Marine Corps Installations Command

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FINAL

Range Environmental Vulnerability Assessment

5-Year Review

MCB Camp Lejeune

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Executive Summary

The United States (U.S.) 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 and 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. Each REVA trigger value is a median value of method detection limits. Modeling results that exceed a trigger value may warrant further investigation 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 (MCICOM) in assessing the potential for degradation of groundwater and/or surface water quality. The results of sampling will be compared to DoD Range and Munitions Use Subcommittee (RMUS) screening values to determine if the release is a threat to human health and/or the environment. Sampling results are also compared to state protection standards obtained from the North Carolina Administrative Code for groundwater (North Carolina Department of Environment and Natural Resources Division of Water Quality, 2010).

This report presents the five-year review assessment results for the operational ranges and training areas at Marine Corps Base (MCB) Camp Lejeune, Marine Corps Air Station New River, and Marine Corps Outlying Field Oak Grove, all located in southeastern North Carolina. Collectively, these areas are referred to as MCB Camp Lejeune. This report serves as the first five-year review assessment documenting the period of munitions loading from October 2004 through September 2010. The baseline assessment conducted in 2007 documented munitions use through 2004 (Malcolm Pirnie, 2009).

Military Munitions Training and Operations

MCB Camp Lejeune is the world's most complete amphibious training base. The installation provides specialized training for those serving in the U.S. Marine Forces Command and is home to the Marine Corps Engineer School, the U.S. Coast Guard's Special Missions Training Center, the Marine Special Operations Command, the School of Infantry-East, the II Marine Expeditionary Force, and other Training and Education Command formal schools. Approximately 37,560 active military personnel are stationed at MCB Camp Lejeune. An additional 19,000 servicemen attend military training/schools at the installation each year (USACE, 2001a).

MCB Camp Lejeune contains approximately 153,439 acres. The REVA team identified 273 operational and historical use areas and training areas within MCB Camp Lejeune. The majority of the installation (approximately 107,263 acres) is designated for training purposes with fixed ranges positioned throughout the installation. A Conceptual Site Model (CSM) was developed for MCB Camp Lejeune using information collected during the REVA team's September 2010 site visit, information contained in the baseline REVA (Malcolm Pirnie, 2009), and information provided by the Environmental Management Division, Range Control, and other installation offices at MCB Camp Lejeune.

MC loading areas are where the majority of MC are deposited within an operational range. MC loading areas were identified and evaluated in 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.

Thirty-three MC loading areas were identified and evaluated during the baseline assessment. Of these, 12 of the 33 were prioritized for modeling purposes based on use, receptors, and environmental characteristics. Due to overlapping uses over time, the 12 prioritized areas were grouped into 10 MC loading areas for fate and transport modeling. Twenty-three small arms ranges (SARs) were identified during the baseline and grouped into 21 SARs for qualitative evaluation based on proximity and use.

During the five-year review process, 31 MC loading areas were identified at MCB Camp Lejeune. These MC loading areas are distributed throughout the installation. Of the 10 MC loading areas modeled in the baseline assessment, 6 were reassessed in the five-year review. Those that were not reassessed were historical loading areas that showed no potential for MC release to off-range areas and have had no additional loading since the time of the baseline assessment.

Fourteen of the 31 identified MC loading areas identified in the five-year review were prioritized for fate and transport modeling based on use and potential for groundwater or surface water receptor exposure. Five of the prioritized MC loading areas were included in the screening-level modeling in the baseline assessment; however, MC loading area boundaries were revised during the five-year review in order to more accurately reflect loading at the MC loading areas.

Table ES-1: Summary of Baseline Assessment Results for MCB Camp Lejeune

MC Loading Area	Screening-Level Modeling Results: REVA Trigger Values Predicted to Be Exceeded Off Range[a]		Samples Collected After Baseline Assessment	Samples Exceed RMUS Values	Historical Use Only	Assessing in Five-Year Review
	Surface Water	Groundwater				
G-10 Impact Area	Y	Y	Y	N	N	Y
K-2 Impact Area	Y	Y	Y	N	N	Y
F-5, F-2 Field Firing Range, Musketry Range A	Y	N	Y[b]	N	N	Y
F-14 Field Firing Range	N	N	Y[b]	N	Y	N
MC Loading Area	**Screening-Level Modeling Results**		**Samples Collected After Baseline Assessment**	**Samples Exceed RMUS Values**	**Historical Use Only**	**Assessing in Five-Year Review**
F-6	Y	N	Y[b]	N	N	Y
L-Impact Area	N	N	N	---	Y	N
L-Ranges	Y	N	N	---	N	Y
Combat Town	N	N	Y[b]	N	N	Y
M-10 Hand Grenade Range	N	N	N	---	Y	N
M-115 Hand Grenade Range	N	N	N	---	Y	N
Assessed Using SARAP	**Surface Water Concern**	**Groundwater Concern**	**Samples Collected**		**Assessing in Five-Year Review**	
A-1	Moderate	Moderate	N		Y	
B-12	Moderate	Moderate	N		Y	
D-29A and D-29B	Moderate	Moderate	N		Y	
D-30	Moderate	High	N		Y	
F-11A and F-11B	Moderate	Moderate	N		Y	
F-18	Moderate	High	N		Y	
I-1	Minimal	Moderate	N		Y	
MAC 1	Moderate	Moderate	N		Y	
MAC 2	Moderate	Moderate	N		Y	
MAC 3	Moderate	Moderate	N		N	
MAC 4	Moderate	Moderate	N		Y	
MAC 5	Moderate	Moderate	N		Y	

Assessed Using SARAP	Surface Water Concern	Groundwater Concern	Samples Collected	Assessing in Five-Year Review
SR-11	Minimal	Moderate	N	Y
Stones Bay Dodge City	Moderate	Moderate	N	Y
Stones Bay Multi-Purpose	Moderate	Moderate	N	Y
Stones Bay Mechanical	Moderate	Moderate	N	Y
Stones Bay Non-Mechanical	Moderate	Moderate	N	Y
Stones Bay Alpha Range	Moderate	Moderate	N	Y
Stones Bay Bravo Range	Moderate	Moderate	N	Y
Stones Bay Charlie Range	Moderate	Moderate	N	Y
Stones Bay Hathcock Range	Moderate	Moderate	N	Y

Note:
N = No, Y = Yes
MAC = Military Operations in Urban Terrain (MOUT) Assault Course
RMUS = Range and Munitions Use Subcommittee
SARAP = Small Arms Range Assessment Protocol
a Result is indicated for downstream receptor.
b Sample was collected at public supply well near MC loading area.

Thirty-seven SARs were evaluated in the five-year review, but some of the SARs with similar characteristics that were in proximity to one another were grouped for the assessment; therefore, 27 SAR assessments were completed in the five-year review. Of the 21 SARs evaluated in the baseline assessment, all but one of these were evaluated in the five-year review. MAC-3 was not re-evaluated because it is an indoor range and, therefore, any potential impacts are assumed to be contained inside. Four SARs were identified in the five-year review that were not evaluated in the baseline assessment: MAC-6, Square Bay, SR-8, and SR-11. Ten ranges were evaluated as part of the K-Impact Area MC loading area in the baseline assessment that were determined to be SARs in the five-year review. These include K-302, K-309, K-317, K-319, K-321, K-321A, K-325, K-402, K-406A, and K-406B. All 14 of these ranges were evaluated with the SARAP for this five-year review.

The REVA assessment team estimated MC loading rates for identified MC loading areas and for lead deposition for MC loading areas and SARs at MCB Camp Lejeune. A CSM was developed for the training areas to qualitatively assess the potential for MC transport from the loading areas to impact identified off-range human and ecological receptors.

Conceptual Site Model for MCB Camp Lejeune

MCB Camp Lejeune is located on the southeastern coast of North Carolina where the climate is warm and temperate, and winters are cool with occasional brief cold spells. Average annual precipitation is approximately 54 inches per year, with an average of 3 inches of snowfall per

year (North Carolina State Climate Office, 2011). Hurricanes are not uncommon in the area and can cause severe flooding in low-lying areas. MCB Camp Lejeune is relatively flat, and elevation ranges from mean sea level (msl) to 72 feet (ft) above msl.

Soil erodibility factors of the predominant soil series at MCB Camp Lejeune are low to moderate (0.1 to 0.3 tons/acre) (USDA SCS, 1992). Even in areas of higher slope, such as stream valleys, the high vegetative cover causes the natural erosion potential to be low. The coastal barrier island complex is subject to erosion from wave action, particularly during storm surges, but serves to protect landward areas from such effects. Areas with moderate potential for erosion are those where the vegetation and soil have been disturbed by military operations. There are several MC loading areas that are vacant or sparsely vegetated; these areas have been estimated to have high erosion potential.

MCB Camp Lejeune is located within the Tidewater region of the Atlantic Coastal Plain physiographic province, in the lower Coastal Plain of North Carolina. It is underlain by an eastward-thickening wedge of marine and nonmarine sediments that vary from a thickness of near zero at the fall line to the west to more than 10,000 ft near and under the Atlantic Ocean (Winner and Coble, 1989). The several thousand ft of interlayered, unconsolidated sediment at the coastline consists of gravel, sand, silt, clay deposits, calcareous clays, shell beds, sandstone, and limestone. The sequence of unconsolidated sedimentary deposits at MCB Camp Lejeune is estimated to reach a thickness of 1,400 to 1,700 ft (O'Brien and Gere, 1988).

The unconsolidated sediment deposits that underlie MCB Camp Lejeune have been divided into seven hydrostratigraphic units or aquifer systems. The aquifer systems from shallow to deep are the surficial, Castle Hayne, Beaufort, Peedee, Black Creek, Upper Cape Fear, and Lower Cape Fear aquifer systems. The surficial aquifer is recharged by rainfall and is a source of recharge for the underlying Castle Hayne aquifer. It also is the source base flow to streams. The surficial aquifer ranges in depth from 0 ft in the channel of the New River and its tributaries to 75 ft in the southeastern portion of MCB Camp Lejeune. The bottom of the surficial aquifer is at or near msl throughout the majority of the installation. The Castle Hayne confining unit lies between the surficial and Castle Hayne aquifers and is a thin, discontinuous layer of clay to clayey sands and silts. The discontinuous nature of the confining unit results in vertical leakage (both upward and downward) throughout the Castle Hayne aquifer. The top of the Castle Hayne aquifer is between 0 and 75 ft below msl, and the aquifer ranges in thickness from 175 ft in the northern part of the installation to 375 ft along the coast. As of January 2012, there are 50 active water supply wells on the installation, which rely entirely on groundwater from the Castle Hayne aquifer. Most of these are located east of the New River along the northern boundary of the installation and on the western boundary of the G-10 Impact Area.

MCB Camp Lejeune is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The Atlantic Ocean forms the

southeastern boundary, which contains approximately 14 miles of beachfront. The majority of MCB Camp Lejeune drains to the New River embayment and its tributaries; however, some southern areas drain directly to the Intracoastal Waterway, which flows into the Atlantic Ocean. Much of the interior area of the installation drains to intermittent and perennial streams that widen into tidal creeks in their downstream segments. Most perennial streams and tidal creeks occupy floodplains with extensive riparian wetlands. The flat terraces contain regions that drain to low areas with no surface water outlets, including pocosins.

Waters in and around MCB Camp Lejeune are used for human recreation, and there are no military restrictions in place for recreational use on the waters of MCB Camp Lejeune. Commercial oyster beds are located in the eastern and southern portions of the New River, and approximately 20 artificial reefs have been established in Onslow Bay to support offshore fishing and recreational diving. Surface waters on the installation are not a drinking water source.

Surface water runoff is a potential transport pathway of MC to surface water bodies, and MC transported to the shallow groundwater may discharge to surface water. Although soil erosion potential is relatively low, erosion potential is higher at many of the identified MC loading areas due to lower vegetative cover and disturbance from range activities. Thus, soil erosion at the identified MC loading areas is also a potential mechanism for MC transport to surface water bodies.

Due to the shallow water table depth and presence of sandy soils, MC have the potential to migrate toward the water table after dissolution in infiltrating rainwater. There are no known receptors for shallow groundwater, but there are potential receptors for surface water into which shallow groundwater discharges. Shallow groundwater is also a recharge source for the Castle Hayne aquifer.

Screening-Level Surface Water, Sediment, and Groundwater Transport Analyses

REVA screening-level modeling was completed for 14 MC loading areas to estimate potential MC concentrations in surface water, sediment, and groundwater at MCB Camp Lejeune. These MC loading areas were selected based on high explosives use and proximity to potential receptor locations. MC modeled included cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), trinitrotoluene (TNT), and perchlorate.

The initial surface water screening estimated annual average edge-of-loading-area MC concentrations in surface water runoff. The evaluation of transport of MC by surface water and sediment beyond the edge of the MC loading area was assisted by grouping MC loading areas into potential receptor locations (subwatershed outlet to the tidal waters).

Additional screening was carried out for those MC loading areas and MC where edge-of-loading-area concentrations were predicted to exceed REVA trigger values in order to estimate concentrations at the downstream receptor location. Results of this analysis are shown in **Table**

ES-2. All MC concentrations in sediment entering downstream receptor locations were predicted to be below REVA trigger values.

Table ES-2: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering Downstream Receptor Locations

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)	**0.110**	**0.113**	**0.114**	**0.021**
Surface Water Receptor Location	**Predicted Concentration at Nearest Surface Water Receptor Location (µg/L)**			
New River between Town Creek and Stones Bay	**0.761**	**0.568**	0.014	0.001
Bear Creek at the Confluence with Intracoastal Waterway	**0.914**	**0.711**	0.018	0.001
New River at Stones Bay	**0.598**	**0.215**	~0	0.001
New River between Stick Creek and Whitehurst Creek	**0.212**	**0.118**	~0	~0
Stones Creek at the confluence with Stones Bay	0.006	0.002	~0	~0
New River between Stones Bay and Intracoastal Waterway	**0.109**	**0.115**	~0	~0
Wallace Creek at the confluence with New River	**0.148**	0.048	~0	~0
Freeman Creek at the confluence with Intracoastal Waterway	0.018	0.013	~0	~0

Note:
µg/L = micrograms per liter
Bold indicates concentration exceeds the REVA trigger value.

A screening-level analysis was conducted on 14 MC loading areas to assess the potential for vertical migration of MC from the ground surface to the water table, the surficial aquifer, and the Castle Hayne aquifer, and from these points to move laterally to a receptor location (e.g., drinking water supply well). Only 10 of these MC loading areas were assessed further for the potential of MC to reach the Castle Hayne aquifer because four of the MC loading areas are not located near drinking water supply wells. Concentrations predicted to reach groundwater receptors are shown in **Table ES-3**.

Table ES-3: MC Concentrations Predicted to Reach Groundwater Receptors

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)	**0.110**	**0.113**	**0.114**	**0.021**
MC Loading Area	**Predicted Concentration at Nearest Drinking Water Well (µg/L)**			
G-10 Impact	~0	~0	~0	**0.046**
F-6	~0	~0	N/A	**0.094**

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)	**0.110**	**0.113**	**0.114**	**0.021**
MC Loading Area	**Predicted Concentration at Nearest Drinking Water Well (µg/L)**			
G-8 and G-9	~0	N/A	~0	N/A
L-5	~0	~0	N/A	**0.431**
F-2 and F-5	**0.308**	~0	N/A	0.016
ETA-1	~0	~0	N/A	**0.105**
ETA-3	~0	~0	N/A	**0.021**
ETA-4	~0	~0	N/A	N/A
ETA-7	~0	~0	N/A	N/A
Stones Bay Area	~0	~0	N/A	N/A

Note:

ETA = Engineer Training Area

Bold indicates concentration exceeds the REVA trigger value.

Field Data Collection

Twenty-one groundwater, eight surface water, and nine public supply well samples were collected in September/December 2010 from around the G-10 and K-2 Impact Areas and analyzed for the full explosive suite, perchlorate, and total and dissolved lead. Collected from around the G-10 Impact Area were 14 groundwater samples, 4 surface water samples, and 9 public supply well samples. Collected from around the K-2 Impact Area were seven groundwater samples, three surface water samples, and zero public supply well samples. A monitoring well was installed into the Castle Hayne aquifer south of Range L-5 in October 2011. A groundwater sample was collected from this well and three additional surface water samples were collected in the New River and Wallace Creek in October 2011.

Explosives were not detected in any surface water samples. Perchlorate was detected at four surface water locations with the highest concentration detected in the background sample. Lead was detected at three surface water locations located around the K-2 Impact Area and in Wallace Creek. All surface water sample results were below RMUS screening values.

Explosives (including 2,4-dinitrotoluene and 2-amino-4,6-dinitrotoluene) were detected at estimated concentrations in one monitoring well near the G-10 Impact Area, and nitroglycerin was detected at an estimated concentration in one monitoring well near the K-2 Impact Area. Perchlorate was detected in eight wells near the G-10 Impact Area and in three wells near the K-2 Impact Area. All but two of the perchlorate detections were estimated concentrations and only one detection (estimated) was in the Castle Hayne aquifer. All explosives and perchlorate detections were below RMUS values, but one detection of 2,4-dinitrotoluene exceeded the

interim maximum allowable concentration for the state of North Carolina. The monitoring well was resampled the following day, and this constituent was not detected.

Lead was detected at estimated concentrations around the G-10 Impact Area in four wells and around the K-2 Impact Area in five wells (two of the detections around the K-2 Impact Area were estimated). A total lead detection of 18 µg/L in one monitoring well at the K-2 Impact Area exceeded the RMUS and North Carolina screening value of 15 µg/L; dissolved lead was not detected in this well. The duplicate sample collected at this well contained a concentration of 14 µg/L. Total and dissolved lead results were well below the screening value at the wells and surface water location down-gradient of the exceedance. No dissolved lead results exceeded screening criteria, and dissolved concentrations were lower than total lead results, indicating that lead is largely immobilized by being bound to sediments. There were no detections in the sample collected from the newly installed well south of Range L-5.

Explosives and perchlorate were not detected in any public supply wells, but lead was detected in six public supply wells (two of these results were estimated concentrations). Total lead exceeded the RMUS and North Carolina screening value of 15 µg/L with a concentration of 38 µg/L in one public supply well located northwest of the G-10 Impact Area; however, total lead was not detected when this well was resampled in December 2010. No detections of dissolved lead exceeded RMUS screening values. Lead appears primarily to be bound to sediments in the surficial and Castle Hayne aquifers, as evidenced by the fact that dissolved lead results were consistently lower than total lead results.

Sampling results do not indicate a current release of MC to off-range areas at MCB Camp Lejeune.

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 generally are unavailable. Therefore, SARs are qualitatively assessed under the REVA program to identify factors that influence the potential for lead migration.

The 37 SARs evaluated at MCB Camp Lejeune are located throughout the installation. Some of these were grouped based on similar use and setting, resulting in assessments for 27 SARs or groups of SARs. Qualitative assessments were completed; 9 SARs were rated as a minimal concern for surface water receptors and 18 SARs as moderate concern. Lead was not detected in field samples near or above the screening value.

Assessments completed to determine concern for groundwater receptors from the SARs rated 3 SARs as a minimal concern to groundwater receptors, 23 as moderate concern, and 1 grouping of SARs as high concern. Only the grouping of Alpha, Bravo, and Charlie ranges received a rating

of high concern to groundwater receptors. These were rated as high concern due to heavy use, the groundwater pathway, and nearby wetlands where shallow groundwater may discharge. No public supply wells or beneficial use for groundwater was identified near these ranges. Sediment near the Alpha, Bravo, and Charlie ranges was sampled in 2008 and 2010 in a study by the University of South Carolina – Beaufort and Georgia Institute of Technology – Savannah. Sediment samples were collected in uplands and within Stones Bay and were analyzed for lead, copper, antimony, manganese, iron, and zinc. Other parameters including bulk density, grain size distribution, total organic carbon, acid volatile sulfide, and simultaneously extracted metals were also analyzed. Results did not indicate metals in the sediment were bioavailable or migrating.

Total lead was detected in a groundwater monitoring well located on the northwest boundary of the K-2 Impact Area exceeding the RMUS and North Carolina screening value of 15 µg/L. Dissolved lead was not detected in this well, indicating that lead is bound to sediment and largely immobilized. It was not detected over or near the screening value at any wells located down-gradient of the exceedance.

One lead detection exceeded its screening value northwest of the G-10 Impact Area in a public supply well with a concentration of 38 µg/L; dissolved lead was detected at 1.7 µg/L. This well was resampled in December 2010 and neither total nor dissolved lead was detected. Other detections of lead were well below the screening value and many were qualified as estimated. Almost all dissolved results were well below total lead results, indicating lead is primarily bound to sediment and largely immobilized. PSWs are sampled semi-annually by MCB Camp Lejeune and analyzed for MC.

Conclusions

- One detection of total lead exceeded the RMUS and North Carolina screening value in a monitoring well on the northwest boundary of the K-2 Impact Area. This detection was slightly above the screening value and the duplicate sample result was just below the screening value. No groundwater receptors are in the vicinity and down-gradient results do not indicate migration.
- One detection of total lead exceeded the RMUS and North Carolina screening value in a public supply well northwest of the G-10 Impact Area. This well was resampled in December 2010, and lead was not detected. MCB Camp Lejeune conducts semi-annual sampling of public supply wells.
- One detection of 2,4-dinitrotoluene exceeded the North Carolina interim maximum allowable concentration for groundwater. This was an estimated concentration, and the constituent was not detected when the well was resampled.
- Sampling results do not indicate an off-range release of MC at MCB Camp Lejeune.

- Groundwater will be sampled annually from monitoring wells in which lead and 2,4-dinitrotoluene exceeded screening criteria. Analytical results will be used to determine if annual monitoring should be continued.
- Surface water and groundwater should be sampled in the next REVA five-year review for re-evaluation.

To view the complete report, please go to:

http://www.lejeune.marines.mil/OfficesStaff/EnvironmentalMgmt/RangeEnvironmentalVulnerabilityAssessment.aspx