing the creation of a “point source”

Soil amendments may be an effective BMP by implementing one or both of the following practices:

- Increasing the retentive capacity of soil by adding organic matter, fertilizer, and/or lime
- Maintaining a pH range between 6 and 8 by adding triple superphosphate, bone meal, or other applicable additives

The recovery and recycling of lead from operational ranges should be considered as a way to control the migration of lead. The following should be considered when implementing recovery and recycling practices:

- Focus on safety as the primary concern of the proposed activities
- Avoid practices that appear as treatment activities (e.g. acid leaching, fixation, etc.)
- Dispose lead by using a lead recycler or smelter
- Use residual soil for the original purpose (e.g. berm/target area soil) following lead recovery practices.

Table A-1: Guidelines for Recommended Actions

Evaluation Ranking	Recommended Action
High	Action required. 1) Consider sampling appropriate media (groundwater, surface water, and/or soil). 2) Identify and implement BMPs, if necessary.
Moderate	1) Consider identifying and implementing BMPs, if necessary. 2) Consider sampling appropriate media (groundwater, surface water, and/or soil).
Minimal	1) No further action is needed at this time. 2) Consider identifying and implementing BMPs, if necessary.

SARAP Tables

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Pistol Range
Marine Corps Air Station (MCAS) Beaufort
Beaufort, South Carolina

ASSESSMENT RESULTS:

The Surface Water Evaluation Ranking resulted in a Moderate score for this range. Precipitation is high at the range, but the surface water should be contained within the range since walls are present three sides of the range with the berm on the forth side. The side walls have two holes in the walls two inches above the range floor. On the basis of the Small Arms Range Assessment Protocol (SARAP), there is moderate potential for lead migration and impacts to surface waters.

The Groundwater Evaluation Ranking resulted in a Moderate score for this range. Precipitation at the range is high, and there is considerable lead loading.

MCAS Beaufort
Pistol Range

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Characteristics**	**Score Criteria**	**Site Score**
Duration of Range Use	Pistol Range has been in operation from 1969 to 1999 then was refurbished with the range reopening in 2003.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	There are no bullet-capturing technologies implemented at the range.	-3 if range usage duration = bullet capture duration -1 if range usage duration – bullet capture duration = 10 to 30 years 0 if range usage duration – bullet capture duration > 30 years	0
MC Loading Rates	The average annual loading rate of lead is approximately 3,600 pounds per year.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	3*
Range Maintenance	The earthen berm was reconstructed in 2003 and mined for lead in 2003 and 2010.	5 if lead is removed more than every three years 3 if lead is removed more than every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			13
Notes: * The Range Maintenance factor of the Range Use and Range Management (Source) Element in the SARAP evaluation is typically evaluated on the basis of frequency. Despite the lack of a formal scheduling of lead removal activities for this range, it is appropriate to score the range as a three during this review period due to the recent lead removal. This score will be reevaluated during the next five-year review period.			

MCAS Beaufort
Pistol Range

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Characteristics**	**Score Criteria**	**Site Score**
pH of Water	The pH of groundwater near the nearby Explosive Ordnance Disposal (EOD) range is less than 6.5.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
Precipitation	Precipitation averages approximately 50 inches per year.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The approximate slope of the berm is 2:1.	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	5
Vegetation	Overall groundcover between the firing position and the target area consists of grass. The berm is predominantly covered by grass. Beyond the backstop berm, the vegetation is predominantly grass then woodland.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	1
Soil Type/Runoff Conditions	Range personnel stated that the soils encountered during the 2010 work were a mix of sand and clay.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	3
Runoff/ Erosion Engineering Controls	The range has concrete walls approximately 15 feet tall on each side of the range, and an earthen berm backstop is present at the northern end of the range. The berm is approximately 17 feet tall and has a 2:1 slope on both sides. Five rows of overhead baffles at various increments downrange and a ballistic canopy directly above the firing line keep projectiles on the range. The concrete walls have two 3-inch openings on each side to allow water to drain from the.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-10
Surface Water Pathway Score			9
Notes:			

MCAS Beaufort
Pistol Range

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Characteristics**	**Score Criteria**	**Site Score**
Depth to Groundwater	Depth to surficial aquifer is estimated to be less than 20 feet, which has been confirmed by work at the EOD range*.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater >300 feet	5
Precipitation	The rainfall at the installation averages approximately 50 inches/year.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Water	The pH of groundwater measured near the EOD range is less than 6.5.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
pH of Soil	Samples collected during the 2010 refurbishment had pH values between 4.39 and 6.05.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
Soil Type/Infiltration Conditions	The Coosaw loamy fine sand is described as having moderate permeability.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Clay Content in Soil	The B Horizon of Coosaw loamy sand contains clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Groundwater Pathway Score			26
Notes: *Environmental data in the immediate vicinity of the Pistol Range is not available so we are using data from the EOD Range.			

MCAS Beaufort
Pistol Range

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Characteristics**	**Score Criteria**	**Site Score**
Drinking Water Usage	The range is not in close proximity to a source of drinking water. Drinking water is from the Savannah River via a canal system.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water may be used for a variety of recreational opportunities and shellfish harvesting. There are restrictions on harvesting shellfish near the base.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	Due to the coastal environment, there is the potential for receptors to access contaminated media. Wetlands are located approximately 1,600 feet east of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	5
Surface Water Receptor Score			8
Notes:			

MCAS Beaufort
Pistol Range

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Characteristics**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is not in close proximity to a source of drinking water. Drinking water is obtained from the Savannah River via a canal system.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure.	2
Wells Identified for Agricultural or Other Beneficial Usage	The small arms range is located on the base and is not near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably. 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Due to the coastal environment, there is the potential for receptors to access contaminated media. Wetlands are located approximately 1,600 feet east of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources. 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	3
Groundwater Receptor Score			6
Notes:			

MCAS Beaufort
Pistol Range

Table 6: Evaluation Results (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Surface Water Pathways	2	9
Surface Water Receptors	4	8
Sum of Surface Water Element Scores		**30**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Groundwater Pathways	3	26
Groundwater Receptors	5	6
Sum of Groundwater Element Scores		**45**
The evaluation ranking for each media is determined by selecting the appropriate score based on the data elements for that media: Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Ranking		**Moderate**
Groundwater Ranking		**Moderate**
Notes:		