Marine Corps Installations Command

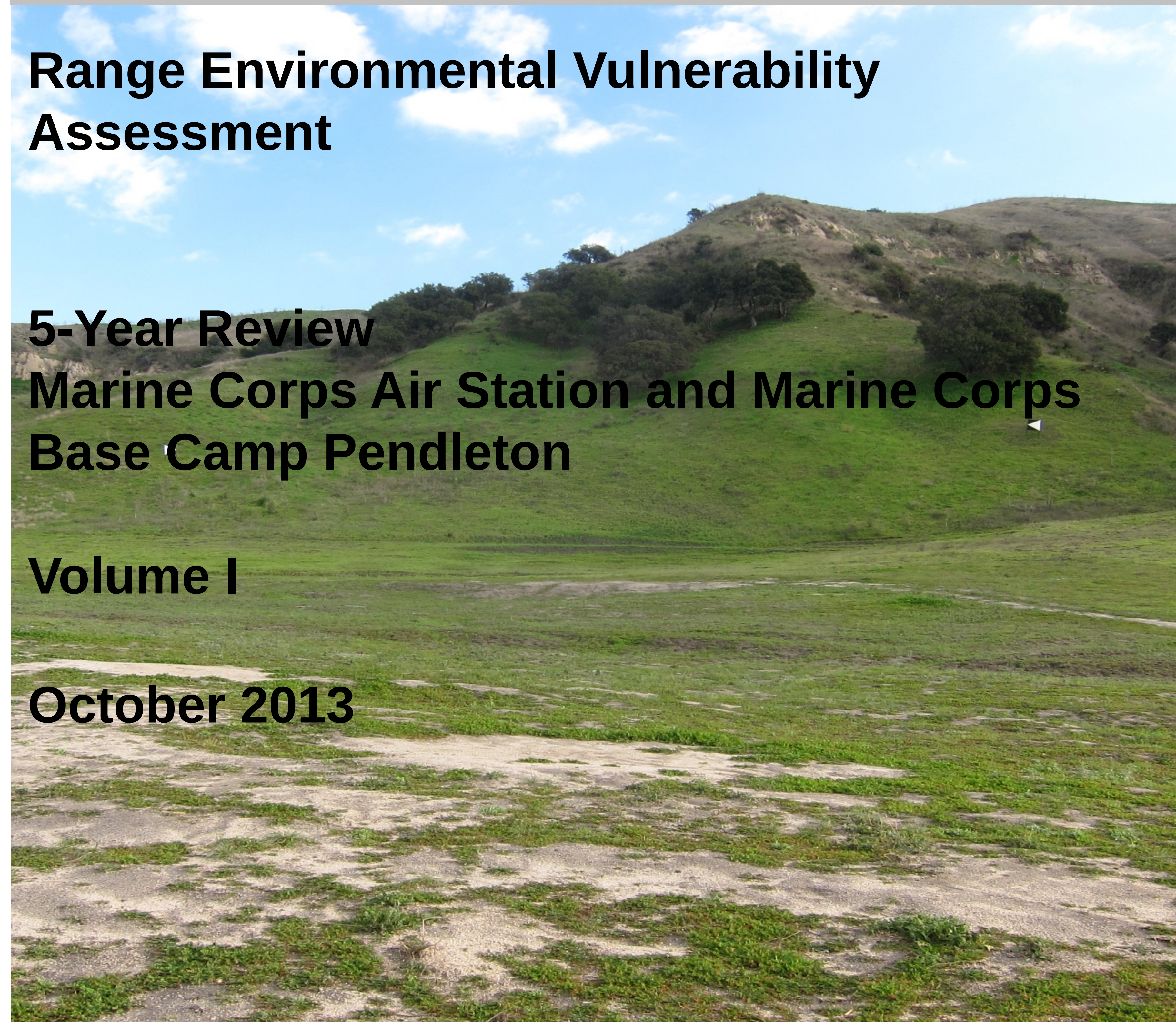
FINAL

Range Environmental Vulnerability Assessment

5-Year Review
Marine Corps Air Station and Marine Corps Base Camp Pendleton

Volume I

October 2013



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Infrastructure · Water · Environment · Buildings

Marine Corps Installations Command

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Range Environmental Vulnerability Assessment

5-Year Review

Marine Corps Air Station and Marine Corps Base Camp Pendleton

October 2013

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Table of Contents

List of Tables

List of Figures

Appendices

Acronym List

Acronym	Definition
°C	Degrees Celsius
°F	Degrees Fahrenheit
µg/kg	Micrograms per Kilogram
µg/L	Micrograms per Liter
2,4-D-6-NT	2,4-Diamino-6-Nitrotoluene
ACU-5	Assault Craft Unit 5
AFA	Artillery Firing Area
amsl	Above Mean Sea Level
AtF	Altmont Clay
bgs	Below Ground Surface
BZO	Battle Site Zero
$CaCO_3$	Calcium Carbonate
cal	Caliber
CAS	Close Air Support
CmE2	Cieneba Rocky Coarse Sandy Loam
CMP	Civilian Marksmanship Program
CmrG	Cieneba-Fallbrook Rocky Sandy Loam
CPAAA	Camp Pendleton Amphibious Assault Area
CPAVA	Camp Pendleton Amphibious Vehicle Training Area
CRWQCB	California Regional Water Quality Control Board
CSM	Conceptual Site Model

Acronym	Definition
DO	Dissolved oxygen
DoD	Department of Defense
DoDI	Department of Defense Instruction
DoDIC	Department of Defense Identification Code
DQO	Data Quality Objective
EMP	Enhanced Marksmanship Program
EOD	Explosive Ordnance Disposal
EPCRA	Emergency Planning and Community Right-To-Know Act
FeE2	Fallbrook Rocky Sandy Loam
ft/min	Feet per Minute
ft/yr	Feet per Year
GaF	Gaviota Fine Sandy Loam
GIS	Geographic Information System
HaG	Hambright Gravelly Clay Loam
HE	High Explosive
HIMARS	High Mobility Artillery Rocket System
HMX	Cyclotetramethylene Tetranitramine
HrD	Huerhuero Loam
I-5	Interstate 5
ID	Identification
IED	Improvised Explosive Device
IIT	Infantry Immersion Trainer

Acronym	Definition
INRMP	Integrated Natural Resource Management Plan
in/yr	Inches per Year
IRP	Installation Restoration Program
JIEDDO	Joint Improvised Explosive Device Defeat Organization
KD	Known Distance
kg/m^2	Kilograms per Square Meter
$kg/m^2/d$	Kilograms per Square Meter per Day
lb	Pound
lb/yd^2	Pounds per Square Yard
LeC	Las Flores Loamy Fine Sand
LFAM	Live-Fire and Maneuver
LsF	Linne Clay Loam
LZ	Landing Zone
m^2	Square Meters
Marine Corps	United States Marine Corps
MC	Munitions Constituents
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCICOM	Marine Corps Installations Command
MCL	Maximum Contaminant Level
MFA	Mortar Firing Area
MGD	Million Gallons per Day

Acronym	Definition
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
MIDAS	Munitions Items Disposition Action System
mm	Millimeter
MMRP	Military Munitions Response Program
MOUT	Military Operations in Urban Terrain
MP	Mortar Position
MS	Matrix Spike
mS/cm	Milliseimens per Centimeter
MSD	Matrix Spike Duplicate
mV	Millivolt
NEW	Net Explosive Weight
NHCP	Naval Hospital Camp Pendleton
NTU	Nephelometric Turbidity Units
Pyro	Pyrotechnic
ORC	Operational Range Clearance
QAPP	Quality Assurance Project Plan
RDX	Cyclotrimethylene Trinitramine
RETS	Remote Target System
REVA	Range Environmental Vulnerability Assessment
RFMSS	Range Facility Management Support System
RL	Reporting Limit

Acronym	Definition
RSOP	Recon Selection and Occupation of Position
RuG	Rough Broken Land
RUSLE	Revised Universal Soil Loss Equation
SACON	Shock Absorbing Concrete
SAP	Sampling and Analysis Plan
SAR	Small Arms Range
SARAP	Small Arms Range Assessment Protocol
SbC	Salinas Loamy Clay
SDZ	Surface Danger Zone
SEAL	Sea Air and Land
SESAMS	Special Effects Small Arms Marking System
SMRUF	San Mateo Regimental Urban Facility
SONGS	San Onofre Nuclear Generating Station
T/E	Threatened or Endangered
TDS	Total dissolved solids
TECOM	Training and Education Command
TERF	Terrain Flight
TNT	Trinitrotoluene
TP	Target Practice
TSE	Tactical Site Exploitation (Training Area)
TuB	Tujunga Sand
U.S.	United States

Acronym	Definition
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UXO	Unexploded Ordnance
WWII	World War II

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 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. Fate and transport modeling provides a conservative examination of MC and how they may migrate through the environment to potential receptors. Results of the model-predicted MC concentrations are compared to an established set of REVA trigger values. Each 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 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 at the Marine Corps Air Station (MCAS) and Marine Corps Base (MCB) Camp Pendleton located in Southern California.[1] 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 2009, examined and documented munitions use through 2005.

[1] There are no operational ranges at the MCAS. The remainder of this summary refers to MCB Camp Pendleton unless otherwise noted.

Military Munitions Training and Operations

MCB Camp Pendleton, the Marine Corps' largest West Coast expeditionary training facility, encompasses more than 125,000 acres in San Diego County, California (MCB Camp Pendleton, 2011d). It is the Marine Corps' premier amphibious training installation and its only West Coast amphibious assault training center. It is the only West Coast installation capable of supporting combined and comprehensive air, sea, and ground combat training. Its mission is "to operate a training base that promotes the combat readiness of the Operating Forces and the mission of other tenant commands by providing training opportunities, facilities, services and support responsive to the needs of Marines, Sailors and their families" (MCB Camp Pendleton, 2011d).

The Marine Corps began operations at MCB Camp Pendleton in 1942. The installation is subdivided into 36 training areas, including two amphibious assault landing beaches adjoining the maritime Camp Pendleton Amphibious Vehicle Training Area; six discrete impact areas; more than 150 live-fire facilities, including artillery firing areas, mortar firing areas, and small arms ranges (SARs); and approximately 230 square miles of special use airspace (MCB Camp Pendleton, 2011c).

MC loading areas are where the majority of MC is deposited within an operational range area. During the baseline REVA assessment in late 2005, MC loading areas were identified and evaluated within the context of the watersheds found within the installation boundary. Prior to assessing the current data, the results of the baseline assessment were considered.

During the five-year review, 38 MC loading areas were identified at MCB Camp Pendleton, delineated to reflect specific locations of current range facilities, known targets, and munitions use. MC loading area sizes and boundaries were adjusted based on new data collected during this five-year review and a better understanding of training activities to more realistically estimate MC loading and deposition. During the baseline assessment, large-scale assumptions were made regarding MC loading areas given the limitations in the data obtained; accordingly, 24 MC loading areas were identified. Data collected during this five-year review were more thorough and allowed for a more precise identification of discrete MC loading areas. Consequently, more MC loading areas were evaluated for this five-year review than in the baseline assessment. A total of 34 SARs were identified at MCB Camp Pendleton, but six were not used for training operations during this review period. Consequently, a total of 28 SARs were assessed during this review, using the Small Arms Range Assessment Protocol (SARAP). The 15 SARs assessed during the baseline assessment were included for this assessment.

Four watersheds, containing a total of 32 MC loading areas, were identified for screening-level analysis (surface water, sediment, and groundwater) during this five-year review: San Mateo, San Onofre, Las Flores, and Santa Margarita. During the baseline assessment, the San Mateo, San Onofre, and Las Flores watersheds underwent screening-level surface water assessment, while San Onofre and Las Flores underwent screening-level groundwater assessment. During the baseline assessment, the Santa Margarita watershed was not subject to screening-level modeling due to very low MC loading estimates for that watershed. Consequently, this is the first time this watershed has undergone screening-level modeling under REVA.

The MC loading rates were estimated for identified MC loading areas and lead loading rates for current SARs at MCB Camp Pendleton. A conceptual site model was developed for the training areas to qualitatively assess the potential for MC transport from the MC loading areas to impact identified off-range human and ecological receptors.

Conceptual Site Model for MCB Camp Pendleton

MCB Camp Pendleton occupies approximately 125,000 acres of coastal Southern California in San Diego County. Aside from nearly 10,000 acres that are developed, most of the installation is largely undeveloped land that is used for training. It consists of various terrain, including sandy shores, seaside cliffs, coastal plains, rolling hills, canyons, and mountains. The installation lies at the southern end of the Santa Ana Mountains, within the Peninsular Range of southwestern California (MCB Camp Pendleton, 2007a). The two major physiographic provinces include the coastal plains, which rise steeply from the coast inland into fairly level terraces, and the rolling foothills of the Santa Margarita Mountains. Part of the coastal area consists of steep, low hills known as the San Onofre Hills, which are dissected by the major stream systems of the installation. East of the San Onofre Hills is gently rolling topography that gives rise to the Santa Margarita Mountains.

The lower (coastal plain and coastal valley) areas of the installation receive an average precipitation of 10 to 14 inches per year (in/yr), while the precipitation at higher (mountain) elevations of the installation averages approximately 22 in/yr. Approximately 75% of the installation's precipitation falls between November and March, with the greatest annual average precipitation in January. The area's year-to-year climatic variability is an important characteristic (MCB Camp Pendleton, 2007a). Periods of drought, heavy seasonal rains, and fire are common. Wildfires occur seasonally from May through November, typically during hot and dry Santa Ana wind conditions and when a heavy vegetative fuel load is present.

The processes of soil erosion and sedimentation are important at MCB Camp Pendleton. The predominant soil series types found at the installation have severe erodibility ratings (USDA NRCS, 2007). The installation is located on a widely varying topography with steep slopes (over 90%) on the rolling hills and mountains of the coast inlands and level terraces near the coast. Soil erosion patterns are influenced largely by the aforementioned year-to-year climatic variability. The installation area is largely covered with grass, scrub, and chaparral vegetation but includes some unvegetated areas; this can vary with wildfire events. Altogether, the overall erosion potential can range from low to severe, depending on these various factors.

There are seven major watersheds within the MCB Camp Pendleton installation boundary: Aliso, Coastal, Las Flores, San Onofre, San Luis Rey, San Mateo, and Santa Margarita. The watersheds range in size from 5,800 to 99,074 acres. They are divided by mountains and mostly consist of non-perennial stream systems that flow in a southerly direction toward the Pacific Ocean, though there are a few perennial streams, including the Santa Margarita River and its tributary on the east side of the installation. Because a majority of the streams are non-perennial, they only flow following successive, major precipitation events.

The primary groundwater basins at MCB Camp Pendleton include, from northwest to southeast, the San Mateo, San Onofre, Las Flores, and Santa Margarita groundwater basins. The primary water-bearing units in the groundwater basins are the alluvial and the San Mateo aquifers; these aquifers are the groundwater-producing units in the San Mateo, San Onofre, and Las Flores basins. However, only the alluvial aquifer is the groundwater-producing unit in the Santa Margarita River basin. Groundwater in the four groundwater basins is encountered at depths shallower than 100 feet below ground surface (Stetson, 2001; Stetson, 2007; MCB Camp Pendleton, 2011e). Between the primary impact areas and the coastal plain, variably saturated alluvial deposits overlie aquitards. The amount of groundwater flowing downward into these aquitards from the alluvium likely is insignificant. The basement complex underlies the aquitards and crops out in the upland area of the installation where some of the MC loading areas are located.

Surface water runoff is the primary MC transport mechanism at operational ranges at MCB Camp Pendleton. While precipitation occurs fairly infrequently, precipitation events occasionally are torrential and lead to flash flood events. This climatic variability, along with moderately steep topography and wildfire conditions, may contribute to very high runoff rates. Further, the erodible nature of soils at the installation provides a potential sediment pathway that can transport MC to canyons through erosion or dissolution of soil and sediments in runoff water. Given that areas near the primary impact areas are underlain by either the basement complex or low permeable aquitards, it generally is anticipated that much of the surface water potentially containing MC may be transported downstream through canyons to coastal plain areas where it recharges the alluvial aquifers. Based on water level maps for the Las Flores basin, groundwater at MCB Camp Pendleton generally follows the surface topography, flowing in a southwest direction toward the Pacific Ocean (Palmer, 1994).

Potential receptors for migrating MC include human and ecological receptors. The alluvial groundwater basins in the coastal plain areas serve as the principle potable water source for MCB Camp Pendleton (MCB Camp Pendleton, 2007a). Groundwater is used for domestic and industrial purposes; over 99% of the installation's water supply is derived from on-base groundwater. Twenty-seven groundwater production wells are located in the San Mateo, San Onofre, Las Flores, and Santa Margarita groundwater basins. Other potential human receptors include contact and noncontact recreation users within major streams, river and creek mouths, coastal lagoons, and the Pacific Ocean. Potential ecological receptors include threatened, endangered, and state-listed species of special concern, which may be found in the diverse habitats located across the installation. Sixteen federally listed species may be found at MCB Camp Pendleton, including the endangered arroyo toad, the threatened California gnatcatcher, the endangered Stephens' kangaroo rat, and the threatened thread-leaved brodiaea.

Surface Water and Sediment Analyses Summary

The screening-level analyses of MC fate and transport in surface water and sediment were conducted for 32 MC loading areas located within four watershed areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing high explosives and surface drainages leading to potential receptor exposure locations. Annual average MC concentrations in surface water runoff and sediment at the edge of each MC loading area were estimated. MC concentrations in surface water and sediment in streams also were estimated at downstream locations where recharge of the alluvial groundwater basins (used as drinking water sources) occurs (i.e., potential receptor exposure locations).

Modeled annual average MC concentrations in surface water entering two identified surface water receptor locations were predicted to be above REVA trigger values (in the San Onofre and Las Flores watersheds), while modeled annual average MC concentrations in sediment entering all surface water receptor locations were predicted to be below REVA trigger values. Based on the model predictions and prior monitoring efforts, additional monitoring was conducted and is summarized in the Field Data Collection section below.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for two groundwater alluvial basins (the San Onofre and Las Flores basins) and for the Range 104B MC loading area located within the middle Santa Margarita alluvial basin. These groundwater basins were selected for quantitative transport analysis based on the surface water screening-level analysis results or the potential for MC migration to groundwater and the presence of potential groundwater receptors (drinking water production wells). Modeled MC concentrations potentially migrating to the groundwater within the San Onofre and Las Flores alluvial groundwater basins were predicted to reach drinking water wells at concentrations above REVA trigger values. At the Range 104B MC loading area, perchlorate was estimated to reach the water table at a concentration above the REVA trigger value. Perchlorate was further estimated to reach a drinking water well within the Santa Margarita alluvial groundwater basin at a concentration above the REVA trigger value. Based on the model predictions and prior monitoring efforts, additional monitoring was conducted and is summarized in the Field Data Collection section below.

Field Data Collection

Field data collection was implemented concurrently with the REVA five-year review. The design of this effort addressed findings made during two prior field data collection events: surface water and groundwater monitoring conducted as part of the baseline REVA assessment; and a 2006 effort by installation personnel involving the collection and analysis of groundwater samples which were analyzed for perchlorate. Between September 2011 and January 2012, a total of four surface water samples and six raw groundwater samples were collected from three surface water locations and six groundwater production wells spread across the San Onofre and Las Flores watersheds. Unlike sampling conducted during the baseline REVA assessment, the 2011–2012 winter season produced less than average precipitation, resulting in limited opportunities to collect surface water samples. Additionally, in the Las Flores basin, one production well was not operable and another had been replaced since the baseline, which provided limited groundwater sampling opportunities in that basin during the five-year review. Samples were analyzed for the full explosive suite and total and dissolved lead. In August 2012, a total of 13 additional raw groundwater samples were collected from productions wells located in the San Mateo, San Onofre, Las Flores, middle Santa Margarita, and upper Santa Margarita groundwater basins; these samples were analyzed for perchlorate. Analytical results from sampling conducted between September 2011 and January 2012, as well as August 2012, were all below applicable screening values.

In November 2012 and December 2012, sampling activities were initiated as part of a subsequent monitoring event; a total of two surface water samples and seven raw groundwater samples were collected from two surface water locations and seven groundwater production wells spread across the San Onofre, Las Flores, and Santa Margarita watersheds. Precipitation for the 2012-2013 winter season is presently trending behind historical averages, resulting in limited opportunities to collect surface water samples. To date, surface water sampling following a storm has not been completed; one well in the San Onofre basin, one well in the Las Flores basin, and one well in the middle Santa Margarita basin have not been operable for sampling activities during the 2012-2013 season. All samples were analyzed for perchlorate and total and dissolved lead; the full explosive suite was also analyzed on samples collected from the San Onofre and Las Flores watersheds. Analytical results from sampling conducted in November 2012 and December 2012 were all below applicable screening values.

Results and Conclusions of the REVA Five-Year Review

A summary of the results and conclusions for the watersheds and MC loading areas assessed at MCB Camp Pendleton in the REVA five-year review is presented in **Table ES-1**.

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, which generally are 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. A total of 28 SARs at MCB Camp Pendleton were evaluated during this REVA five-year review. Some of these were grouped based on similar use and setting, resulting in a total of 24 individual assessments.

SARAP evaluations completed to determine potential exposure to receptors in surface water resulted in 4 SARs with Minimal scores and 20 SARs with Moderate scores; none were rated with High scores. Assessments completed to determine potential exposure to groundwater receptors concluded 13 SARs had Minimal scores, 11 SARs had Moderate scores, and none had High scores. The predominance of Moderate scores was generally driven by a couple key factors. Most SARs at MCB Camp Pendleton are characterized by relatively high lead deposition, long history of use, and lack of bullet capture technology. This is counterbalanced by the relatively low annual precipitation that occurs at the installation, which limits transport of metals to potential receptors; scores may vary based on proximity to ecological receptors and groundwater-producing alluvial basins. Moderate and Minimal scores indicate that there is no immediate threat to human health or the environment.

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Table ES-1: Summary of Five-Year Review Assessment Results for MCB Camp Pendleton

Watershed	Analysis	Findings/Results
San Mateo	*Surface Water Screening-Level Modeling*	The modeled average annual concentrations of MC in surface water entering San Mateo Creek at the up gradient edge of the alluvial groundwater basin were predicted to be below REVA trigger values.
	Sediment Screening-Level Modeling	The average annual MC concentrations in sediment of all MC loading areas were predicted to be below REVA trigger values.
	Groundwater Screening-Level Modeling	Given the results of surface water screening-level modeling and the context of the conceptual site model, no groundwater screening-level modeling was required.
	Field Sampling	Background surface water samples from the upper portion of the watershed were collected as part of the 2012-2013 study. No detections were found with the exception of dissolved lead (maximum 0.25 μg/L). Groundwater sampling was conducted after the preliminary assessment to address data provided by the installation. Perchlorate was detected below its screening value in samples collected from two groundwater supply wells during the 2011-2012 study. No other analysis was performed on groundwater samples, nor were additional samples collected.
	CONCLUSION	**There is no immediate threat to identified receptors. No further analysis is required at this time.**
San Onofre	*Surface Water Screening-Level Modeling*	The modeled average annual concentrations of RDX, TNT, and perchlorate in surface water entering San Onofre Creek at the up gradient edge of the alluvial groundwater basin were predicted to be above REVA trigger values.
	Sediment Screening-Level Modeling	Average annual MC concentrations in sediment entering the San Onofre Creek at the up gradient edge of the alluvial groundwater basin were predicted to be below REVA trigger values.
	Groundwater Screening-Level Modeling	Saturated zone modeling predicted groundwater concentrations of RDX, TNT, and perchlorate in groundwater at the nearest drinking water production well to be above respective REVA trigger values. HMX in groundwater was not assessed based on the conceptual site model and results of the surface water screening-level modeling.

Watershed	Analysis	Findings/Results
San Onofre (continued)	*Field Sampling*	Surface water sampling was only performed during the 2011-2012 study. No explosives were detected in samples. Total lead was detected in one sample, with an estimated concentration of 0.73 µg/L. RDX was detected below its screening value in groundwater samples collected from a single well during the 2012-2013 study. Perchlorate was detected below its screening value in samples collected from four groundwater supply wells during both studies. No other analytes were detected in groundwater samples.
	CONCLUSION	**There is no immediate threat to identified receptors. As a proactive measure, annual REVA field sampling of surface water and groundwater will be conducted.**
Las Flores	*Surface Water Screening-Level Modeling*	The modeled average annual concentrations of RDX, TNT, and perchlorate in surface water entering Las Pulgas Canyon at the up gradient edge of the Las Flores alluvial groundwater basin were predicted to be above REVA trigger values.
	Sediment Screening-Level Modeling	Average annual MC concentrations in sediment entering the Las Pulgas Canyon at the up gradient edge of the Las Flores alluvial groundwater basin were predicted to be below REVA trigger values.
	Groundwater Screening-Level Modeling	Saturated zone modeling predicted concentrations of RDX, TNT, and perchlorate in groundwater at the nearest drinking water production well to be above respective REVA trigger values. HMX in groundwater was not assessed based on the conceptual site model and results of the surface water screening-level modeling.
	Field Sampling	During the 2011-2012 study, RDX was detected below its screening value in one surface water sample; 2,4-D-6-NT was detected in two surface water samples collected from one location, with a maximum estimated concentration of 1.1 µg/L; and total lead was detected in one surface water sample, with an estimated concentration of 0.64 µg/L. During the 2012-2013 study, only dissolved lead was detected below its screening level in two surface water samples. Perchlorate was detected below its screening level in samples collected from two groundwater supply wells during the 2011-2012 study. It was also detected below its screening level in two samples collected during the 2012-2013 study.
	CONCLUSION	**There is no immediate threat to identified receptors. As a proactive measure, annual REVA field sampling of surface water and groundwater will be conducted.**

Watershed	Analysis	Findings/Results
Santa Margarita	*Surface Water Screening-Level Modeling*	The modeled average annual concentrations of all MC in surface water entering three receptor locations within the Santa Margarita watershed were predicted to be below REVA trigger values.
	Sediment Screening-Level Modeling	The average annual MC concentrations in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values.
	Groundwater Screening-Level Modeling	Range 104B MC loading area is located above the middle Santa Margarita alluvial groundwater basin and was assessed separately for direct infiltration of MC and transport to groundwater. Saturated zone modeling incorporating decay mechanisms only predicted the groundwater concentration of perchlorate at the nearest drinking water production to be above its REVA trigger value.
	Field Sampling	No surface water samples were collected in this watershed during the REVA five-year review, since screening-level modeling results did not indicate MC transported in surface water would reach alluvial basins. Groundwater sampling was conducted after the preliminary assessment to address screening-level modeling results and data provided by the installation. During the 2011-2012 study, perchlorate was detected below its screening value in three of the five groundwater supply wells included in the study; no other analysis was performed on these groundwater samples. During the 2012-2013 study, no perchlorate was detected in the three groundwater supply wells included in the study. However, analysis for lead was included for this study, and total and dissolved lead was detected below applicable screening values in a sample from one groundwater supply well.
	CONCLUSION	**There is no immediate threat to identified receptors. As a proactive measure, annual REVA field sampling of groundwater production wells in the middle Santa Margarita alluvial basin will be conducted.**

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1. Introduction

1.1. Purpose

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 (DoDI) 4715.14 *Operational Range Assessments*.

The REVA program is a proactive and comprehensive program designed to support the Marine Corps' Range Sustainment Program. Operational ranges across the Marine Corps are being assessed to identify areas and activities that are subject to possible impacts from external influences, as well as to determine whether a release or substantial threat of a release of munitions constituents (MC) from operational ranges to off-range areas creates an unacceptable risk to human health and/or the environment. This is accomplished through assessments of operational range areas and periodic five-year review assessments, and, where applicable, the use of fate and transport modeling/analysis of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas.

This report presents the five-year review assessment results for the operational ranges at the Marine Corps Air Station (MCAS) and Marine Corps Base (MCB) Camp Pendleton located in Southern California.[1] This report serves as the first five-year review assessment for this installation, documenting the period of munitions loading from 2006 through 2011. The baseline assessment conducted in 2005 documented munitions use at MCB Camp Pendleton through 2004.

MCB Camp Pendleton maintains operational ranges and training areas within the installation boundaries. It encompasses approximately 125,000 acres in San Diego County, California, and is situated between two major metropolitan areas: Los Angeles, 82 miles to the north, and San Diego, 38 miles to the south. A site location map is provided as **Figure 1-1**.

[1] There are no operational ranges at the MCAS. The remainder of this report refers to MCB Camp Pendleton unless otherwise noted.

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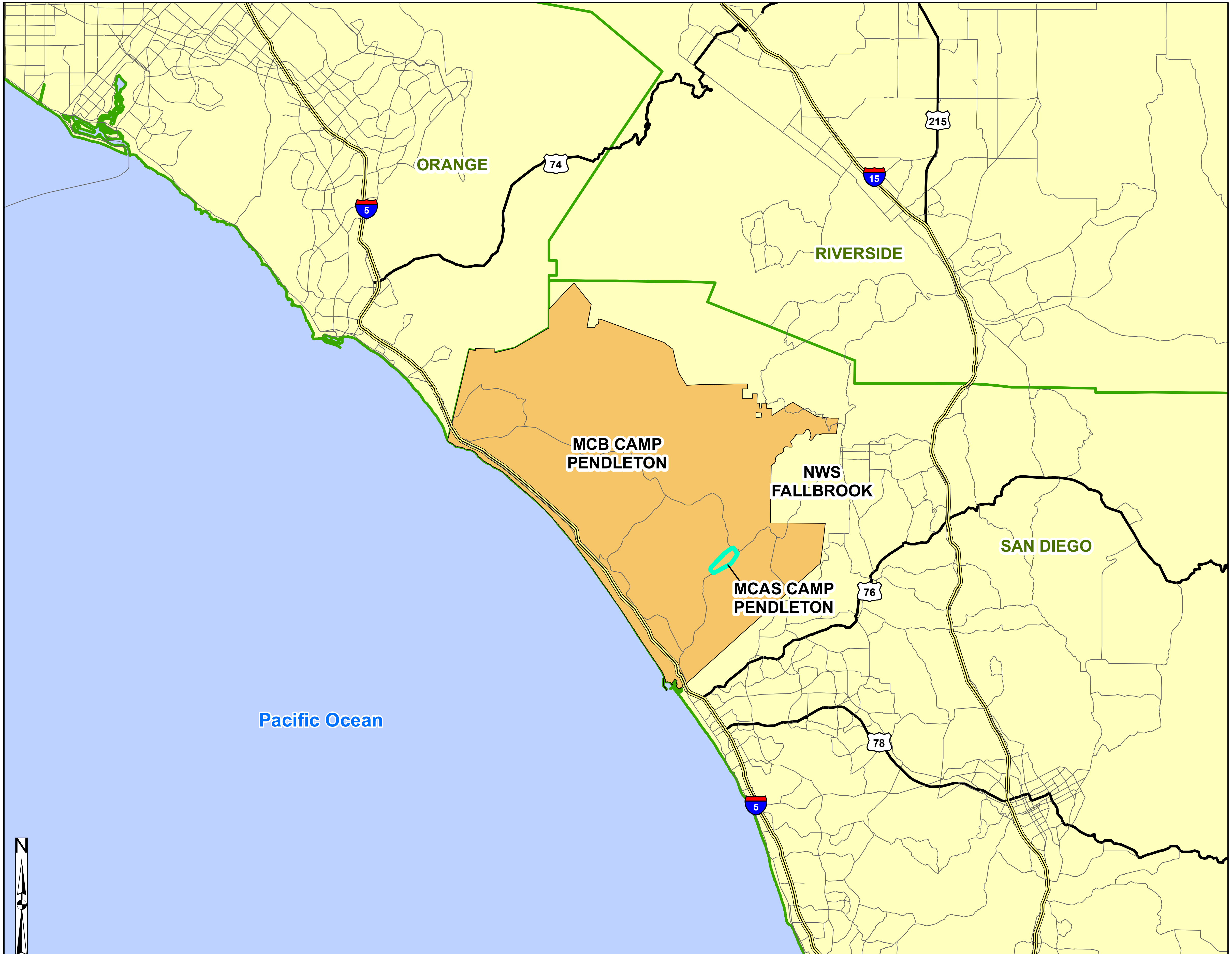
Figure 1-1

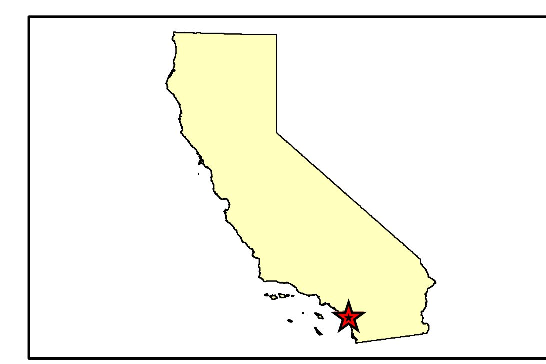
Site Location Map

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary
- County Boundary
- Road
- Interstate
- State Highway



0 5 10
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

ARCADIS MALCOLM PIRNIE

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 DoDI 4715.14 and are not assessed as part of the REVA program. Operational ranges that have a Resource Conservation and Recovery Act 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 non-operational 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. Any ranges located wholly indoors also are not included, as any 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 uses screening-level transport analyses that conservatively estimate the concentrations of MC potentially migrating to identified receptor locations. 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 5-Year Review Manual* (HQMC, 2010). 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 each considered an 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 the compound 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, and 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 detonation. As such, lead loading was estimated based on the total amount of lead content associated with the munition's 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, the results of screening-level fate and transport modeling for MC loading areas, and the results of the field sampling efforts conducted at the installation. 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 the range environmental vulnerability assessments, 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 five-year review REVA report 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. Data required for the operational range assessments were obtained from the installation during a site visit by the REVA assessment team, from Marine Corps Installations Command (MCICOM), 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 systems (GIS) files.

The REVA assessment team conducted a site visit to MCB Camp Pendleton on 25–29 September 2011. MCICOM 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:

- Assistant Chief of Staff, G-3/5
- Assistant Chief of Staff, Environmental Security
- Facilities Management Division
- Geographic Information Systems
- Public Affairs

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 approximately 30 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 MCB Camp Pendleton 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 Assessments

Section 8 – Field Data Collection Results

Section 9 – References

2. Baseline Results and Installation Changes

2.1. Baseline Results

The baseline assessment for MCB Camp Pendleton was conducted using information obtained through interviews during the baseline visit to the installation in September 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 Base Camp Pendleton* (Malcolm Pirnie, 2009). 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.

A total of 24 MC loading areas were identified in the baseline assessment. Based on discussions with installation range personnel, three of these MC loading areas (the Quebec, Whiskey, and Zulu impact areas) were designated “primary” MC loading areas, as they represent the most significant MC loading areas at the installation. These primary MC loading areas are located in the San Mateo, San Onofre, and Las Flores watersheds and were determined to require further evaluation to examine the potential for MC migration to off-site human and threatened or endangered (T/E) ecological receptors. These three impact areas were assumed to be potential up gradient sources of contamination and were modeled using surface water and groundwater screening-level analyses. The remaining MC loading areas (training areas and impact areas) outside of these three impact areas (Quebec, Whisky, and Zulu) were ranked as a lower priority or had inadequate information available to estimate MC loading rates. Consequently, these other areas were not modeled. The results of the watershed evaluations in the baseline assessment are summarized in **Table 2-1**.

A Small Arms Range Assessment Protocol (SARAP) was completed for 15 SARs identified by the REVA team as a part of the baseline assessment; results are presented in **Table 2-2**. The SARs were selected as a representative cross section of SARs present at the MCB Camp Pendleton, including consideration of the presence of berms; munitions use, including those locations with relatively high expenditures counts; environmental sensitivity related to potential lead migration; and range design. The SARAP employs a consistent methodology to identify and assess factors that influence the potential for lead migration at an operational SAR. Some of these factors include range design and layout, physical and chemical characteristics of the area, and past and present operation and maintenance practices. In addition, potential receptors and pathways are identified, and the potential for an identified receptor to be impacted by MC migration through a recognized pathway is evaluated. Through this protocol, ranges are prioritized for possible further assessment or management practices.

Table 2-1: Summary of Watersheds Evaluated in the Baseline Assessment

Watershed	Contributing MC Loading Area(s)	Screening-Level Modeling Results Predicted Exceedence of REVA Trigger Values[a]		Samples Collected After Baseline Assessment[b]	Samples Exceed DoD Values	Assess in Five-Year Review
		Surface Water	Groundwater			
Las Flores	Zulu Impact	Yes	Yes	Yes	No	Yes
San Mateo	Quebec Impact	No	No	No	Not sampled	Yes
San Onofre	Quebec Impact; Whiskey Impact	Yes	Yes	Yes	Yes[c]	Yes

Notes:
[a] Result is indicated for downstream alluvial basin.
[b] Samples were collected from surface drainages (when available) and drinking water supply wells during the 2007–2008 rainy season; more details are provided in the REVA baseline assessment (Malcolm Pirnie, 2009).
[c] A single qualified result for dissolved lead from an early-season surface water sample (collected January 2008) slightly exceeded the adjusted DoD screening value. Samples later in the rainy season were below screening values.

Table 2-2: Summary of SAR Prioritization for the Baseline Assessment

Range Number	Range Type	Surface Water Ranking	Groundwater Ranking
Range 102 (Wilcox Pistol)	KD Pistol Range	Minimal/Moderate	Moderate/High
Range 103 (Wilcox Rifle)	KD Rifle Range	Minimal/Moderate	Moderate/High
Range 111	Transition Rifle Course	Moderate	Moderate/High
Range 116A	Navy SEAL KD Rifle Range	Minimal/Moderate	Minimal/Moderate
Range 116B	Navy SEAL BZO Range	Minimal/Moderate	Minimal/Moderate
Range 130, Bay 1	Rifle/Pistol Range	Minimal	Minimal/Moderate
Range 130, Bay 2	Rifle/Pistol Range	Minimal/Moderate	Minimal/Moderate
Range 206	BZO/Non-Lethal Familiarization Firing Range	Minimal/Moderate	Moderate/High
Range 210C	BZO/EMP Range	Moderate	Moderate

Range Number	Range Type	Surface Water Ranking	Groundwater Ranking
Range 212A	BZO/Non-Lethal Familiarization Firing Range	Moderate	Moderate/High
Range 213 (Horno Pistol)	KD Pistol Range	Moderate	Moderate/High
Range 214 (Horno Rifle)	KD Rifle Range	Minimal/Moderate	Moderate/High
Range 300	BZO/EMP Range	Moderate	Moderate/High
Edson Pistol Range	KD Pistol Range	Minimal	Moderate
Edson Rifle Range B	KD Rifle Range	Minimal/Moderate	Moderate

Notes:
BZO = Battle Sight Zero
EMP = Enhanced Markmanship Program
KD = Known Distance
SEAL = Sea, Air and Land

As part of the baseline assessment, four sampling events were completed between December 2007 and April 2008 in the Las Flores and San Onofre watersheds. These events included surface water and groundwater sampling and were conducted to obtain samples at the seasonal "first flow" as well as at subsequent times during the rainy season when water flow continued at surface water sampling locations. All samples were analyzed for the full suite of explosives (excluding perchlorate) and total and dissolved lead. The results supported continued monitoring, though did not constitute an immediate threat to human health or the environment. These findings are further detailed in the baseline report, and also were used to compare to the sampling results from this five-year review.

2.2. Installation Changes

2.2.1. Changes at MCB Camp Pendleton

Training at MCB Camp Pendleton has undergone modifications since the baseline assessment, which has resulted in changes to the range areas. These changes are as follows:

- Several new Military Operations in Urban Terrain (MOUT) facilities, along with associated improvised explosive device (IED) and combat vehicle courses, have been constructed to better reflect the current mission requirements of today's Marines.
- Three new training areas, three new fixed ranges, and one new live-fire and maneuver (LFAM) area have been established since the baseline assessment.

- The installation's main explosive ordnance disposal (EOD) facility has been relocated from Range 401 to Range 108. G-3/5 personnel indicate that future plans for Range 108 include additional construction to better facilitate the EOD operations conducted there.
- Use of the High Mobility Artillery Rocket System (HIMARS) has been incorporated as an authorized weapon system at three artillery firing areas (AFAs).
- Various ranges have had increases/decreases in expenditures.
- The training and impact area boundaries observed during the baseline REVA assessment have undergone minor changes; however, the operational training and impact areas generally encompass the same areas.
- MCB Camp Pendleton initiated an installation-wide operational range clearance (ORC) program in December 2008 to supplement routine range maintenance activities provided by EOD personnel.

Additional details pertaining to the installation changes since the baseline assessment can be found in **Section 3.5**.

2.2.2. Changes in REVA Assessment

The baseline REVA evaluation of MCB Camp Pendleton focused on linking MC loading to training and impact areas. For this REVA review, the MC loading area boundaries were adjusted to reflect specific locations of range facilities, known targets, and munitions data. This adjustment resulted in a different number of MC loading areas and significant changes in size of some key MC loading areas. There were fewer yet typically larger MC loading areas during the baseline; this change resulted in a greater number of typically smaller MC loading areas, which provides a more realistic representation of MC deposition areas across the installation. This will be discussed in further detail in **Section 3**.

MC loading rates in the baseline assessment were estimated by evaluating the level of use, duration of MC loading (to include historical loading), expected presence of REVA indicator MC, size, and current status for each MC loading area. Expenditure data were not available from range personnel for use in the baseline assessment, which posed a significant source of uncertainty to the MC loading calculations. In late 2009, increased tracking of expenditures by MCB Camp Pendleton was implemented using the Range Facility Management Support System (RFMSS). This yielded expenditure data that better reflects range use during the five-year review period. Therefore, MC loading rates for the five-year review assessment were based on actual expenditure data, which resulted in a greater level of confidence in the MC loading estimates and the screening-level transport analysis results.

Lead was considered only for SARs in the baseline assessment. 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 this review. The total 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 generally are not available without site-specific investigations.

No other significant changes from the baseline assessment to operational range boundaries, training mission, training tempo, or other parameters were identified during the five-year review data gathering effort that would impact MC loading or input parameters for fate and transport modeling.

2.3. Summary of Areas Addressed

The baseline assessment report identified 24 MC loading areas. Based on the results of the baseline assessment as detailed above and additional data collected for the five-year review effort, 38 MC loading areas were defined for MCB Camp Pendleton as follows:

- Horno Combat Town
- Kilo 2 Combat Town
- LFAM 706
- PDL Combat Town
- Quebec Impact
- Range 104B
- Range 108
- Range 109
- Range 130 Breach
- Range 132 Complex
- Range 201
- Range 202
- Range 203
- Range 204B
- Range 207
- Range 208C
- Range 210D
- Range 210E/210F
- Range 211
- Range 215A
- Range 216 House
- Range 217/219
- Range 218A
- Range 221/222
- Range 223B
- Range 225
- Range 227
- Range 301
- Range 302
- Range 307
- Range 314 Complex
- Range 401
- Range 407 Complex
- Range 408
- Range 409A
- Range 600
- Whiskey Impact
- Zulu Impact

The baseline assessment report evaluated 15 SARs using the SARAP. These 15 SARs represented a cross-section of all SAR designs at MCB Camp Pendleton, as well as locations of high munitions use and environmental sensitivity related to potential lead migration. During the five-year review, a total of 28 active SARs were evaluated through the completion of 24 SARAPs. This was due to the combination of multiple adjacent ranges/bays into a single SARAP (Edson Rifle Ranges A-D; Bays 1 and 2 of Range 130). Thirteen of these SARs were not evaluated in the baseline assessment and are denoted in the list below by an asterisk. The following SARs were evaluated through the SARAP in the five-year review:

- Edson Pistol
- Edson Rifle A*
- Edson Rifle B
- Edson Rifle C*
- Edson Rifle D*
- Range 102
- Range 103
- Range 110*
- Range 111
- Range 112A*
- Range 116A
- Range 116B
- Range 116C*
- Range 117A*
- Range 127*
- Range 130, Bay 1
- Range 130, Bay 2
- Range 206
- Range 210C
- Range 210G*
- Range 212A
- Range 213
- Range 214
- Range 216 BZO*
- Range 223A 200-Yard*
- Range 300
- Range 303*
- Range 501*

3. Munitions Constituents Loading Rates and Assumptions

The qualitative 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 review of training at MCB Camp Pendleton, 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 MCB Camp Pendleton are discussed in its baseline REVA Report (Malcolm Pirnie, 2009). This five-year review utilizes and builds upon this process, developing MC loading estimates expressed as the average areal 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 present). 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 MCB Camp Pendleton and defines the specific MC loading areas identified for the installation 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 6**.

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 ORDATA database (2012).

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 (high order, low order, and UXO) for a given MC loading area. Details on this process are included in the MCB Camp Pendleton baseline report (Malcolm Pirnie, 2009) and the *REVA Reference Manual* (HQMC, 2009).

When calculating MC loading for a range/training area that is determined to be regularly and intensely managed for explosive hazards (e.g., demolition or engineering range), dud and low order rates were set to zero. Dud/UXO rates associated with DoDICs reported in the expenditure data were not used in place of the standard dud assumptions for 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 five-year review. Small arms are presumed to be the most significant contributor to lead deposition at operational ranges and training areas, though the metal also may 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 of REVA indicator MC (i.e., no loss due to detonation of the munition) from impact and that all of the lead contained within the munition is deposited in the MC loading area. Estimation of lead available for transport is not possible without site-specific information; consequently, the lead deposition estimates do not include a consideration of exposure to the environment. This is further complicated 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, lead deposition rates are not intended to be used for quantitative or qualitative analysis with regard to potential transport from the MC loading area. 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 the potential for off-site impacts, as covered in **Section 7**.

Additional specifics regarding how these data were incorporated are explored in the aforementioned *REVA Reference Manual* and baseline *REVA Report for MCB Camp Pendleton*.

3.2. Expenditure Data

G-3/5 is responsible for the management of the training areas and ranges present at MCB Camp Pendleton. G-3/5 coordinates primary recordkeeping for munitions expenditures at the operational ranges of the installation through use of the RFMSS. Expenditure tracking using RFMSS was not fully implemented at MCB Camp Pendleton until late 2009. These data were provided in electronic format.

The use of documented expenditure data is preferred in the REVA program. A quality review of the expenditure data provided by the installation resulted in a series of assumptions applicable across operational training areas at MCB Camp Pendleton:

- Two sources of expenditure data were provided by the installation. Environmental Security provided expenditure data gathered to support annual Emergency Planning and Community Right-To-Know Act Section 313 (EPCRA) reports for 2004 to 2010. G-3/5 provided RFMSS data for the period January 2010 through August 2011. G-3/5 indicated that expenditure reports were not consistently entered into RFMSS prior to this time, because use of RFMSS for reporting expenditures was not required during this time period.
    - Data used to support EPCRA reporting raised significant issues concerning the degree to which the data could be extrapolated to produce useful MC loading estimates. In many cases, millions of rounds were listed without association to a range or training facility. Numerous instances were identified in each year of available data where the type or volume of munitions was inconsistent with other available information. Consequently, these data were not used in the calculation of MC loading rates.
    - Installation personnel indicated that training patterns and rates have not experienced significant shifts during the elapsed time since the baseline REVA assessment. Consequently, it was assumed that the RFMSS data covering the period of January 2010 through August 2011 could be extrapolated to estimate annual averages of expenditures. Other available information was used to determine when ranges operated during the review period. Regardless, the annual expenditure averages for each range developed from the 20 months of RFMSS data were assumed to be representative of use for any given range during its time of operation during the five-year review period.
    - The RFMSS data for 2011 did not constitute a full year at the time it was collected because it did not include counts for September, October, November, and December. Expenditure counts from the available eight months of data were increased proportionately to estimate total expenditures for the entire 2011 year.
- The expenditure summaries contain some DoDICs for which data regarding MC content were not available in MIDAS or other inventories.

  - In some of these instances, general descriptions of the munitions associated with these DoDICs were identified, either as part of the installation data or as found in other readily available sources. These were reviewed, along with available information regarding the associated range, its design, and its regulations, and a surrogate MC loading factor was chosen from available data for similar munitions for use in MC loading calculations.
  - In other instances, no description of the munitions was provided. The associated expenditure counts for the unknown DoDICs were distributed proportionally among other known DoDICs (and within known locations, when available), based on totals for the other DoDICs listed for the same range within that given year.
- In a few instances, expenditure data with known DoDICs were associated with ranges where some or all of the listed munitions would not be permitted. In a couple of these scenarios, the actual range or training area could not be discerned based on the provided information. Consequently, these munitions were distributed proportionally among other known occurrences of the DoDICs for that given year.

Additionally, key assumptions were developed with regard to EOD activities at MCB Camp Pendleton. As previously mentioned, Range 108 currently is the primary EOD range at the installation. The items destroyed at Range 108 are not captured in the RFMSS data. Also, EOD occasionally may destroy items in place due to transportation safety hazards or may elect to recover suitable items for resubmission to the Ammunition Supply Point. RFMSS does not account for these EOD activities and, therefore, does not account for how these activities may affect MC loading.

EOD personnel provided a record of commitment sheets used to account for EOD-related expenditures that may not be captured in the RFMSS data. The sheets cover the period of 31 August 2010 to 26 August 2011 and contain detailed information about what UXO was found, where it was found, and what remedy was applied, including a record of any transport or demolition materials used. These data were used to develop a single year of averages, which supplemented information extracted from the RFMSS data, using the following assumptions:

- DoDICs where MC content data were not available in MIDAS or other inventories were managed using assumptions similar to those described previously in this section.
- Only EOD calls involving demolitions (as opposed to recovery, for example) were reviewed for this assessment. Counts of destroyed items found at a demolition location were not included because it was assumed that those munitions were part of regular training activities and already captured in the expenditure data.
- When information regarding the location of demolition was not provided, it was assumed to have occurred at Range 108.

- The EOD data covered 12 months of operations. These data were assumed to represent a typical year of operation, and the totals were added to corresponding annual averages developed from the expenditure data.
- As previously noted, one of the significant changes that occurred during this review period was the transfer of the primary EOD demolition and training activities from Range 401 to Range 108 in June 2009. Considering that RFMSS data were only available from January 2010 to September of 2011 and the commitment sheets did not account for demolition activities taking place within the period that Range 401 was active, there was no representation of activities at Range 401. Assuming the assembled data represent an average year of demolition activities throughout the review period, expenditure averages estimated for Range 108 were assumed to be representative of Range 401 during the years it served as the primary EOD range (2006–2009).

Given these considerations, RFMSS expenditure data spanning approximately 20 months (January 2010 through August 2011) and EOD commitment sheet data spanning 1 year (August 2010 through August 2011) were used for MC loading calculations associated with current MC loading areas at MCB Camp Pendleton, 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 3.6**. 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 and low order and high order detonations. Additionally, it utilizes training factors (discussed in **Section 3.4**) to account for fluctuations in training during periods of use where no expenditure data are available.

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 elsewhere in **Section 3** and in **Section 6**.

3.4. Training Factor

Typically, the REVA program assesses the potential influence of historical MC loading through the use of training factors in the MC Loading Calculator. Training factors are associated with different time periods and are based on fluctuations associated with the start and cessation of a conflict or war. Subject matter experts within the Marine Corps were queried to establish training factors and time periods (a total of five periods), and this information is used to extrapolate historical MC loading across the entire known time period of range operation using current expenditure data:

- Period A: 1914–1924 (baseline + 40%)
- Period B: 1925–1937 (baseline)
- Period C: 1938–1976 (baseline + 50%)
- Period D: 1977–1988 (baseline + 20%)
- Period E: 1989–baseline REVA assessment (baseline + 50%)

Training factors were used to complete the baseline REVA assessment of MCB Camp Pendleton. However, since no additional historical MC loading was identified during this five-year review, training factors were unnecessary for MC loading calculations. A "Period F" was established to represent the time period covered by this five-year review; no training factor was applied to this time period since actual expenditure data were obtained from RFMSS.

3.5. Munitions Constituents Loading at MCB Camp Pendleton

MCB Camp Pendleton, the Marine Corps' largest West Coast expeditionary training facility, encompasses more than 125,000 acres in San Diego County, California (MCB Camp Pendleton, 2011d). It is the Marine Corps' premier amphibious training installation and its only West Coast amphibious assault training center. It is the only West Coast installation capable of supporting combined and comprehensive air, sea, and ground combat training. MCB Camp Pendleton is home to the 1st Marine Expeditionary Force, 1st Marine Division, 1st Marine Logistics Group, and many tenant units, including Marine Corps Installation-West, 1st Marine Special Operations Battalion, Wounded Warriors Battalion-West, MCAS at Munn Field, Marine Aircraft Group 39, Marine Corps Tactical Systems Support Activity, Marine Corps Recruit Depot San Diego's Weapons & Field Training Battalion, Marine Corps and Army Reserve Forces, the United States Navy's Assault Craft Unit 5 (ACU-5), Naval Hospital Camp Pendleton (NHCP), and the 1st Dental Battalion. The coastal and mountain terrain supports a variety of military training, and Fleet Marine Force units use MCB Camp Pendleton's ranges and training areas to maintain combat readiness.

MCB Camp Pendleton's operational training space includes training areas, impact areas, live-fire and maneuver zones, and fixed ranges (including SAR, EOD, and MOUT ranges). Each of these operational training spaces is described in the following sections. A summary of each range and training area, including information regarding location, size, usage profile, and authorized munitions, is provided in **Table 3-1**.

3.5.1. Training Areas

As the Marine Corps' premier amphibious assault training base, MCB Camp Pendleton utilizes the marine waters and coastline immediately west of the installation. These areas include the Camp Pendleton Amphibious Vehicle Training Area (CPAVA), which is located within the Navy's Camp Pendleton Amphibious Assault Area (CPAAA). The CPAVA is an ocean area adjacent to the shoreline of MCB Camp Pendleton used for nearshore amphibious vehicle and landing craft training (DoN, 2008). Due to the lack of restrictions on public access imposed in the CPAVA and the CPAAA, small pleasure craft and fishing boats often operate within their boundaries; thus, neither supports live-fire training (MCB Camp Pendleton, 2008).

MCB Camp Pendleton contains approximately 115,000 acres dedicated to maneuver, live-fire, and tactical training. There currently are 36 operational training areas including beaches within that 115,000 acres that are utilized as maneuver and training areas for light, heavy, or amphibious forces (see **Figure 3-1)**. Authorized military munitions in these areas are limited to blanks and pyrotechnics, unless other munitions are permitted by the ranges contained within the training areas. Additionally, several reconnaissance selection and occupation of position (RSOP) sites, landing zones (LZs), and terrain flight (TERF) routes are present throughout the training areas.

As previously mentioned, three new training areas have been designated since the baseline REVA assessment. The Sierra One, Sierra Two, and Sierra Three Training Areas encompass approximately 470 acres located immediately west of the Bravo Three. A summary of training areas and facilities is provided in **Table 3-1**.

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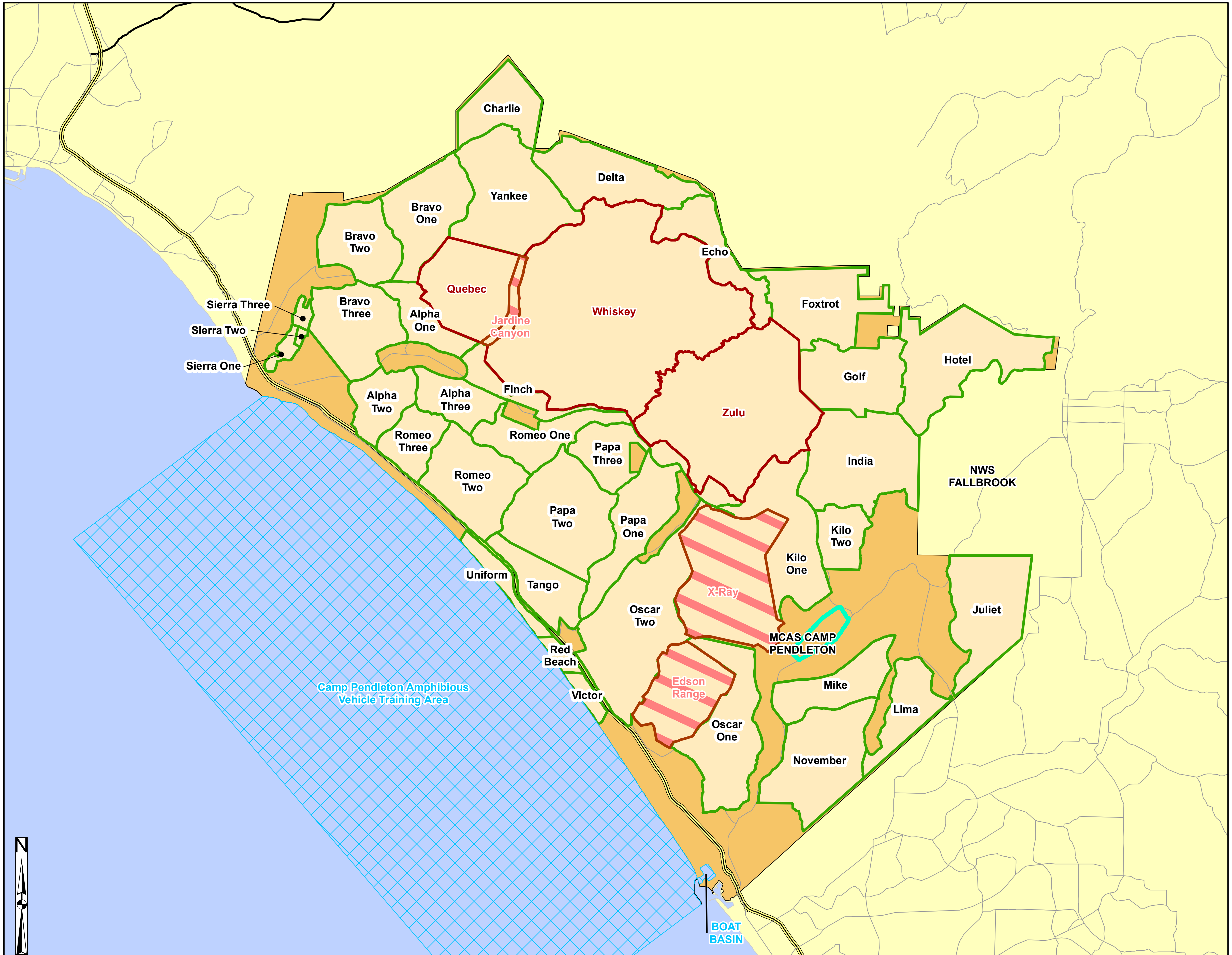
Figure 3-1

Training Areas and Impact Areas at MCB Camp Pendleton

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Dud Producing Impact Area
- Non-Dud Producing Impact Area (Limited Access)
- Training Area, Land
- Training Area, Water
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary

Note:
Only impact areas associated with multiple ranges are presented due to scale.

0 3 6
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

Table 3-1: Summary of Operational Ranges and Training Areas, MCB Camp Pendleton

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
Alpha One	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**1,100**	**Maneuver and training area, light forces**
Alpha Two	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,329**	**Maneuver and training area, amphibious forces**
	52 Area Combat Town	--	X	SESAMS, all blanks, pyrotechnics, CS/HC, artillery sims	--	Also listed as "CBT 52." Combat town adjacent to south side of San Onofre Creek. Per current range complex management plan (2008), it is planned to be replaced by the Bravo Three Combat Town. Still active as of 2011.
	Range 200	--	--	None	--	Inactive 2006–present. Combat trail / infiltration course
	Range 200B	--	--	SESAMS, all blanks, pyrotechnics	--	**Inactive** 2006–present. Small arms (blanks) and infiltration course
	Range 207A	--	X	SESAMS, all blanks, flash bang grenade, artillery sims, small arms breacher rounds, explosives (0.18 lb NEW)	--	MOUT with light demolition for breaching; associated non-dud-producing impact area
Alpha Three	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,265**	**Maneuver and training area, light forces**

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 207	--	--	Explosives (2 lb NEW)	--	Light demolition range; associated non-dud-producing impact area
Bravo One	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**2,494**	**Maneuver and training area, amphibious forces**
	AFA-H	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-I	--	--	Artillery, mortars, small arms	--	AFA; fires into Whiskey and Zulu Impact Areas.
	LFAM 706 (portion in Quebec Impact Area)	--	--	Small arms, practice/signal, hand grenades, mortars, rockets, smoke grenades, explosives (15 lb NEW), SESAMS	--	LFAM used by platoon-sized or smaller infantry assault units within a live-fire, ambush scenario. Fires into Quebec Impact Area.
	LFAM 710A (portion in Quebec Impact Area, Whiskey Impact Area, and TA Yankee)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized units in mobile assault scenarios that integrate infantry units with direct fire and aerial support and include the use of ordnance. Fires into Quebec and Whiskey Impact Areas. Represents a portion of "LFAM 710," identified in the REVA baseline.
	Range 307	--	--	Grenades	--	Hand grenade range

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 312A	X	--	Small arms	--	**Inactive** 2006–present. Pistol KD range. Associated non-dud-producing impact area linked to San Mateo Canyon Impact Area in REVA baseline.
	Range 313	X	--	Small arms	--	**Inactive** 2006–present. Rifle KD range. Identified in REVA baseline as "Range 313A." Associated non-dud-producing impact area linked to San Mateo Canyon Impact Area in REVA baseline.
	Range 314D	--	--	SESAMS, blanks, pyrotechnics	--	SESAMS range used for force-on-force training; no operational activity identified during REVA baseline assessment (operation commenced August 2005).
	San Mateo Convoy Course (portion in TA Yankee, TA Delta, TA Echo, and Whiskey Impact Area)	--	--	Small arms	--	LFAM for vehicle maneuvering exercises. Only permitted to use non-dud-producing ordnance outside of Whiskey Impact Area. Operations commenced April 2011.
	Tactical Site Exploitation	--	X	SESAMS, all blanks, pyrotechnics, artillery sims, BFX	--	Also listed as TSE. Non-live-fire MOUT facility; includes IED training lanes associated with the JIEDDO. Operations commenced March 2010.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
Bravo Two	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,986**	**Maneuver and training area, amphibious forces**
	AFA-5	--	--	Artillery	--	AFA; fires into Whiskey Impact Area; no operational activity identified during REVA baseline assessment.
	AFA-6	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	AFA-7	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	Bravo Two Combat Town	--	X	SESAMS, all blanks, pyrotechnics, CS/HC, artillery sims, BFX	--	Also listed as “CBT B2.” Non-live-fire MOUT facility; operation commenced 2010.
	Range 302	--	--	Small arms, fragmentation and practice grenades, flash bang grenades	--	SACON house (no roof); constructed 2007 and operation commenced September 2009.
Bravo Three	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**2,467**	**Maneuver and training area, amphibious forces**
	Bravo Three Combat Town	--	X	SESAMS, small arms breaching rounds, all blanks, pyrotechnics, CS/HC, smoke grenades, non-lethal grenades, artillery sims	--	Also listed as “CBT B3”; non-live-fire MOUT facility
	Range 300	X	--	Small arms	--	Basic zero firing range; associated non-dud-producing impact area

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 301	--	--	Small arms, practice mines, flash bang grenades	--	Three SACON houses (no roofs); constructed 2007 and operation commenced September 2009.
	SMRUF/62 RUF	--	X	SESAMS, all blanks, pyrotechnics, artillery sims, BFX	--	Also listed as "CBT 62 RUF." Non-live-fire MOUT facility; operation commenced February 2010.
Charlie	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**1,641**	**Maneuver and training area, light forces**
Delta	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**2,635**	**Maneuver and training area, amphibious forces**
	AFA-44 (portion in TA Echo)	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	AFA-45	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-46	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-A (portion in TA Yankee)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-B	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas; no operational activity identified during previous REVA baseline assessment.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 710B (portion in TA Echo, TA Yankee, and Whiskey Impact Area)	--	--	Unknown, though assumed to include munitions authorized for LFAM 710A	--	LFAM largely located over Whiskey Impact Area; assumed to fire into Whiskey Impact Area. Represents a portion of "LFAM 710," identified in the REVA baseline.
	San Mateo Convoy Course (portion in TA Bravo One, TA Echo, TA Yankee, and Whiskey Impact Area)	--	--	Small arms	--	LFAM for vehicle maneuvering exercises. Only permitted to use non-dud-producing ordnance outside of Whiskey Impact Area. Operations commenced April 2011.
Echo	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,704**	**Maneuver and training area, amphibious forces**
	AFA-40	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-41	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-42	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-43 (portion in Whiskey Impact Area)	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	AFA-44 (portion in TA Delta)	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	AFA-C (portion in Whiskey Impact Area)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-D	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	LFAM 710B (portion in TA Delta, TA Yankee, and Whiskey Impact Area)	--	--	Unknown, though assumed to include munitions authorized for LFAM 710A	--	LFAM largely located over Whiskey Impact Area; assumed to fire into Whiskey Impact Area. Represents a portion of "LFAM 710," identified in the REVA baseline.
	LFAM 711 (portion in Whiskey Impact Area and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company-sized units for heavy weapon insertion by helicopter and live-fire attacks in an offensive scenario; fires into Whiskey Impact Area.
	LFAM 800 (portion in Whiskey Impact Area)	--	--	Unknown, though assumed to include munitions authorized for Range 800		LFAM, which overlaps with Range 800; fires into Whiskey Impact Area. No operational activity identified during REVA baseline assessment.
	MFA-8 (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-9 (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	MFA-9A (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	Range 800 (portion in Whiskey Impact Area)	--	--	Small arms, explosives (27 lb NEW), rifle grenades, mines, obstacle-clearing munitions, mines, hand grenades, missiles, mortars, smoke grenade, cannons, rockets	--	Company-level live-fire and maneuver range. Associated non-dud-producing impact area located in Echo, immediately adjacent to Whiskey Impact Area
	San Mateo Convoy Course (portion in TA Bravo One, TA Delta, TA Yankee, and Whiskey Impact Area)	--	--	Small arms	--	LFAM for vehicle maneuvering exercises. Only permitted to use non-dud-producing ordnance outside of Whiskey Impact Area. Operations commenced April 2011.
Edson Range Impact Area	**--**	**--**	**--**	**Small arms, hand grenades, and pyrotechnics permitted**	**2,299**	**Non-dud-producing impact area supporting WFTBN recruit training; designation based on historical use**
	Edson A	X	--	Small arms, pyrotechnics	--	Rifle KD range
	Edson B	X	--	Small arms, pyrotechnics	--	Rifle KD range
	Edson C	X	--	Small arms, pyrotechnics	--	Rifle KD range
	Edson D	X	--	Small arms, pyrotechnics	--	Rifle KD range
	Edson Pistol	X	--	Small arms	--	Pistol KD range

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 501	X	--	Small arms, pyrotechnics	--	Automated field firing range
Finch	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,447**	**Maneuver and training area, light forces**
	AFA-10 (portion in Zulu Impact Area)	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-17 (portion in Zulu Impact Area)	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-18	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-J (portion in Whiskey Impact Area)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	HRUF	--	X	SESAMS, all blanks, pyrotechnics, artillery sims, BFX	--	Also listed as “CBT HRUF.” Non-live-fire MOUT facility; construction commenced September 2010; operation commenced August 2011.
	LFAM 703 (portion in Zulu Impact Area)	--	--	Small arms, mortars, cannons, rockets, rifle grenades, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by squad-sized units within an offensive range, live-fire scenario. Fires into Zulu Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 708 (portion in Whiskey Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	**Inactive 2006–present.** LFAM used by squad-sized infantry for live-fire assault scenarios; fires into Whiskey Impact Area.
	MFA-13 (portion in Zulu Impact Area)	--	--	Mortars	--	Fires into Zulu Impact Area.
	MFA-15 (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.
Foxtrot	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**2,673**	**Maneuver and training area, amphibious forces**
Golf	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**2,542**	**Maneuver and training area, amphibious forces**
	AFA-36	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-37	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-38	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 700 (portion in TA India, TA Kilo One, TA Kilo Two, X-Ray Impact Area, and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by battalion-sized units for integration of infantry, aviation, and mechanized units; fires into Zulu Impact Area.
	MFA-10 (portion in Zulu Impact Area)	--	--	Mortars	--	Fires into Zulu Impact Area.
	Range 409A	--	--	Small arms, rifle grenades, rockets, missiles, mortars, cannons, rockets	--	Automated multipurpose training range. Associated non-dud-producing impact area located in TA Golf and TA Foxtrot.
Hotel	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,746**	**Maneuver and training area, amphibious forces**
	AFA-35	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-39	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-E	--	--	Artillery	--	AFA; fires into Zulu Impact Area; no operational activity identified during previous REVA baseline assessment.
	AFA-F	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
India	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,736**	**Maneuver and training area, amphibious forces**

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	AFA-26	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	AFA-27	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-28	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-29	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-31	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-32 (portion in Zulu Impact Area)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-33	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-34	--	--	Artillery		AFA; fires into Whiskey and Zulu Impact Areas.
	Camp DeLuz Combat Town	--	X	SESAMS, all blanks, pyrotechnics, CS/HC smoke, artillery sims	--	Also listed as “CBT DLZ.” Non-live-fire MOUT facility. Operations commenced October 2009.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 700 (portion in TA Golf, TA Kilo One, TA Kilo Two, X-Ray Impact Area, and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by battalion-sized units for integration of infantry, aviation, and mechanized units; fires into Zulu Impact Area.
Jardine Canyon Impact Area	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**350**	**Maneuver and training area; non-dud-producing impact area designated for safety purposes**
	LFAM 709 (portion in Whiskey Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used to support aerial assaults on a mechanized enemy column using anti-armor weapons systems. Fires into Whiskey Impact Area.
	MFA-5 (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.
Juliet	**--**	--	--	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,014**	**Maneuver and training area, amphibious forces**
	Range 403A	X	--	Small arms	--	**Inactive** 2006–present; associated non-dud-producing impact area
	Range 403B	X	--	Small arms	--	**Inactive** 2006–present; associated non-dud-producing impact area

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 403C	X	--	Small arms	--	**Inactive** 2006–present; associated non-dud-producing impact area
	Range 403D	X	--	Small arms	--	**Inactive** 2006–present; associated non-dud-producing impact area
Kilo One	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,125**	**Maneuver and training area, amphibious forces**
	AFA-19	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-21	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-22	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-30	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	LFAM 700 (portion in TA Golf, TA India, TA Kilo Two, X-Ray Impact Area, and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by battalion-sized units for integration of infantry, aviation, and mechanized units; fires into Zulu Impact Area.
	MFA-11	--	--	Mortars	--	Fires into Zulu Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
Kilo Two	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,064**	**Maneuver and training area, amphibious forces**
	AFA-24	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	25 Area Combat Town	--	X	SESAMS, blanks, pyrotechnics, CS/HC smoke, artillery sims, breaching-related munitions (0.25 lb NEW for explosives if authorized)	--	Also listed as "CBT 25." Non-live-fire MOUT facility
	Kilo Two Combat Town	--	X	SESAMS	--	Also listed as "CBT K2." Non-live-fire MOUT facility. Built 2007, operations commenced March 2008.
	LFAM 700 (portion in TA Golf, TA India, TA Kilo One, X-Ray Impact Area, and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by battalion-sized units for integration of infantry, aviation, and mechanized units; fires into Zulu Impact Area.
Lima	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**1,488**	**Maneuver and training area, heavy forces**
Mike	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**1,776**	**Maneuver and training area, amphibious forces**
November	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,245**	**Maneuver and training area, amphibious forces**

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	FMSS Combat Town	--	X	SESAMS, all blanks, pyrotechnics, CS and HC smoke, artillery sims	--	Also listed as "CBT FMSS." Also Field Medical Training Battalion Facility; non-live-fire MOUT facility
	Range 401	--	--	Explosives (95 lb NEW)	--	Previously known as Range 101. Former main EOD range (with associated non-dud-producing impact area) as of June 2009. This range will be converted into military police K-9 training area.
Ocean Range (Boat Basin and CPAVA)	**--**	**--**	**--**	**Blanks only**	**--**	**Maritime maneuver and training area**
Oscar One	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,093**	**Maneuver and training area, amphibious forces**
	Range 503	--	--	Grenades	--	**Inactive** 2006–present; live hand grenade range
	Range 505	--	--	Blanks only	--	Infiltration course; non-live-fire permitted only
	Range 505A	--	--	Blanks only	--	Infiltration course; non-live-fire permitted only
	Range 505B	--	--	Blanks only	--	Infiltration course; non-live-fire permitted only

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
Oscar Two	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**5,079**	**Maneuver and training area, amphibious forces**
	Range 108	--	--	Small arms, explosives (300 lb NEW)	--	Main EOD demolitions range as of June 2009. EOD is primary user, but range is still utilized as sniper field fire range.
	Range 109	--	--	Grenades	--	Live hand grenade range
	Range 110	X	--	Small arms, practice rifle grenades	--	Familiarization range; previously accommodated M203 HE in adjacent area until 2009. Also used by visiting law enforcement agencies. No operational activity identified during previous REVA baseline assessment.
	Range 112A	X	--	Small arms, laser	--	Basic zero firing / civilian marksmanship program range. Primarily used by visiting SONGS security personnel.
	Range 127	X	--	Small arms	--	Scaled gunnery range; associated non-dud-producing impact area
	School of Infantry Forward Operating Base	--	X	All blanks	--	Also listed as SOI FOB. MOUT for pre-deployment initial operational testing. Operations commenced February 2011.
Papa One	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**2,298**	**Maneuver and training area, amphibious forces**

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	AFA-G (portion in TA Papa Two and TA Papa Three)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-16 (portion in TA Tango)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	LFAM 702 (portion in TA Papa Two and TA Papa Three)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized infantry units for direct live fire and supporting arms live fire.
	PDL Combat Town	--	X	SESAMS, all blanks, pyrotechnics, CS/HC smoke, artillery sims, BFX	--	Also listed as “CBT PDL.” Non-live-fire MOUT facility; operation commenced September 2010.
Papa Two	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,606**	**Maneuver and training area, amphibious forces**
	AFA-12 (portion in TA Papa Three)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-G (portion in TA Papa One and TA Papa Three)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 702 (portion in TA Papa One and TA Papa Three)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized infantry units for direct live fire and supporting arms live fire.
	LFAM 704 (portion in TA Tango)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized infantry units for direct live fire and integration mechanized units. LFAM not located near any major impact areas.
	LFAM 705 (portion in TA Romeo One and TA Romeo Two)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized mobile assault scenarios that integrate both mechanical and motorized units in live-fire attacks. LFAM not located near any major impact areas.
Papa Three	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,273**	**Maneuver and training area, amphibious forces**
	AFA-8 (portion in TA Romeo One)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-11	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	AFA-12 (portion in TA Papa Two)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	AFA-G (portion in TA Papa One and TA Papa Two)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	LFAM 702 (portion in TA Papa One and TA Papa Two)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized infantry units for direct live fire and supporting arms live fire.
Quebec Impact Area	**--**	**--**	**--**	**Small arms, blanks, SESAMS, grenades, mortars, guided missiles, rockets, and explosives**	**2,710**	**Dudded impact area**
	LFAM 706 (portion in TA Bravo One)	--	--	Small arms, practice/signal, hand grenades, mortars, rockets, smoke grenades, explosives (15 lb NEW), SESAMS	--	LFAM used by platoon-sized or smaller infantry assault units within a live-fire, ambush scenario. Fires into Quebec Impact Area.
	LFAM 710A (portion in TA Bravo One, Whiskey Impact Area, and TA Yankee)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized units in mobile assault scenarios that integrate infantry units with direct fire and aerial support. Fires into Quebec and Whiskey Impact Areas. Represents a portion of "LFAM 710." identified in the REVA baseline.
	MP-5	--	--	Mortars	--	Fires into Quebec Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	MP-6	--	--	Mortars	--	Fires into Quebec Impact Area.
	Range 201	--	--	Small arms, pyro/TP rifle grenades, TP rockets, illum mortars	--	Automatic rifle range
	Range 202	--	--	Grenades	--	Live hand grenade range
	Range 203	--	--	Cannon, rifle grenades, rockets, small arms	--	Range active 2006; 25 November 2008–present**; Inactive** 2007**;** machine gun and LAV-25 (field firing) range
	Range 204B	--	--	Small arms, mortars	--	Automatic rifle range. Machine gun positions renovated in August 2011.
	Range 208C	--	--	Small arms, pyro/TP rifle grenades, claymore, obstacle-clearing munitions, rockets, illum mortars	--	Fire and movement range
	Range 314	--	--	Pyro/TP rifle grenades, rockets, illum mortars	--	Field firing range
	Range 314A	--	--	Small arms, pyro/TP rifle grenades, TP rockets, illum mortars	--	BZO / field fire range
	Range 314B	--	--	Small arms, pyro/TP rifle grenades, sub-cal trainer rockets, lasers	--	Static combat range. Active 9 June 2008–present; no operational activity identified during REVA baseline assessment.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 314C	--	--	Small arms, rubber ball hand grenades, pyro/TP rifle grenades	--	Offensive combat and rifle range
Range 303	**--**	**X**	**--**	**Small arms**	**N/A**	**Pistol BZO range (and much of associated non-dud producing impact area) outside of other TAs but within installation boundary (near 63 Area and 64 Area); operation commenced April 2009.**
Romeo One	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,689**	**Maneuver and training area, amphibious forces**
	AFA-8 (portion in TA Papa Three)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	Horno Canyon Combat Town	--	X	SESAMS, all blanks, pyrotechnics, artillery sims, BFX	--	Also listed as “CBT HC” or “Romeo One Combat Town.” Non-live-fire MOUT facility; operation commenced July 2010.
	LFAM 705 (portion in TA Papa Two and TA Romeo Two)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized mobile assault scenarios that integrate both mechanical and motorized units in live-fire attacks. LFAM not located near any major impact areas.
	Range 206	X	--	Small arms, non-lethal grenades	--	Basic zero firing range. Associated non-dud-producing impact area located in TA Alpha One and TA Romeo One.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
Romeo Two	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**2,665**	**Maneuver and training area, amphibious forces**
	LFAM 705 (portion in TA Papa Two and TA Romeo One)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized mobile assault scenarios that integrate both mechanical and motorized units in live-fire attacks. LFAM not located near any major impact areas.
Romeo Three	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**1,172**	**Maneuver and training area, light forces**
Section C Red Beach (Las Pulgas)	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**274**	**Maneuver and training area, amphibious forces**
	Red Beach Combat Town	--	X	All blanks	--	Also listed as “CBT RB.” Non-live-fire MOUT facility. Operation pending.
Sierra One	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**244**	**Maneuver and training area, light forces; including FOB and CIED courses**
Sierra Two	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**58**	**Maneuver and training area, light forces**

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Infantry Immersion Trainer	--	X	SESAMS, all blanks, lasers	--	Also listed as IIT. Non-live-fire MOUT facility; operation of IIT Phase 1 commenced November 2007; Phase 2 commenced November 2010.
Sierra Three	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**168**	**Maneuver and training area, light forces; including FOB and CIED courses**
Tango	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**1,592**	**Maneuver and training area, amphibious forces**
	AFA-14	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-15	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-16 (portion in TA Papa One)	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	Combat Vehicle Operator Course	--	X	All blanks	--	Also listed as CVOC. MOUT facility; operation commenced November 2010. Previously known as El Camino Combat Town.
	LFAM 704 (portion in TA Papa Two)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized infantry units for direct live fire and integration mechanized units. LFAM not located near any major impact areas.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Tango Combat Town	--	X	SESAMS, all blanks, pyrotechnics (not airborne), artillery sims	--	Also listed as "CBT T." Non-live-fire MOUT facility; operation commenced April 2010.
Uniform and Section B Beach (Gold) Training Area	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**663**	**Maneuver and training area, amphibious forces; these two areas are identified as a single area.**
Victor	**--**	**--**	**--**	**Only blanks and pyrotechnics**	**323**	**Maneuver and training area, amphibious forces**
Whiskey Impact Area	**--**	**--**	**--**	**Small arms, SESAMS, blanks, grenades, mortars, rockets, guided missiles, artillery, and aerial gunnery**	**13,489**	**Dudded impact area. Close Air Support site added April 2010.**
	AFA-43 (portion in TA Echo)	--	--	Artillery	--	AFA; fires into Whiskey Impact Area.
	AFA-C (portion in TA Echo)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	AFA-J (portion in TA Finch)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 219	--	--	Small arms, mortars, TP rifle grenades, rockets, explosives (breaching and claymore only), SESAMS	--	LFAM used to simulate offensive combat scenarios. Fires into Whiskey Impact Area.
	LFAM 600	--	--	Small arms, cannon, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM, which overlaps with Range 600
	LFAM 707	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by squad-sized infantry units within an offensive range, live-fire scenario. Fires into Whiskey Impact Area.
	LFAM 708 (portion in TA Finch)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	**Inactive 2006–present.** LFAM used by squad-sized infantry for live-fire assault scenarios; fires into Whiskey Impact Area.
	LFAM 709 (portion in Jardine Canyon Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used to support assaults on a mechanized enemy column using anti-armor weapons systems. Fires into Whiskey Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 710A (portion in TA Bravo One, Quebec Impact Area, and TA Yankee)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized units in mobile assault scenarios that integrate infantry units with direct fire and aerial support and include the use of ordnance. Fires into Quebec and Whiskey Impact Areas. Represents a portion of "LFAM 710," identified in the REVA baseline.
	LFAM 710B (portion in TA Delta, TA Echo, and TA Yankee)	--	--	Unknown, though assumed to include munitions authorized for LFAM 710A	--	LFAM largely located over Whiskey Impact Area; assumed to fire into Whiskey Impact Area. Represents a portion of "LFAM 710," identified in the REVA baseline.
	LFAM 711 (portion in TA Echo and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company-sized units for helicopter insertion of heavy weapons and coordinated, live-fire attacks. Fires into Whiskey and Zulu Impact Areas.
	LFAM 800 (portion in TA Echo)	--	--	Unknown, though assumed to include munitions authorized for Range 800		LFAM, which overlaps with Range 800; fires into Whiskey Impact Area. No operational activity identified during REVA baseline assessment.
	MFA-5 (portion in Jardine Canyon Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	MFA-6 (portion in TA Yankee)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-7 (portion in TA Yankee)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-8 (portion in TA Echo)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-9 (portion in TA Echo)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-9A (portion in TA Echo)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-15 (portion in TA Finch)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MP-3	--	--	Mortars	--	Fires into Whiskey Impact Area.
	Range 210B	--	--	Small arms, rifle grenades, rockets	--	**Inactive** Fall 2006–present; field firing range
	Range 210C	X	--	Small arms, claymore	--	Automatic rifle range
	Range 210D	--	--	Rifle grenades	--	Grenade launcher range
	Range 210E	--	--	Small arms, rifle grenades, rockets, missiles	--	Multipurpose training range

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 210F	--	--	Small arms, pyro/TP rifle grenades, obstacle-clearing munitions, trainer rockets	--	Automatic rifle range, along with rockets and obstacle-clearing munitions
	Range 210G	X	--	Small arms, pyro rifle grenades	--	Squad defense range
	Range 211	--	--	Breacher small arms, explosives (15 lb NEW), claymore	--	Light demolition range; associated non-dud-producing impact area
	Range 212A	X	--	Small arms	--	Recognized as "212 Complex" in recent range documentation.
	Range 212 TOW	--	--	Missiles, rockets	--	**Inactive** 2006–present; anti-armor tracking and live-fire range with associated TERF route
	Range 213	X	--	Small arms	--	Pistol KD range
	Range 214	X	--	Small arms, pyro rifle grenades	--	Rifle KD range
	Range 215A	--	--	Small arms, pyro/TP rifle grenades, claymore, trainer rockets	--	Automated field fire range
	Range 216	X	--	Small arms, grenades	--	SACON house/enhanced marksmanship program/sniper range; formerly machine gun range. SACON house installed 2007.
	Range 217	--	--	Rifle grenades, small arms, rockets	--	Rifle grenade range

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 218A	--	--	Small arms, pyro/TP rifle grenades, rockets, illum mortars	--	Infantry squad battle course
	Range 219	--	--	Explosives (50 lb NEW), mines, obstacle-clearing munitions, breacher small arms	--	Light demolition range; associated non-dud-producing impact area
	Range 220	--	--	Small arms, cannon, rockets	--	Aerial gunnery range designation for Whiskey Impact Area; urban target site added in 2010.
	Range 600	--	--	Explosives (200 lb NEW untamped and 600 lb NEW tamped), small arms, mines, obstacle-clearing munitions, entry rifle grenade	--	Light demolition range; associated non-dud-producing impact area
	Range 800 (portion in TA Echo)	--	--	Small arms, explosives (27 lb NEW), rifle grenades, mines, obstacle-clearing munitions, mines, hand grenades, missiles, mortars, smoke grenade, cannons, rockets	--	Company-level live fire and maneuver range. Associated non-dud-producing impact area located in Echo, immediately adjacent to Whiskey Impact Area.
	San Mateo Convoy Course (portion in TA Bravo One, TA Delta, TA Echo, and TA Yankee)	--	--	Small arms	--	LFAM for vehicle maneuvering exercises. Only permitted to use non-dud-producing ordnance outside of Whiskey Impact Area. Operations commenced April 2011.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
X-Ray Impact Area	**--**	**--**	**--**	**SESAMS, blanks, small arms, grenades, and explosives**	**4,369**	**Non-dud-producing impact area, designation based on historical use**
	LFAM 700 (portion in TA Golf, TA India, TA Kilo One, TA Kilo Two, and Zulu Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by battalion-sized units for integration of infantry, aviation, and mechanized units; fires into Zulu Impact Area.
	LFAM 701	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used to integrate battalion-sized or larger infantry, mechanized, aviation, and motorized assault units with scenarios including minefield breaching, direct fire, and supporting arms fire. Fires into X-Ray Impact Area.
	Range 102	X	--	Small arms	--	Pistol KD range
	Range 103	X	--	Small arms, pyro rifle grenades	--	Rifle KD range
	Range 104B	--	--	Small arms, grenades, SESAMS, explosives (0.18 lb NEW)	--	Hand grenade practice range/SACON. Sniper fires at single target.
	Range 111	X	--	Small arms, TP and non-lethal grenades	--	Transition rifle basic zero/enhanced marksmanship program/civilian marksmanship program range
	Range 116A	X	--	Small arms, pyro rifle grenades	--	Rifle KD range; operated by Naval Special Warfare

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 116B	X	--	Small arms	--	Basic zero firing/enhanced marksmanship program range; operated by Naval Special Warfare
	Range 116C	X	--	Small arms	--	Multitarget combat engagement RETS range; operated by Naval Special Warfare
	Range 116D	--	--	Small arms, SESAMS, lasers, explosives (0.25 lb NEW)	--	360-degree shoot house and outdoor breaching range; operated by Naval Special Warfare
	Range 117A	X	--	Small arms	--	KD sniper range
	Range 130 Complex	X	--	Small arms, breaching-related munitions (including 0.5 lb NEW limit), flash bang grenades	--	Assorted training ranges (one with non-dud-producing impact area), including two small arms firing bays, sniper training facilities, CQB training house, and inactive rappel tower
	Range 131 Complex	--	X	SESAMS, all blanks, nonlethal grenades, pyrotechnics, BFX	--	Non-live MOUT facility occupying 27 acres. Inactive portions previously accommodated live-fire small arms and grenades.
	Range 132	- -	- -	Small arms, blanks, SESAMS, nonlethal grenades	--	Urban RETS range
	Range 133	--	--	Small arms, grenades, SESAMS, explosives (0.25 lb NEW)	--	CQB shoot house; outdoor breaching with live-fire inside house (no roof)

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
Yankee	**--**	**--**	**--**	**With exceptions for fixed ranges, only blanks and pyrotechnics**	**3,806**	**Maneuver and training area, amphibious forces**
	AFA-A (portion in TA Delta)	--	--	Artillery	--	Artillery firing area; fires into Whiskey Impact Area.
	LFAM 710A (portion in TA Bravo One, Quebec Impact Area, and Whiskey Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company- and platoon-sized units in mobile assault scenarios that integrate infantry units with direct fire and aerial support, and includes the use of ordnance. Fires into Quebec and Whiskey Impact Areas. Represents a portion of "LFAM 710" identified in the REVA baseline.
	LFAM 710B (portion in TA Delta, TA Echo, and Whiskey Impact Area)	--	--	Unknown, though assumed to include munitions authorized for LFAM 710A	--	LFAM largely located over Whiskey Impact Area; assumed to fire into Whiskey Impact Area. Represents a portion of "LFAM 710" identified in the REVA baseline.
	MFA-6 (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.
	MFA-7 (portion in Whiskey Impact Area)	--	--	Mortars	--	Fires into Whiskey Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	San Mateo Convoy Course (portion in TA Bravo One, TA Delta, TA Echo, and Whiskey Impact Area)	--	--	Small arms	--	LFAM for vehicle maneuvering exercises. Only permitted to use non-dud-producing ordnance outside of Whiskey Impact Area. Operations commenced April 2011.
Zulu Impact Area	--	--	--	**Small arms, SESAMS, blanks, grenades, mortars, rockets, guided missiles, artillery, aerial gunnery, and aerial bombs**	**7,390**	**Dudded impact area. Close Air Support site added July 2010.**
	AFA-10 (portion in TA Finch)	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-17 (portion in TA Finch)	--	--	Artillery	--	AFA; fires into Zulu Impact Area.
	AFA-32 (portion in TA India)	--	--	Artillery	--	AFA; fires into Whiskey and Zulu Impact Areas.
	LFAM 700 (portion in TA Golf, TA India, TA Kilo One, TA Kilo Two, and X-Ray Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by battalion-sized units for integration of infantry, aviation, and mechanized units; fires into Zulu Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	LFAM 703 (portion in TA Finch)	--	--	Small arms, mortars, cannons, rockets, rifle grenades, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by squad-sized units within an offensive range, live-fire scenario. Fires into Zulu Impact Area.
	LFAM 711 (portion in TA Echo and Whiskey Impact Area)	--	--	Small arms, rifle grenades, rockets, mortars, hand grenades, explosives (breaching and claymore only), SESAMS	--	LFAM used by company-sized units for helicopter insertion of heavy weapons and coordinated, live-fire attacks. Fires into Whiskey and Zulu Impact Areas.
	MFA-10 (portion in TA Golf)	--	--	Mortars	--	Fires into Zulu Impact Area.
	MFA-12	--	--	Mortars	--	Fires into Zulu Impact Area.
	MFA-13 (portion in TA Finch)	--	--	Mortars	--	Fires into Zulu Impact Area.
	MFA-14	--	--	Mortars	--	Fires into Zulu Impact Area.
	MP-1	--	--	Mortars	--	Fires into Zulu Impact Area.
	MP-2	--	--	Mortars	--	Fires into Zulu Impact Area.
	MP-4	--	--	Mortars	--	Fires into Zulu Impact Area.
	MP-E	--	--	Mortars	--	Fires into Zulu Impact Area.

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	MP-I	--	--	Mortars	--	Fires into Zulu Impact Area.
	Range 221	--	--	Small arms, TP rifle grenade, trainer rockets	--	Enhanced marksmanship program/basic zero firing/field firing/machine gun field fire range
	Range 222	--	--	Small arms, mortars, cannons, trainer rockets, lasers	--	Range active 15 April 2008–present; no operational activity identified during REVA baseline assessment; machine gun and LAV range
	Range 223A	X	--	Small arms, flash bang grenade, SESAMS (in house only), breaching explosives (0.18 lb NEW)	--	Range active 21 July 2008–present; no operational activity identified during REVA baseline assessment; shoot house and turning target range
	Range 223B	--	--	Small arms, pyro/TP rifle grenades, rockets, missiles, illum mortars	--	Multipurpose machine gun range
	Range 225	--	--	Small arms, pyro/TP rifle grenades, rubber ball and non-lethal grenades, trainer rockets, illum mortars	--	Automatic rifle range
	Range 227	--	--	Small arms, TP rifle grenades, trainer rockets, mortars	--	Machine gun field fire/enhanced marksmanship program/basic zero firing range
	Range 407	--	--	Small arms, rocket grenades, rockets, missiles, artillery, cannons, mortars	--	Multipurpose training range/field firing range

Training Area	Facility	SAR	MOUT	Authorized Military Munitions	Size (acres)	Notes/Comments
	Range 407 T&LAV	--	--	Small arms, rifle grenades, TP cannons	--	**Inactive** 2006–present. Multipurpose training range/field firing range/tank and LAV gunnery range
	Range 407A	--	--	Small arms, rifle grenades, rockets, cannons, mortars	--	Field firing range/basic zero firing/enhanced marksmanship program range
	Range 407B	--	--	Small arms, rifle grenades	--	Field firing/multipurpose training range
	Range 408	--	--	Small arms, TP rifle grenades, rockets, missiles, claymore, obstacle-clearing munitions, explosives (10 lb NEW), mortars, cannons	--	Offensive combat (platoon) mounted/dismounted range
	Range 408A	--	--	Small arms, TP rifle grenades, missiles, artillery, cannons	--	Tank and fighting vehicle range
	Range 440	--	--	Small arms, rockets, missiles, bombs	--	Aerial gunnery range; urban target site added along southern border in 2010

Notes:

BFX = Battle Effects
cal = Caliber
CS = Orthochlorobenzylidene Malononitrile (crowd control agent)
CIED = Counter Improvised Explosive Device
CQB = Close Quarters Battle
CVOC = Combat Vehicle Operator Course
FMSS = Field Medical Service School
FOB = Forward Operating Base
HC = Zinc chloride smoke mixture (crowd control agent)
HRUF = Horno Regimental Urban Facility
IIT = Infantry Immersion Trainer
Illum = Illumination
JIEDDO = Joint Improvised Explosive Device Defeat Organization
LAV = Light Armored Vehicle
lb = Pound
MP = Mortar Position
NEW = Net Explosive Weight
pyro = Pyrotechnic
RETS = Remote Target System
SACON = Shock Absorbing Concrete
SESAMS = Special Effects Small Arms Marking System
sim = simulator
SMRUF = San Mateo Regimental Urban Facility
SONGS = San Onofre Nuclear Generating Station
TA = Training area
TOW = Tube-launched Optically-tracked Wire-guided
TP = Target Practice
WFTBN = Weapons and Field Training Battalion

New or modified range/facility since baseline REVA installation visit (12–17 September 2005)

The designation "SAR" identifies ranges where its facilities or subset thereof are specifically designed to only accommodate the use of live small arms, along with supporting simulation or illumination munitions. Range 210C is an exception, which has specifically been identified as a SAR during previous assessments.

The designation "MOUT" denotes facilities identified by installation G-3/5 personnel that accommodate training scenarios affected by man-made constructions.

Total acreage of training areas based on modified Range Control GIS information.

Listed as **Inactive**: Range is used infrequently but is **not** considered closed.

Observation points are not listed in this table.

Active obstacle or rappel towers are not listed in this table.

RSOPs are not listed in this table. There are 16 such facilities at MCB Camp Pendleton. No munitions are specifically authorized on these facilities.

Two active mechanized assault courses (in TA Papa Three and TA Bravo Three) are not listed in this table; no munitions are authorized for these courses.

LZs, drop zones, helicopter maneuver areas (e.g., confined area landing sites, helicopter outlying landing fields, short take-off and landing sites, lift pads), and Harrier landing pads are not listed in this table. There are approximately 84 such facilities at MCB Camp Pendleton. Five active TERF routes (Case Springs, Devil's, DeLuz, Mike, and Pulgas) are not listed in this table; no munitions are specifically authorized on these routes.

Section A Green Beach (San Onofre), Section E White Beach (Aliso), Section G Blue Beach (Margarita), Door Gunner No. 1, Door Gunner No. 2, Range 212, and Range 502—all identified during the REVA baseline assessment—no longer appear to have training operations occurring and, consequently, are not listed in this table.

Indoor range training facilities, such as the Nuclear, Biological, and Chemical Gas Chamber, are not included in this table.

Recreational ranges at the installation—such as R-102A, R-107, and Cristianitos Archery—are not included in this table.

Areas designated for recreational hunting – including SMR LO, SMR UP, SMR One, and SMR Two – are not considered part of the range training area inventory, and are included in this table.

Section A Green Beach (San Onofre), Section E White Beach (Aliso), Section G Blue Beach (Margarita), Door Gunner No. 1, Door Gunner No. 2, Range 212, and Range 502—all identified during the REVA baseline assessment—no longer appear to have training operations occurring and, consequently, are not listed in this table.

Historical training and historical facilities were addressed in the baseline REVA assessment (2008); no additional historical training areas were identified during this review.

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3.5.2. Impact Areas

Approximately 31,000 acres of the operational use area at MCB Camp Pendleton consists of seven impact areas utilized for live-fire training exercises. Three of these impact areas (Quebec, Whiskey, and Zulu) are designated as dud-producing impact areas, as they receive all of the mortar and artillery fire from the current active array of 47 AFAs, 12 mortar firing areas (MFAs), and eight mortar points (MPs), as well as other range facilities where such munitions are authorized. Additionally, all of the air-to-ground ordnance delivery and HIMARS rockets at MCB Camp Pendleton are directed into the Whiskey and Zulu Impact Areas. Since the baseline assessment, close air support (CAS) urban target areas were constructed in the Whiskey and Zulu Impact Areas to allow Marines on the ground to call in air strikes on urban targets from forward observation positions. Non-dud-producing impact areas at MCB Camp Pendleton include Edson Range Impact Area, Jardine Canyon Impact Area, Range 409A Impact Area, and X-Ray Impact Area. There are also a small number of ranges outside the boundaries of the main impact areas, such as Range 303, Range 206, Range 401, and Range 409A, that have associated non-dud-producing impact areas designated to reflect surface danger zone (SDZ) considerations.

3.5.3. Live-Fire and Maneuver Areas

LFAM activities involve field-training exercises that practice coordination of infantry, vehicles, flight operations, and combat service support operations during various realistic combat scenarios (MCB Camp Pendleton, 2007b). There currently are 16 LFAM areas present at MCB Camp Pendleton. Refer to **Table 3-1** for descriptions of the LFAM areas.

Some LFAM areas have undergone minor changes since the baseline REVA assessment. LFAM 708 has been inactive from 2006 to present. LFAM 710, which was identified in the REVA baseline assessment, was divided into LFAM 710A and LFAM 710B. LFAM 710A and LFAM 710B are still used by company- and platoon-sized units in mobile assault scenarios that integrate infantry units with direct fire and aerial support. In addition, the San Mateo Convoy Course was established in April 2011.

3.5.4. Fixed Firing Ranges

Based on this REVA assessment, there are 146 fixed ranges designated for a variety of training activities at MCB Camp Pendleton. The ranges are oriented primarily around the perimeter of the impact areas (see **Table 3-1**). Forty-seven of these fixed ranges are designed to accommodate various HE and other munitions larger than small arms munitions; 67 of these ranges are designated as AFAs, MFAs, and MPs; and 32 ranges are designated as SARs.

There were relatively minor changes to training pertaining to the fixed firing ranges at MCB Camp Pendleton during the review period. SARs associated with the Edson Impact Area, the Horno Ranges (Ranges 213 and 214), and the Wilcox Ranges (Ranges 102 and 103) continue to be among the most heavily utilized SARs at MCB Camp Pendleton. In contrast, a number of

SARs, such as those in Bravo One Training Area (Ranges 312A and 313) and Juliet Training Area (Ranges 403A–403D), have received little to no use.

As previously mentioned, three new fixed ranges (Ranges 301, 302, and 303) have been established since the baseline assessment. Ranges 301 and 302 located within Bravo Three and Bravo Two Training Areas, respectively, commenced operations in September 2009 and are designed for the use of small arms and grenades. They are equipped with SACON houses for training Marines in urban combat techniques. Range 303 commenced operations in April 2009 as a pistol basic zero range. Unlike most of the fixed range facilities at MCB Camp Pendleton, Range 303 does not fall within the boundaries of a training area; its SDZ partially extends into Bravo Two Training Area.

The use of four ranges (Range 110, Range 216, Range 401, and Range 108) has changed since the baseline assessment. Expenditure of 40 mm HE munitions at Range 110 ceased after 2009, thus changing the X-Ray Impact Area from a dud-producing to a non-dud-producing impact area. A small SACON house was constructed in 2007 adjacent to the BZO area at Range 216, which accommodates the use of live-fire small arms and grenades. Lastly, EOD shifted its operations from Range 401 to Range 108 in June 2009, which is discussed further in **Section 3.5.5**.

3.5.5. Explosive Ordnance Disposal and Demolition Ranges

Of the fixed range facilities at MCB Camp Pendleton, five ranges are designed to primarily accommodate demolition activities, including the new primary EOD range located at Range 108 and the existing primary engineering range located at Range 219. The primary EOD demolition and training range noted in the baseline REVA assessment was Range 401. EOD shifted its operations to Range 108 in June 2009 due to the Federal Aviation Administration’s decision to no longer grant a control firing area for EOD operations with vertical hazards at Range 401. According to G-3/5 personnel, Range 401 will be converted into a military police K-9 training area, and there are plans for the construction of new facilities at Range 108 to enhance its usability for EOD operations.

3.5.6. Military Operations in Urban Terrain

Several new MOUT facilities, along with associated IED and combat vehicle courses, have been constructed as part of the U.S. Marine Corps’ initiative to enhance realistic training capabilities to better reflect the current mission requirements of today’s Marines. There currently are 19 MOUT facilities at MCB Camp Pendleton, 13 of which have been constructed since the baseline REVA assessment (see **Table 3-1**). MOUT facilities installed since the baseline assessment was conducted include the following:

- Bravo Two Combat Town (2010)
- Camp DeLuz Combat Town (October 2009)
- Combat Vehicle Operator Course (November 2010)

- Horno Canyon Combat Town (July 2010)
- Horno Regimental Urban Facility (August 2011)
- Infantry Immersion Trainer (November 2007)
- Kilo Two Combat Town (March 2008)
- PDL Combat Town (September 2010)
- Red Beach Combat Town (operation pending)
- San Mateo Regimental Urban Facility (February 2010)
- School of Infantry Forward Operating Base (February 2011)
- Tactical Site Exploitation Training Area (TSE) (March 2010)
- Tango Combat Town (April 2010)

These facilities simulate developed areas for urban terrain training and generally consist of one- and two-story concrete block and wood buildings or containers to simulate infiltration, patrolling of built-up areas, building searches, and various other urban scenarios. With the exception of a small number of facilities on the installation equipped with SACON construction, training in the MOUT facilities is conducted using blanks, SESAMS, smoke grenades, and limited detonation of various explosive breaching charges. In some of the more advanced MOUT facilities, the effects include simulated artillery and machine gun fire from propane cannons, tear gas, and pyrotechnics (MCB Camp Pendleton, 2007a).

One significant MOUT addition is the IIT located in the Sierra Two Training Area, constructed in two phases in November 2007 and November 2010. This MOUT facility is a hyper-realistic environment and implements a variety of atmospheric effects and props, providing a live training area with the best of virtual training environments. It contains numerous structures, adjustable faux walls, and a tactical video capture system with virtual projection capability (MCB Camp Pendleton, 2010). Another notable MOUT facility constructed since the baseline assessment is the TSE and the co-located JIEDDO training area located in the Bravo One Training Area. The TSE, which began operations in March 2010, was designed with Afghanistan atmospherics in rooms equipped with false walls and trap doors (MCB Camp Pendleton, 2010). The JIEDDO training area provides opportunities to train in the identification and mitigation of IEDs (Shaw, 2011a).

3.5.7. Operational Range Clearance Program

As previously stated, MCB Camp Pendleton initiated an installation-wide ORC program in December 2008 to supplement routine range maintenance activities provided by EOD personnel. G-3/5 personnel indicate this program identifies ranges or construction projects for clearance activities, which will prevent accumulation of ordnance scrap, target debris, UXO, and munitions and explosives of concern that may impair or prohibit safe conduct of training operations. Consequently, many of the locations that have undergone clearance under this program represent ranges that receive relatively heavy use of HE munitions. Since December 2008, it is estimated that the ORC program has removed over 2,200 tons of range debris and demilitarized UXO from 14 ranges at the installation (MCB Camp Pendleton, 2011b). **Table 3-2** summarizes clearance activities conducted under this program.

Table 3-2: Operational Range Clearance Program Summary

Location	Date(s) of Clearance	Clearance Area (acres)	Debris Removed (lb of metal)	UXO Items Destroyed
JIEDDO Training Area	8 Jul 2009–18 Jan 2011	26.1	8,993	56
LFAM 219	2 Jun 2010–15 Feb 2011	256.2	444,945	941
LFAM 703	11 May 2009–21 Sep 2009	144	30,949	62
LFAM 706	5 Oct 2009–22 Feb 2010	231	131,886	129
Range 108	10 May 2009–30 Jul 2009	47	241,441	530
Range 110	7 Jun 2010–17 Nov 2010	44.6	24,913	48
Range 208C	27 Oct 2009–9 Dec 2009	81	81,986	34
Range 210B	16 Dec 2010	6.4	206	4
Range 210D	28 Jul 2010–9 Feb 2011	11.7	34,203	191
Range 210E	19 Feb 2010–2 Jun 2010	23	434,423	1,273
Range 210F	27 Jul 2010-21 Feb 2011	75.6	89,717	159
Range 218	11 Aug 2010–14 Oct 2010	209	60,375	206
Range 314	14 Dec 2009–11 Jan 2010	78	170,302	754
Range 408	19 Jan 2009–16 May 2009	377	214,910	1,084
Range 409	13 Jul 2009–23 Jul 2010	390	367,093	5,458

Source: Shaw, 2011a through 2001o

The range clearance activities included in this program employ a combination of surface and subsurface techniques. Surface sweeps were conducted over the range areas in 100-foot-by-100-

foot grids, and subsurface clearances were conducted to a depth of 2 feet on access roads and pathways to target locations (Shaw, 2011a). Only munitions larger than .50 cal were targeted for clearance under this program. Once the baseline clearance event for each range has been completed, MCB Camp Pendleton will establish a 2-year or 5-year ORC program for each range and LFAM area based on the range usage rate for training (Marano, 2009).

3.6. Munitions Constituents Loading Assumptions

3.6.1. Selection of Munitions Constituents Loading Areas

The REVA assessment team reviewed existing operational ranges and training areas to determine the locations of MC loading areas at MCB Camp Pendleton. These areas represent the locations at which significant MC loading is occurring or is suspected to have occurred as a result of training with munitions containing HE (HMX, RDX, and TNT) or illumination rounds/munitions containing solid propellants (perchlorate). Lead deposition was evaluated for all operational ranges during the five-year assessment. Based on the information provided in this section, 38 MC loading areas at MCB Camp Pendleton were delineated for the five-year review (see **Figure 3-2)**:

- Horno Combat Town
- Kilo 2 Combat Town
- LFAM 706
- PDL Combat Town
- Quebec Impact
- Range 104B
- Range 108
- Range 109
- Range 130 Breach
- Range 132 Complex
- Range 201
- Range 202
- Range 203
- Range 204B
- Range 207
- Range 208C
- Range 210D
- Range 210E/210F
- Range 215A
- Range 216 House
- Range 217/219
- Range 218A
- Range 221/222
- Range 223B
- Range 225
- Range 227
- Range 301
- Range 302
- Range 307
- Range 314 Complex
- Range 401
- Range 407 Complex
- Range 408
- Range 409A
- Range 600
- Whiskey Impact

- Range 211
- Zulu Impact

As indicated in **Section 2.2**, MC loading areas in the five-year review were selected to capture the use of munitions at various operational training areas and ranges, and represent the areas in which most MC are expected to be deposited as a result of training operations. This resulted in a different number of defined MC loading areas compared to the baseline assessment. It also resulted in some significant boundary updates to previously defined MC loading areas, including the Quebec, Whiskey, and Zulu Impact MC loading areas.

3.6.2. Overarching Assumptions

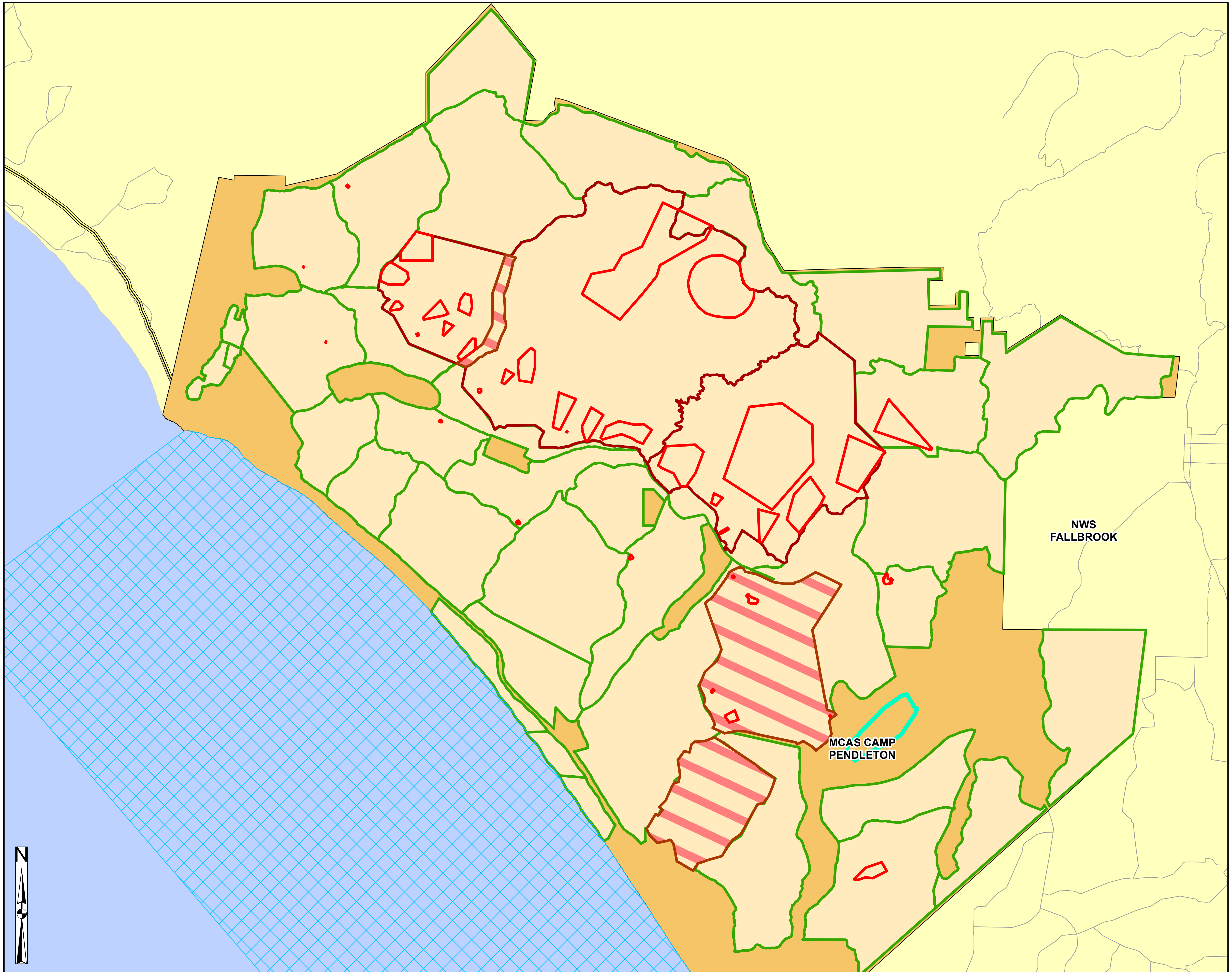
To estimate MC loading for operational ranges, assumptions were developed to apply to data collected during the five-year review. Complete details and background of these assumptions and data are available in the *REVA Reference Manual for Baseline Assessments* (HQMC, 2009). The following represent the 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 the MC within a munition remains when a UXO event occurs. 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 MC 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 MC loading area, as detailed in the R*EVA 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.

Figure 3-2

MC Loading Areas at
MCB Camp Pendleton

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- MC Loading Areas
- Dud-Producing Impact Area
- Non-Dud Producing Impact Area (Limited Access)
- Training Area, Land
- Training Area, Water
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary

0 2 4
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

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- Dud/UXO rates associated with DoDICs reported in the RFMSS data are not used in place of the standard dud assumptions for 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 REVA standard dud rate assumptions are used in order to maintain a higher level of conservatism in the estimate.
- The ORC program implemented at MCB Camp Pendleton helps to reduce the overall MC loading contribution to the MC loading areas; however, this was not factored into the MC loading calculations in an effort to maintain conservative MC loading rate estimates.

HE and perchlorate were evaluated at MC loading areas where significant HE use has been documented; lead was evaluated at all MC loading areas and SARs. Calculation of representative annual expenditure estimates at the ranges was performed to help characterize MC 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.

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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 MCB Camp Pendleton 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.

A CSM was developed for the operational ranges at MCB Camp Pendleton. Key information sources used in the development of the CSM include the following:

- Military munitions expenditure data
- MCB Camp Pendleton Environmental Security GIS data
- Installation Restoration Program (IRP) site data
- Installation-specific data, including the following:
  - Water quality data for drinking water wells
  - Drinking water vulnerability assessment report
  - Precipitation data
- U.S. Geologic Survey (USGS) topographic maps and regional groundwater resource reports
- California Regional Water Quality Control Board (CRWQCB) Colorado River Basin Plan
- MCB Camp Pendleton Integrated Natural Resources Management Plan (INRMP)
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil survey

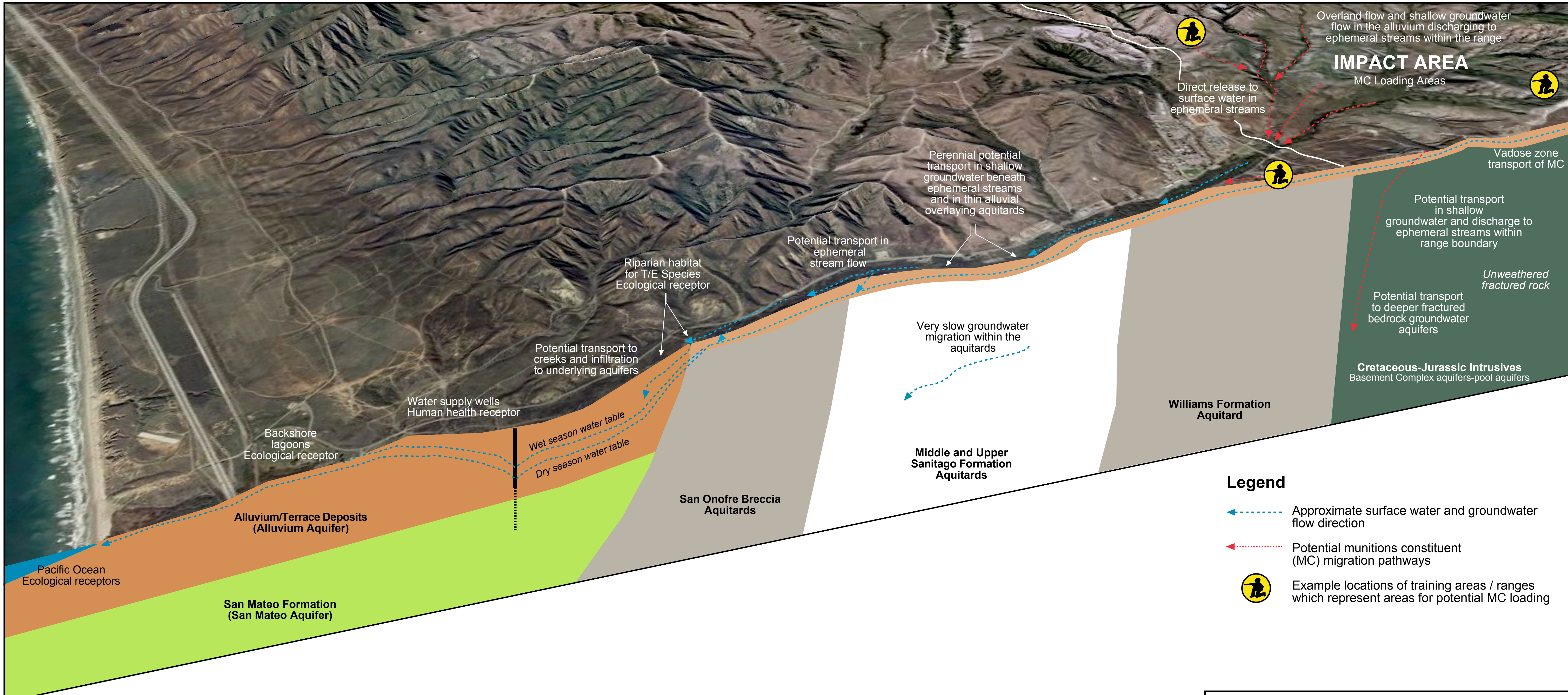
Where detailed information of site-specific characteristics and information did not exist, available regional information was used to estimate local characteristics.

A schematic diagram depicting the site conditions addressed in the CSM is presented in **Figure 4-1**. The geomorphology is shown relative to generalized MC loading areas, the installation boundary, and potential receptors (e.g., drinking water wells, ecological receptors).

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	MCB Camp Pendleton occupies approximately 125,000 acres of coastal Southern California in San Diego County. It is located about halfway between San Diego and Los Angeles on the California Pacific Coast, along the Interstate 5 (I-5) highway. Nearby communities include Oceanside to the south, Fallbrook to the east, and San Clemente to the northwest. The installation shares portions (approximately 8 miles) of its northern border with the San Mateo Wilderness Area of the Cleveland National Forest and its eastern border with the Fallbrook Naval Weapons Station. Aside from the wilderness area and the Naval Weapons Station (which are both largely natural areas), surrounding land use includes urban development, rural residential development, and working farms and ranches.
Date of installation establishment	In March 1942, the Department of the Navy purchased a large cattle ranch in southwest California for use as a military training center. Construction on the installation commenced immediately, which included an airstrip and a 600-bed hospital. Originally, MCB Camp Pendleton was intended to serve as an auxiliary training camp for a Marine Corps installation in San Diego. It quickly became the center of West Coast Marine Corps activity, as the Marine Corps took on an increasingly crucial role in amphibious warfare necessary to take control of Pacific Islands from the Japanese in the Pacific Theater of World War II (WWII). Throughout the war, MCB Camp Pendleton was responsible for training Marines for full-scale combat in the Pacific. Its land area was large enough so that it could support training for three full divisions (MCB Camp Pendleton, 2007a).
Installation area and layout	Aside from nearly 10,000 acres that are developed, most of the installation is largely undeveloped land that is used for training. Seven separate cantonment areas for infantry and artillery regiments and schools are located along Basilone and San Mateo Roads, namely San Mateo, San Onofre, Horno, Las Pulgas, Margarita, Vado Del Rio, and Talega. Two



Notes:

The cross-section and its features present a typical representation of drainage basins relative to potential MC.

Four major processes control the potential movement of MC from loading areas:

1. Potential transport of MC to ephemeral streams through mobilization in surface water runoff (dissolution and erosion of soil and sediments).
2. Potential transport of MC to alluvium aquifer in the coastal plain through preferential recharge of stream beds.
3. Potential vadose zone transport to shallow groundwater in thin alluvial deposits underlying MC loading areas.
4. Potential shallow groundwater discharge to ephemeral streams within MC loading areas.

Potential Receptors:

1. Installation drinking water supply wells may be affected by off-range MC migration.
2. Threatened/endangered species may be affected by MC present in surface water and groundwater in off-range habitat area.

Geology modified from PL Ehig, 1979

Figure 4-1

Graphical Conceptual Site Model (CSM)
MCB Camp Pendleton
OCTOBER 2013

Not to scale.

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Infrastructure · Water · Environment · Buildings

CSM Information Profiles – Installation Profile	
Information Needs	**Preliminary Information**
Installation area and layout (cont.)	cantonment areas, Las Flores and Edson Range, are located on the coastal plain east of I-5, and three other cantonment areas (Del Mar, Marine Corps Tactical Systems Support Activity, and ACU-5) are located on the coastal plain west of I-5. MCB Camp Pendleton and the adjacent Cleveland National Forest occupy some of the last significant open space and wildlife habitats in the coastal areas of Southern California. With the exception of the ocean and the Cleveland National Forest, urbanization is expected to surround MCB Camp Pendleton eventually.
Installation mission	MCB Camp Pendleton's mission is to operate a training base that promotes the combat readiness of operating forces and the mission of other tenant commands by providing training opportunities, facilities, services, and support responsive to the needs of Marines, Sailors, and their families (MCB Camp Pendleton, 2011d).

4.2. Operational Range Profile

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
MC loading areas	The 38 MC loading areas, as shown in **Figure 3-2,** identified for assessment during the five-year review are as follows: • Horno Combat Town • Kilo 2 Combat Town • LFAM 706 • PDL Combat Town • Quebec Impact • Range 104B • Range 108 • Range 109 • Range 130 Breach • Range 132 • Range 215A • Range 216 House • Range 217/219 • Range 218A • Range 221/222 • Range 223B • Range 225 • Range 227 • Range 301 • Range 302

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
MC loading areas (cont.)	• Range 201 • Range 202 • Range 203 • Range 204B • Range 207 • Range 208C • Range 210D • Range 201E/210F • Range 211 • Range 307 • Range 314 Complex • Range 401 • Range 407 Complex • Range 408 • Range 409A • Range 600 • Whiskey Impact • Zulu Impact The MC loading areas were determined based on a review of existing operational ranges and evaluation of munitions expenditures tracked by the installation.
Range names	The installation is subdivided into 36 training areas (including beaches) and six non-overlapping impact areas. 146 fixed range facilities are present at the installation, including AFAs, MPs, MFAs, and fixed ranges (including SARs). The training areas and fixed range facilities located at MCB Camp Pendleton are presented in **Table 3-1**.
Date of range establishment	The Marine Corps began operating at MCB Camp Pendleton in 1942. Many ranges were established in 1942 through 1945 during initial construction phases; however, construction of new ranges has continued since WWII. Several ranges have been established since the 2005 baseline. These are further detailed in **Section 2.2**. See Range Use and Design section below.
Range design and use	*Training and Impact Areas* Forty training areas (including beaches) are defined at MCB Camp Pendleton. The training areas are defined as maneuver and training areas for light, heavy, or amphibious forces. Authorized military munitions are limited to blanks and pyrotechnics, unless other munitions are permitted via ranges contained within the training areas (e.g., LFAM area, fixed range facility). Additionally, several RSOP sites, LZs, and TERF routes are present throughout the training areas. Three dud-producing impact areas are present at MCB Camp Pendleton:

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
Range design and use (cont.)	Quebec, Whiskey, and Zulu. These areas may receive mortar, artillery, and other HE munitions from the surrounding range facilities. Whiskey and Zulu Impact Areas also may receive air-to-ground ordnance. Additionally, there are three major non-dud-producing impact areas that do not overlap with other training areas: Edson, Jardine Canyon, and X-Ray. *Fixed Range Facilities* There are 146 fixed range facilities at the installation. Forty-seven of these fixed ranges are designed to accommodate various HE and other munitions larger than small arms munitions; 67 of these ranges are designated as AFAs, MFAs, and MPs; and 32 ranges are designated as SARs. Five of these ranges are designed to primarily accommodate demolition activities, including the primary EOD range at Range 108 and the primary engineering range at Range 219. In addition to these facilities, there are 16 LFAM areas defined across the training and impact areas.
Range security	The installation is patrolled actively. Access gates, such as the San Luis Rey, Main, Del Mar, Fallbrook, Las Pulgas, Cristianitos and San Onofre gates, provide access to the installation. Approved military access must be provided to enter the installation. Portions of the installation are fenced in, particularly the developed areas and facilities, with additional fencing on some portions of the installation and range boundaries. The majority of fences on the installation are chain link; however, there are also some barbed wire and wooden fences. Access to training areas is controlled by Range Control and scheduled according to training activities. On occasion, trespassing occurs on the installation by civilian beach users, campers, hikers, mountain bikers, and off-road vehicle operators; the trespassing can interfere with training operations, the installation's own recreational programs, and natural resources management actions. Unauthorized access continues to adversely impact sensitive habitat; damage trails, roads, and firebreaks; and increase the potential for erosion (MCB Camp Pendleton, 2007a).

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
Military munitions usage	Authorized military munitions for each training area and fixed range facilities are listed in **Table 3-1**. For training areas and ranges (including MOUT facilities) that are designated as non-live-fire, authorized military munitions generally include blank ammunition, smoke grenades, and illumination rounds. For the ranges, LFAM areas, and impact areas that are designated for live-fire, a wide range of munitions is authorized for use dependent on range design, including all conventional munitions associated with ground and air vehicles, artillery, and infantry training activities. Quebec, Whiskey, and Zulu Impact Areas receive the majority of HE munitions. Ranges that accommodate HE munitions outside of these areas typically include hand grenade and SACON houses, as well as the multipurpose Range 409A in the Golf Training Area. SARs are located across the installation, with the Edson, Horno (Range 213 and Range 214), and Wilcox (Range 102 and Range 103) ranges receiving the heaviest use. Range 108, whose operations commenced in June 2009, serves as the primary EOD range facility with a NEW of 300 lb. Range 219 serves as the primary engineering training facility, with a NEW of 50 lb.
Munitions constituents	The types of munitions used at the non-live-fire ranges and areas (blanks, simulators, and pyrotechnics) have relatively small amounts of REVA indicator MC (TNT, HMX, RDX, and perchlorate). These MC, as well as lead, are potentially present on the live-fire ranges. Targets where MC are likely to accumulate are present throughout the installation. The only indicator MC anticipated at SARs is lead.
Maintenance	G-3/5 is responsible for maintaining all range and training areas at the installation in order to provide a safe and realistic training environment. Such responsibilities include maintaining vegetation on ranges, berm maintenance, range and training area inspections, and any other general maintenance requirements within ranges or training areas. Due to the conditions at MCB Camp Pendleton, brush fires are common; therefore, fire breaks must be maintained across all ranges and training areas. Range users and managers also may coordinate with the MCB Camp Pendleton EOD personnel to conduct range sweeps of the training areas for the identification and removal of UXO. Some frequently used ranges are swept when schedule allows.

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
Maintenance (cont.)	In December 2008, MCB Camp Pendleton initiated an installation-wide ORC program to supplement routine range maintenance activities provided by EOD personnel. Since December 2008, it is estimated that the ORC program has removed over 2,200 tons of range debris and demilitarized UXO from 14 ranges at the installation (MCB Camp Pendleton, 2011b).
Engineered controls	Some ranges, including many of the SARs, possess earthen berms or natural hillside features, which potentially limit distribution of MC as well as potentially limit run-on of surface water from higher elevations. Some of these berms are maintained through periodic resurfacing. Riprap and metal grates were observed in potential drainage pathways at some ranges, but many such existing improvements and controls appear to be unmaintained. A best management practice design was submitted to MCB Camp Pendleton in 2010 for mitigating potential releases of MC in storm water runoff from Range 208C and the up gradient Quebec Impact Area. The design includes storm water diversion, check dams, flocculation blocks, and small settling pools. The potential environmental impacts of the proposed project currently are being addressed through the National Environmental Policy Act process.

4.3. Physical Profile

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Climate	MCB Camp Pendleton has several climatic zones that roughly coincide with the three geomorphic regions present: coastal plain, coastal valley, and mountain. In general, the installation has a semiarid Mediterranean climate with warm, dry summers and mild, wet winters. The annual average daily temperature ranges from a low of 51 degrees Fahrenheit (^{0}F) at lower elevations to a high of 75^{0}F (NOAA, 2008).

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Climate (cont.)	Recent climate reports received from MCB Camp Pendleton for 2006 through 2011 indicate precipitation at MCB Camp Pendleton ranged from 6.7 to 21.7 inches per year (in/yr), with an average of 11.3 in/yr (MCB Camp Pendleton, 2011a). Based on 100 years of data, the lower (coastal plain and coastal valley) areas of the installation receive an average precipitation of 10 to 14 in/yr, ranging from a minimum of 4.51 in/yr to a maximum of 38.2 in/yr (MCB Camp Pendleton, 2007a). The precipitation at higher (mountain) elevations of the installation averages approximately 22 in/yr (based on 40 years of records at Case Springs in the San Mateo watershed), with a minimum of 6.08 in/yr and a maximum of 50.42 in/yr. Approximately 75% of the installation's precipitation falls between November and March, with the greatest annual average precipitation in January. Winds generally originate from the west or southwest, carrying in cool, moist offshore air. The area's year-to-year variability is an important climate characteristic (MCB Camp Pendleton, 2007a). Periods of drought, heavy seasonal rains, and fire are common. Wildfires occur seasonally from May through November, typically during hot and dry Santa Ana wind conditions and when a heavy vegetative fuel load exists.
Elevation and topography	MCB Camp Pendleton lies at the southern end of the Santa Ana Mountains, within the Peninsular Range of southwestern California (MCB Camp Pendleton, 2007a). The installation consists of various terrain, including sandy shores, seaside cliffs, coastal plains, rolling hills, canyons, and mountains. The installation lies within two major physiographic provinces. They include the coastal plains, which rise steeply from the coast inland into fairly level terraces, and the rolling foothills of the Santa Margarita Mountains (MCB Camp Pendleton, 2007a). Part of the coastal area consists of steep, low hills known as the San Onofre Hills, which are dissected by the major stream systems of the installation. East of the San Onofre Hills is gently rolling topography that gives rise to the Santa Margarita Mountains. The elevation at MCB Camp Pendleton ranges from sea level at the coastline to approximately 2,900 feet above mean sea level (amsl) on the Santa Margarita Mountains near the north-central boundary of the

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Elevation and topography (cont.)	installation. The majority of the land where operational range areas are located has an elevation ranging from approximately 300 feet amsl to approximately 2,250 feet amsl (MCB Camp Pendleton, 2011c).
Stratigraphy	MCB Camp Pendleton contains diverse geologic units, ranging from the oldest metavolcanic rocks and granite to stream or ocean-cut terrace sequences and recent alluvium. In general, the installation is underlain by Holocene to late Pleistocene unconsolidated sedimentary deposits that include alluvium in canyon bottoms and coastal terraces, Eocene to Pliocene sedimentary rocks of marine and non-marine origin, and Cretaceous to Triassic bedrock that includes highly consolidated and cemented sedimentary rock and plutonic and metamorphic crystalline rock (MCB Camp Pendleton, 2007a). A Triassic-Jurassic basement complex of metamorphic and igneous intrusive rock underlies the entire installation area. The Triassic age rock is low grade metamorphosed slate, argillite, and quartzite. The Jurassic age rock consists of alternating tuffs, breccias, and flows composed principally of andesite, quartz latite, rhyolite, and possibly some basalt (Worts and Boss, 1954). In inland areas, the basement rock is close to the ground surface, cropping out to form the Santa Margarita Mountains overlain by a small thin alluvial layer in the river valleys. Seaward of the Santa Margarita Mountains, the basement rock is overlain by three formations: ▪ Upper Cretaceous Trabuco Formation ▪ Williams Formation ▪ Eocene Santiago Formation In the foothills between the San Onofre and Santa Margarita mountains, only a thin alluvial layer overlies these formations. The San Onofre Breccia, which forms the San Onofre Mountains, generally overlies the Santiago Formation, dropping below the surface between the mountains and the ocean underlying the greater part of San Onofre Hills. The San Onofre Breccia is composed essentially of angular rock fragments or blocks contained in a hard matrix. It is interbedded with thin beds of gray, gray-green, and brown sandstone; grit; siltstone; and some pebble and cobble conglomerates (Worts and Boss, 1954). The rock fragments vary in size from small pebbles to very large boulders.

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Stratigraphy (cont.)	Thickness of the San Onofre Breccia ranges from 1,500 feet near the Santa Margarita River to 3,000 feet in Horno Canyon (Worts and Boss, 1954). The San Mateo, Capistrano, and Monterey Formations overlie the San Onofre Breccia in the Coastal Plains area. The Monterey Formation that directly overlies the San Onofre Breccia has been described as a very light gray, thinly bedded sandy siltstone and mudstone separated by diatomite parting (Craig, 1984). This formation has scarce exposures beneath terrace deposits. The Capistrano Formation, which overlies the Monterey Formation and is overlain unconformably by the San Mateo Formation, is exposed in the extreme northwest part of MCB Camp Pendleton and also is likely exposed in areas along the coast. The stratigraphy of the formation includes two lithologic units (upper and lower). The upper one is a yellow-brown siltstone separated by a disconformity from the lower one, which is dark brown sandstone with limestone beds (White, 1952). Thickness of the formation on base is no more than 1,000 feet (Wort and Boss, 1954). The San Mateo Formation is exposed in the area between the San Onofre Creek and the San Mateo Creek on the west side of the Cristianitos fault (Wort and Boss, 1954). A small exposure of the San Mateo Formation also has been observed just south of San Onofre Creek near the base of San Onofre Hills. The formation underlies a large part of the coastal terrace and alluvium deposits. Outcrops of the San Mateo Formation have been found near Las Pulgas Canyon, a little over 2 miles inland from the coast (Wort and Boss, 1954). Based on an assessment of the San Mateo Formation in the area between San Onofre and San Mateo Creeks, the San Mateo Formation consists of coarse, poorly sorted yellow-brown pebbly sand that is somewhat cross-bedded near the coast. Geologic cross-sections presented by Wort and Boss (1954) indicate that the thickness of the San Mateo Formation near the Santa Margarita River valley may be on the order of 1,000 feet. The Pleistocene terrace deposits and Holocene alluvium deposits largely overlie the San Mateo Formation and underlie much of the California coast. The alluvial deposits are located in many of the deeply incised mountain valleys and consist of unconsolidated silts, sands, gravels, and conglomerates (Cranham et al., 1994). The terrace deposits that generally underlie the alluvium deposits occur principally along the coast and the sides of principal stream valleys (Wort and Boss, 1954).

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Stratigraphy (cont.)	Terrance deposits have been described as being light brown to reddish-brown, poorly bedded sandy, pebble to cobble conglomerate (Cranham et al., 1994).
Soil and vadose zone characteristics	At MCB Camp Pendleton, the Coastal Plain soils are composed mostly of poorly consolidated marine sediments, whereas foothill soils are granitic with some metasedimentary and metavolcanic inclusions (MCB Camp Pendleton, 2007a). The predominant soil series types at MCB Camp Pendleton include Cieneba-Fallbrook rocky sandy loam (CmrG), rough broken land (RuG), Hambright gravelly clay loam (HaG), Gaviota fine sandy loam (GaF), and Fallbrook rocky sandy loam (FeE2). These soil series types are well to excessively well drained, generally have low organic carbon content, have soil erodibility rated to be severe, and have a surface runoff potential of low to very high. The GaF, HaG, and RuG soil series types have runoff potential of high to very high, and the runoff potentials of the FeE2 and the CmrG soil series types are fairly low to moderate (USDA NRCS, 2007). Soil pH generally ranges from 5.6 to 7.3, with the CmrG having the lower range pH of 5.6 to 6.0, (USDA NRCS, 2007).
Erosion potential	The installation is located on a widely varying topography with steep slopes on the rolling hills and mountains of the coast inlands (over 90%) and level terraces near the coast. The area is covered largely with grass, scrub, and chaparral but includes some unvegetated areas. As mentioned for the soil and vadose zone characteristics, the predominant soil series types found at MCB Camp Pendleton have severe erodibility ratings (USDA NRCS, 2007). Soil erosion and sedimentation are widespread on MCB Camp Pendleton. Soil erosion patterns are influenced largely by the year-to-year climatic variability. The overall erosion potential at MCB Camp Pendleton can range from low to severe. Areas that potentially can experience severe soil erosion are those with steep topography and unvegetated cover. Also, areas where the vegetation and soil have been disturbed by military operations, such as the identified MC loading areas, can have high to severe soil erosion potential.

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Potential MC release mechanisms	Potential MC release mechanisms include mobilization in surface water runoff or groundwater. Precipitation at MCB Camp Pendleton occurs fairly infrequently, but precipitation events can be torrential and lead to flash flood events. As a result of this and also due to the relative steep topography of the area and the soil characteristics on site, surface water runoff rates can be very high. Surface water runoff can transport MC in soil through dissolution in runoff water or erosion and transport of soil and sediments with sorbed MC. MC in surface water runoff potentially can be released into non-perennial streams, small lakes and ponds, backshore lagoons and, ultimately, to the Pacific Ocean. A very small proportion of the precipitation infiltrates through the thin alluvium overlying the basement complex at impact areas and potentially migrates to deeper fractured bedrock. However, MC are more likely to be transported to groundwater through preferential recharge of the non-perennial streams to the underlying alluvium and terrace deposits in the Coastal Plain area where alluvium and terrace deposits have significant thickness and are underlain by the high yielding San Mateo aquifer.

4.4. Surface Water Profile

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water drainage	Surface water drainage at MCB Camp Pendleton generally is ephemeral or intermittent, though a notable portion of the Santa Margarita River and its tributary on the east are perennial. Because many streams are non-perennial, they only flow following significant precipitation. As noted in the Physical Profile, less precipitation generally falls in the coastal areas of the installation compared to the western mountainous areas. Due to the extreme variability of precipitation and runoff, the potential for large floods is high on MCB Camp Pendleton. Some of the larger drainages at MCB Camp Pendleton include the Santa Margarita River, the San Mateo Canyon, the San Onofre Canyon, and the Las Pulgas Canyon (**Figure 4-2**).

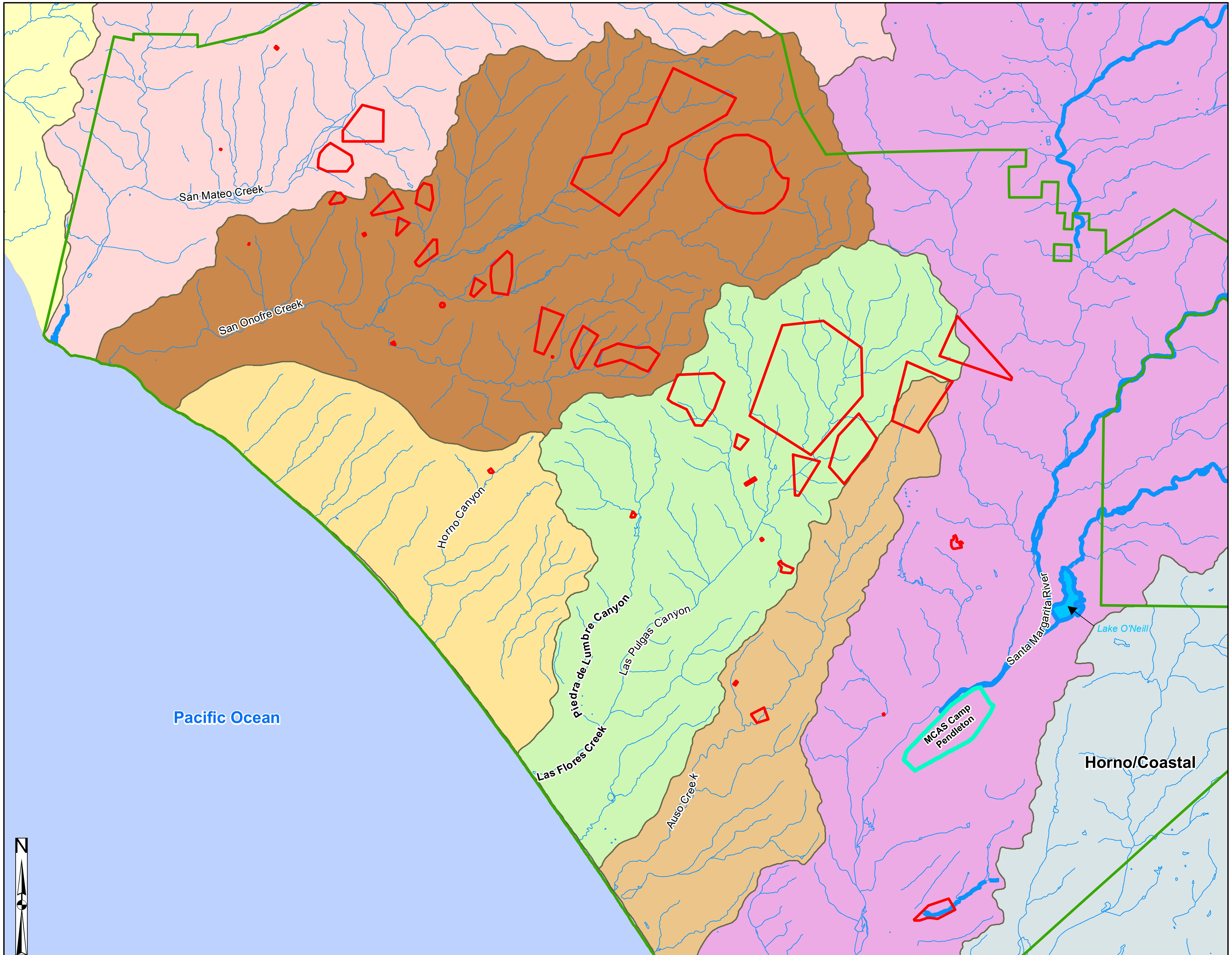

Figure 4-2

Watersheds and Streams

REVA MCB Camp Pendleton
Oceanside, CA

Legend

- Non-Perennial Stream
- Perennial Stream
- Lake
- Aliso Watershed
- Horno/Coastal Watershed
- Las Flores Watershed
- San Luis Rey Watershed
- San Mateo Watershed
- San Onofre Watershed
- Santa Margarita Watershed
- MC Loading Area
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary

0 2 4
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

ARCADIS MALCOLM PIRNIE

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water drainage (cont.)	These streams originate on the western slopes of the Peninsular Ranges, drain in southwesterly and southeasterly directions within the installation boundary, and ultimately discharge into the Pacific Ocean. The drainages form broad alluvial plains as they approach the Pacific Ocean. The three largest estuaries on the installation are situated at the mouths of the Santa Margarita, Las Flores, and San Mateo Streams (MCB Camp Pendleton, 2007a).
Hydrological unit & watershed areas	MCB Camp Pendleton is located within the San Juan and the Santa Margarita hydrologic units (CRWQCB, 1994). There are seven major watersheds within the MCB Camp Pendleton installation boundary: Aliso, Horno/Coastal, Las Flores, San Onofre, San Luis Rey, San Mateo, and Santa Margarita. The watersheds range in size from 5,800 to 99,074 acres; they are divided by mountain ranges and mostly consist of non-perennial stream systems that flow in a southwesterly direction toward the Pacific Ocean (**Figure 4-2**). Drainage generally is in the form of rapid runoff following rainfall events. The Aliso, Horno/Coastal, San Onofre and Las Flores watersheds are contained principally within the installation boundaries. The San Mateo, Santa Margarita, and San Luis Rey watersheds extend up gradient beyond the northern, eastern, and western boundaries of the installation. MC loading areas are located in six of the seven watersheds within MCB Camp Pendleton: Aliso, Horno/Coastal, Las Flores, San Onofre, San Mateo, and Santa Margarita watersheds (**Figure 4-2**).
Santa Margarita watershed	The Santa Margarita watershed is the largest watershed draining through MCB Camp Pendleton. It has an area of approximately 99,074 acres, and over 50% of the watershed is located outside of the installation boundary. This watershed covers the eastern portion of the installation and extends northward into the Cleveland National Forest. Most of the developed area of MCB Camp Pendleton and all of MCAS Camp Pendleton lie within the Santa Margarita watershed. The major hydrologic feature in this watershed is the Santa Margarita River, which flows southwesterly to the Pacific Ocean from Palomar, Santa Ana, Santa Margarita Mountains, and the Santa Rosa Plateau. A notable portion of the Santa Margarita River and its tributary on the east flow perennially. The watershed drains Murrieta and Temecula Creeks within the upper Santa Margarita basin and drains Rainbow, Sandia, and De Luz Creeks within the lower Santa Margarita basin. All of Range

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Santa Margarita watershed (cont.)	104B, Range 401, the Kilo 2 Combat Town, approximately 70% of Range 409A, and approximately 5% of Range 408 MC loading areas are located within this watershed.
San Mateo watershed	The San Mateo watershed is the second largest watershed draining through the installation. It has an area of approximately 85,500 acres (MCB Camp Pendleton, 2011c). This watershed lies on the western edge of MCB Camp Pendleton and extends northward into the Cleveland National Forest. Approximately 21% of the total watershed area is within the MCB Camp Pendleton boundary. The watershed includes San Mateo Canyon, which originates several miles up gradient of the installation boundary and flows southwesterly with a dendritic drainage pattern through the installation and discharges into the Pacific Ocean. Major tributaries of San Mateo Canyon include Cristianitos and Talega Canyons. All of the LFAM 706, Range 314 Complex, Range 302, and Range 307 MC loading areas are located within this watershed.
San Onofre watershed	The San Onofre watershed lies almost completely within MCB Camp Pendleton. Only a small portion of the northern portion of the watershed is outside of the installation boundary (approximately 1% of the total watershed). The watershed has an area of approximately 28,000 acres and is located between the Las Flores watershed on the east and the San Mateo watershed to the west. From west to northeast, it drains an area extending from the western slopes of Jardine Canyon to Case Springs. It includes the San Onofre Canyon, which flows southwesterly within the installation boundary and discharges to the Pacific Ocean just north of the San Onofre Nuclear Generating Station (MCB Camp Pendleton, 2007a). Jardine Canyon is one of the major tributaries to San Onofre Canyon. This watershed area contains the largest number of identified MC loading areas. All of the Whiskey Impact, Range 600, Range 217/219, Range 218A, Range 216 House, Range 215A, Range 210D, Range 210E/210F, Range 211, Range 208C, Range 204B, Range 202, Range 203, Range 201, Quebec Impact, Range 207, and Range 301 MC loading areas are located within this watershed.
Las Flores watershed	The Las Flores watershed is located entirely within the boundary of MCB Camp Pendleton. It is one of the smaller watersheds draining through the installation. It has an area of approximately 17,300 acres and is located

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Las Flores watershed (cont.)	between the Aliso watershed on the east and the San Onofre watershed on the west. Surface water in the Las Flores watershed includes a freshwater lake, coastal lagoons, and non-perennial creeks. Approximately 1 mile east of the Pacific Ocean, the Las Pulgas and Piedra de Lumbre Creeks join to form the Las Flores Creek (also called Las Pulgas). The Las Flores Creek originates approximately 10 miles from the Pacific Ocean in the Santa Margarita Mountains. Low-flow surface water was observed along portions of the Las Flores Creek near the Basilone Road overpass during the REVA baseline site visit (Malcolm Pirnie, 2009). The source of water is unknown. At least one reference specific to the water sources of Las Flores watershed indicates that all creeks are non-perennial (Palmer, 1990). All of the Zulu Impact, Range 407 Complex, Range 221/222, Range 223B, Range 225, Range 227, Range 109, Range 108 Demo, and PDL Combat Town MC loading areas and approximately 20% of the Range 408 and approximately 30% of the Range 409A MC loading areas are located within this watershed.
Horno/ Coastal watershed	The Horno/Coastal watershed is approximately 10,400 acres, all of which is located on the installation. The watershed area is located along the shoreline between the San Onofre and the Las Flores watersheds. It consists of short non-perennial streams with a dendritic drainage pattern that do not connect prior to discharge to the ocean. The Horno Canyon, which is the major hydrologic feature within the watershed, originates approximately 3 miles north of the Pacific Ocean and flows in a southeasterly direction toward the Pacific Ocean. All of the Horno Combat Town MC loading area is located within this watershed.
Aliso watershed	The Aliso watershed is located entirely within the boundary of MCB Camp Pendleton. It is the smallest watershed within MCB Camp Pendleton. It has an area of approximately 5,800 acres and is located between the Santa Margarita watershed on the east and the Las Flores watershed on the west. The major hydrologic feature in this watershed is the Aliso Canyon, which originates approximately 9 miles north of the Pacific Ocean within the installation and flows in a southeasterly direction toward the Pacific Ocean. All streams within the watershed are non-perennial. The Range 130 Breach and Range 132 Complex MC loading areas and approximately 75% of the Range 408 MC loading area are located within this watershed.

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Known water quality character-istics	Based on a 2-year water quality program conducted at San Mateo, San Onofre, and Las Flores Creek watersheds, some constituents sampled were found to be in exceedance of the San Diego Basin Plan (Basin Plan) limits at different locations (Stetson, 2010). Total dissolved solids (TDS), iron, and manganese exceeded the Basin Plan limits at locations within the three watershed areas at least 20% of the times sampled. Dissolved oxygen (DO), total nitrogen, and turbidity exceeded the Basin Plan limits at locations within the San Mateo watershed at least 50% of the times sampled. Total phosphorous, chloride, and thallium exceeded the Basin Plan limits at locations within the Las Flores watershed at least 71% of the times sampled. Storm water monitoring data collected at the installation within the Santa Margarita River watershed indicate dissolved and total lead concentrations generally are below the water quality objectives, which are based on federal standards (Hughart, 2003; Hughart, 2004; Hughart, 2007). Only 1 out of 10 samples taken in late 2002 and early 2003 had a total lead concentration slightly above the water quality objective. Only 13% of the dissolved lead samples measured from 2000 through 2008 had exceedences of the water quality objective. As part of the REVA baseline analysis for MCB Camp Pendleton, samples for MC, lead, and other water quality parameters were collected at select surface water locations in the Las Flores and San Onofre watersheds, as well as at a background location in the San Mateo watershed (Malcolm Pirnie, 2009). Samples were collected multiple times during the rainy season of 2007–2008. Of the indicator MC, only lead was detected in the Las Flores watershed. Total lead ranged from a qualified 0.13 micrograms per liter (µg/L) (later in season) to 23 µg/L (early in season). Dissolved lead was detected only in early-season samples, from 3.9 to 4.3 µg/L, all below the respective hardness-adjusted DoD screening value. pH ranged from 7.33 to 8.07; DO ranged from 6.95 to 12.68 milligrams per liter (mg/L); and hardness ranged from 340 to 420 mg/L. In the San Onofre watershed, total lead ranged from a qualified 0.15 µg/L (later in season) to 74 µg/L (early in season); dissolved lead was only detected in early-season samples, from qualified 0.61 to 4.5 µg/L. Only a single dissolved lead result of 4.5 µg/L slightly exceeded its hardness-adjusted DoD screening value, and it was not detected later in the season. RDX was detected below its respective DoD screening value only in early-

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Known water quality character-istics (cont.)	season samples from 0.70 to 2.6 μg/L. Later in the season, 2-nitrotoluene and 3-nitrotoluene were detected in a single sample below respective laboratory reporting limits (RLs) and below respective DoD screening values. pH ranged from 6.24 to 7.77; DO ranged from 11.75 to 13.05 mg/L; and hardness ranged from 160 to 170 mg/L. No REVA indicator MC were detected in the single background sample collected from the upper reaches of the San Mateo watershed; pH was 7.12 and DO was 9.36 mg/L.
Designated beneficial uses	Many of the inland surface waters at MCB Camp Pendleton have been designated by the CRWQCB San Diego Region to have beneficial uses of contact and noncontact recreation, warm and cold freshwater habitat, wildlife habitat, rare, T/E species, spawning, and agricultural supply (CRWQCB, 1994). In addition to the above beneficial use designation, the Santa Margarita and the San Luis Rey Rivers also have been designated to have beneficial uses of municipal and domestic supply and industrial service supply. Most other inland surface waters within MCB Camp Pendleton have been exempted from the designation for municipal and domestic supply. The coastal waters at MCB Camp Pendleton, including the Pacific Ocean, river and creek mouths, and coastal lagoons, have been designated to have beneficial uses of industrial service supply, navigation, contact and noncontact recreation, commercial and sport fishing, marine habitat, aquaculture, migration of aquatic organisms, spawning, and shellfish harvesting. Surface water at MCB Camp Pendleton is not used directly for municipal and domestic supply, although the stream and rivers recharge the groundwater basins that are used for domestic purposes. Drinking water at MCB Camp Pendleton is obtained from groundwater supply wells. Additional detail concerning the installation groundwater drinking water supply is included in the Groundwater Profile.
Supported habitats/ ecosystems	MCB Camp Pendleton provides a rich diversity of species and habitat types. The MCB Camp Pendleton INRMP has divided the installation conceptually into three major ecosystems: estuary and beach, riparian, and uplands (MCB Camp Pendleton, 2007a). MCB Camp Pendleton's estuarine and beach ecosystem includes 319 acres of habitat associated with beaches along the coastline, coastal lagoons, and river estuaries.

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Supported habitats/ ecosystems (cont.)	The Santa Margarita River estuary is the installation's largest estuary and supports four major habitat types: salt marsh, brackish marsh / willow swamp, salt flats, and coastal sand dunes. These habitats support about 148 plant species, 9 species of reptiles and amphibians, 24 fish species, 17 mammalian species, and 184 bird species, including several federally and state-listed species, such as the California least tern, light-footed clapper rail, western snowy plover, tidewater goby, and Belding's savannah sparrow. Riparian ecosystems contain a wide variety of habitat types, including riparian woodlands, riparian scrublands, freshwater marsh, and open water and occur in drainages, seepages, and riverine areas where water availability is high. Out of approximately 9,800 acres of floodplain on MCB Camp Pendleton, riparian habitats currently cover about 8,200 acres. The Santa Margarita River is the most biologically intact riparian corridor remaining in Southern California (USFWS, 1995). Other areas on base that support riparian communities include the drainages of San Mateo, San Onofre, Las Flores, Aliso, and portions of San Luis Rey (MCB Camp Pendleton, 2007a). Upland ecosystems contain habitats such as vernal pools, shrublands, oak woodlands, and grasslands that occur from just inland of the coastal bluffs to the higher elevation of the Santa Margarita Mountains. Several plant and animal species on MCB Camp Pendleton are federally and state-listed T/E species, and several species have been identified as California special concern species. Additional information of T/E species and species of special concern is provided in the Natural Resources Profile.
Gaining or losing streams	Infiltration of water from streams is a dominant recharge mechanism to the alluvial groundwater basins located in the coastal plain areas just inland of the Pacific Ocean (Palmer, 1990). However, the discontinuous and narrow saturated alluvial deposits along the streams in the upland areas farther upstream may either gain from or lose water to the streams, depending on seasonal changes in water table elevation.
Surface water collection points	Although three major dams (at Vail Lake, Skinner, and Diamond Valley Reservoirs) are located far upstream in the Santa Margarita watershed, MCB Camp Pendleton has only a low-flow impoundment on this river, which is used to divert water to Lake O'Neill and off-channel recharge ponds. Lake O'Neill, a small lake constructed across Fallbrook Creek in 1883, historically

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water collection points (cont.)	was used primarily to store water for farm irrigation. After the installation was purchased, the operation of the lake continued, but now the water is released to recharge downstream aquifers that are used to provide the majority of the installation's water supply. Lake O'Neill also provides recreational benefits to the Marines. The capacity of the reservoir is 1,200 acre-feet; the Santa Margarita River (through the O'Neill Ditch diversion), Fallbrook Creek, and rainfall/runoff supply Lake O'Neill. Small naturally occurring ponds are located throughout the installation, including Case Springs and Whitman Pond (San Onofre watershed); Pulgas Lake (Las Flores watershed); Broodmare Pond, Pilgrim Creek Pond, Horseshoe Lake, and Windmill Lake (San Luis Rey watershed); and Wildcat Ponds and India Ponds (Santa Margarita watershed) (MCB Camp Pendleton, 2007a).

4.5. Groundwater Profile

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Groundwater basins	The primary groundwater basins at MCB Camp Pendleton include, from northwest to southeast, the San Mateo, the San Onofre, the Las Flores, and the Santa Margarita groundwater basins. These groundwater basins include the alluvial groundwater basins in the Coastal Plain that serve as the principal water source for the installation (MCB Camp Pendleton, 2007a) (**Figure 4-3**). Primarily streams recharge the alluvial groundwater basins. The primary water-bearing units in the groundwater basins are the alluvial aquifer and the San Mateo aquifer, which underlies the alluvial aquifer (**Figure 4-1**). Groundwater extracted from these aquifers is used by MCB Camp Pendleton for drinking water and localized landscape irrigation (Palmer, 1990).

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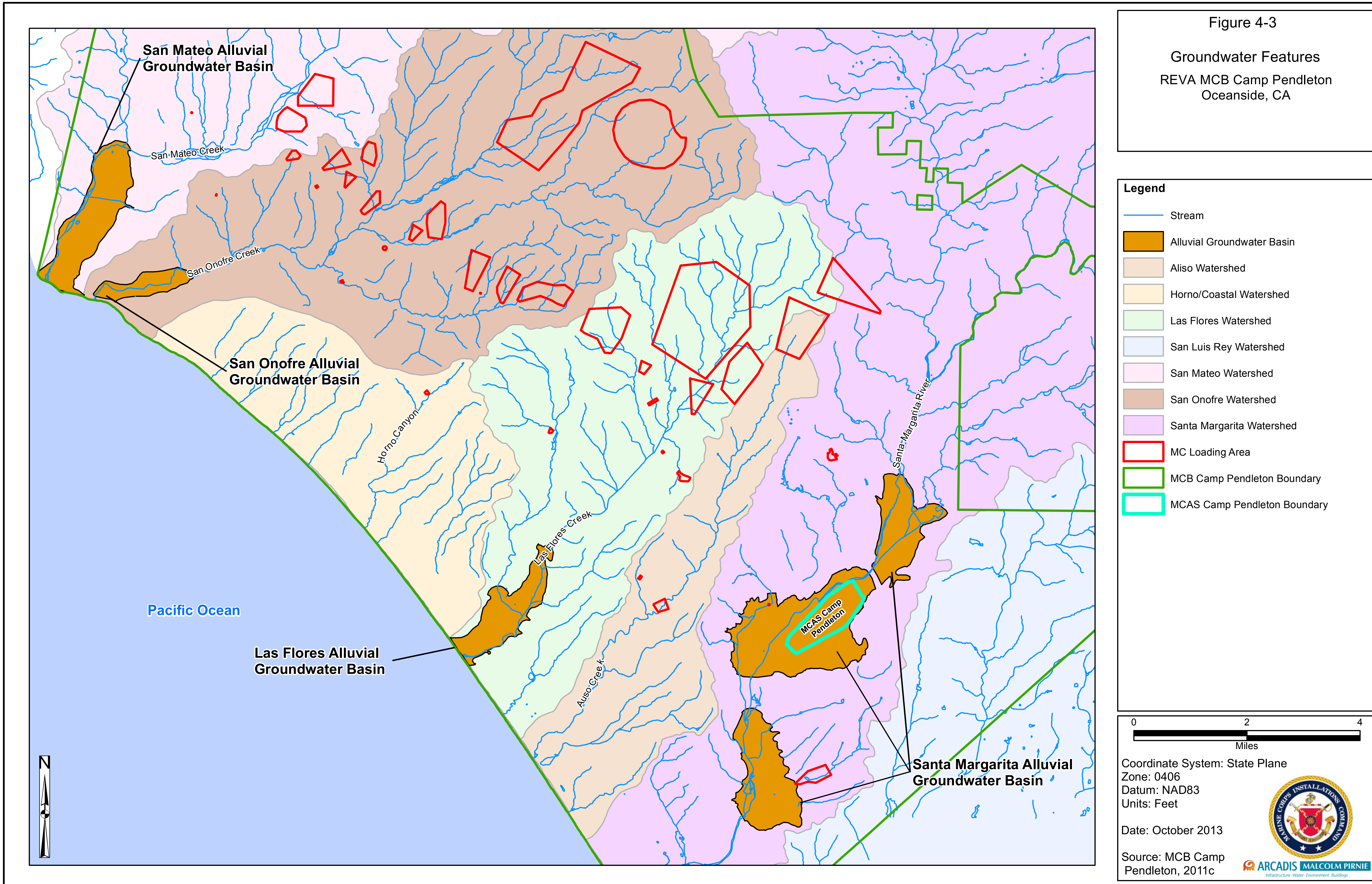

Figure 4-3

Groundwater Features

REVA MCB Camp Pendleton
Oceanside, CA

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Groundwater basins (cont.)	The alluvial and the San Mateo aquifers are the groundwater-producing units in the San Mateo, San Onofre, and Las Flores basins; only the alluvial aquifer is the groundwater-producing unit in the Santa Margarita River basin. The San Onofre Breccia underlies the San Mateo aquifer. This breccia functions as an aquitard and does not contain or transmit substantial quantities of groundwater due to its poor sorting and high percentage of fine-grained materials (Peterson, 1978). Three other hydrostratigraphic units classified as aquitards underlie this breccia layer: the Santiago, Williams, and Trabuco Formations. Between the identified MC loading areas and the coastal plain, variably saturated alluvial deposits overlie the aquitards. The amount of groundwater flowing downward into these aquitards from the alluvium is likely insignificant. The basement complex underlies the aquitards and crops out in the upland area of the installation where some of the MC loading areas are located. Groundwater within the fractures and joints of the basement complex currently is not considered economically viable for water supply purposes (Stetson, 2005). *Alluvial Aquifer* The alluvial aquifers in the coastal plain area of the installation are the most important aquifers for REVA due to their connection with both surface water and the San Mateo aquifer. These quaternary alluvial deposits are located in many of the deeply incised mountain valleys and consist of unconsolidated silts, sands, gravels, and conglomerates (Cranham et al., 1994). The thicknesses of the alluvial aquifers vary from 18 to 105 feet; the aquifers generally are thickest toward the center of the stream valleys (Palmer, 1990). Hydraulic conductivity values estimated from aquifer pumping tests conducted in the Santa Margarita groundwater basin within the alluvial aquifer can range from 0.00056 to 0.31 feet per minute (ft/min) (Stetson, 2001). Presence of groundwater within the alluvium varies seasonally, with the greatest saturated thickness likely occurring in the winter and spring. The alluvium in many of the identified MC loading areas is likely unsaturated for much of the year. *San Mateo Aquifer* The Monterey Formation, the San Mateo Formation, and the Capistrano Formation are assumed to be hydraulically similar and comprise the San

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Groundwater basins (cont.)	Mateo aquifer, which ranges in thickness from 33 to 1,400 feet (Palmer, 1990). The San Mateo Formation, which underlies the alluvial aquifers, is in direct contact (no separating confining unit) with the alluvial aquifers and the Pacific Ocean. Groundwater within the San Mateo aquifer is found primarily under unconfined conditions. While there is no hydraulic separation between the two, the alluvial aquifer and San Mateo aquifer are identified as two separate aquifers because of their varying hydraulic characteristics; however, they are in direct contact with one another. According to Palmer (1994), the San Mateo aquifer is the major water-producing aquifer in the Las Flores basin. The aquifer generally is composed of coarse-grained sediments, such as sand, sandstone, gravel and cobbles, interbedded with fine-grained sediments such as clay, sandy clay, and silty clay (Stetson, 2007; Worts and Boss, 1954). Aquifer pumping tests for wells screened just within the San Mateo aquifer indicated a hydraulic conductivity of the San Mateo aquifer ranging from 0.03 to 0.19 ft/min and a specific yield of 0.12. The small range of hydraulic conductivities from different wells suggests fairly homogeneous deposits that comprise the San Mateo aquifer (Palmer, 1990). The estimated hydraulic conductivity of the alluvial and San Mateo aquifers within the San Mateo, San Onofre, and Las Flores groundwater basins can range from 0.0083 to 0.412 ft/min, with an average value of approximately 0.12 ft/min (Stetson, 2005; Palmer, 1994).
Designated beneficial uses	Groundwater within the San Mateo, San Onofre, and Santa Margarita basins at MCB Camp Pendleton have been designated by the CRWQCB San Diego Region to have existing beneficial uses for municipal and domestic supply, agricultural supply, and industrial service supply (CRWQCB, 1994). Additionally, some portion of the Santa Margarita basin is designated to have existing and beneficial uses for industrial process supply. Groundwater use at MCB Camp Pendleton includes military, domestic, and industrial uses (Stetson, 2008). During the REVA five-year review site visit, it was discovered that the installation no longer uses groundwater for agricultural purposes. The installation pumps groundwater from the Las Flores and Santa Margarita basins to supply potable water to its southern service areas, which include the military headquarters, the NHCP, MCAS Camp Pendleton, and many military

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Designated beneficial uses (cont.)	family residential areas (Stetson, 2008). The San Mateo and San Onofre basins supply potable water to its northern service area, which includes the San Mateo, San Onofre, Cristianitos, Talega, and Horno service areas (Stetson, 2008). Off-installation wells are located up gradient of MCB Camp Pendleton and the identified MC loading areas. Communities residing in metropolitan areas (Murrieta and Temecula) located approximately 7.5 and 10 miles northeast of the installation boundary draw water from the Temecula-Murrieta basin, consisting of alluvial and consolidated sediments.
Groundwater supply wells	MCB Camp Pendleton's domestic and industrial water supply is produced from aquifers that are recharged primarily by infiltration from overlying rivers and streams. Twenty-seven groundwater production wells extract groundwater from the San Mateo, San Onofre, Las Flores, and Santa Margarita alluvial basins (6 in San Mateo, 4 in San Onofre, 4 in Las Flores, and 13 in Santa Margarita) (**Figure 4-3**). The wells are screened in the alluvial aquifer and the San Mateo aquifer. Based on the annual pumping statistics for water years 1961 to 2006, the average water pumped from the wells in the four groundwater basins was 7.4 million gallons per day (MGD) (Stetson, 2008). Water provided from the Santa Margarita basin wells represents about 65% of the total water consumed on the installation. Prior to 2006, agricultural water use in the northern portion of the installation was about 0.7 MGD. Since 2006, agricultural use has been discontinued; however, military consumption has increased. The net result has been a decrease in total consumption of about 0.4 MGD in the northern portion of the installation (MCB Camp Pendleton, 2007a).
Recharge source(s)	Infiltration of streamflow is a dominant groundwater recharge mechanism to the alluvial aquifers (Palmer, 1990). When water is flowing in the streams, water infiltrates through the vadose zone and recharges the alluvial aquifer. Groundwater flows in the alluvium during periods of active streamflow and for periods of days to weeks afterward. The groundwater in the alluvial aquifer then recharges the underlying San Mateo aquifer.
Porous or fracture flow	Groundwater flow through the water-bearing units at MCB Camp Pendleton generally is porous-media flow. The water-bearing units

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Porous or fracture flow (cont.)	contain alluvial deposits, largely composed of unconsolidated silts, sands, gravels, and conglomerates underlain by the San Mateo, Capistrano, and the Monterey Formations. These formations are composed of coarse, poorly sorted pebbly sand that is somewhat cross-bedded near the coast; thinly bedded sandy siltstone and mudstone separated by diatomic parting; and siltstone separated by a disconformity of dark brown sandstone with limestone beds. Fracture flows can occur within the fractures and joints of the basement complex that outcrops the upland areas of the installation. However, only a small proportion of precipitation likely infiltrates this formation, and the water within the fractures and joints is not considered economically viable for water supply purposes (Stetson, 2005).
Depth to groundwater	Groundwater in the groundwater alluvial basins is encountered at depths shallower than 100 feet below ground surface (bgs). Based on water levels measured in monitoring and production wells, the depth to groundwater in the four groundwater basins can be 12 to 32 feet bgs in the San Mateo basin, 28 to 43 feet bgs in the San Onofre basin, 10 to 58 feet bgs in the Las Flores basin, and 3 to 58 feet bgs in the Santa Margarita basin (Stetson, 2001; Stetson, 2007; MCB Camp Pendleton, 2011e).
Gradient and flow velocity	In the absence of pumping by production wells, groundwater flow at MCB Camp Pendleton generally parallels the surface topography, flowing in a southwest direction toward the Pacific Ocean. However, the significant groundwater withdrawal (7.4 MGD) by the installation production wells induces a localized hydraulic gradient toward the production wells. Water level maps for the Las Flores basin, based on 1987 data, indicate that groundwater is moving in a southwest direction, down the axis of Las Pulgas Canyon (along Las Flores / Las Pulgas Creek) (Palmer, 1994). The gradient in the Las Flores basin ranges from 0.08 in Las Pulgas Canyon to a flatter slope of 0.01 near the coast (Palmer, 1990). The average velocities in the San Mateo, San Onofre, Las Flores, and Santa Margarita basins are estimated to be 0.00077 ft/min, 0.0022 ft/min, 0.0013 ft/min, and 0.0013 ft/min, respectively. These velocities were derived from a median gradient value of 0.045 at all four groundwater basins, the average hydraulic conductivity values estimated for the basins by Stetson (2001; 2005) and Palmer (1994),

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Gradient and flow velocity (cont.)	and the average effective porosity for mixed sand, gravel, silt and clay,
Known water quality characteristics	Water quality always has been a high priority for MCB Camp Pendleton because nearly all of the drinking water consumed by the installation is drawn from local aquifers. The quality of MCB Camp Pendleton's drinking water generally meets or exceeds State of California and federal health-related drinking water standards (MCB Camp Pendleton, 2005). Studies of water quality data for the groundwater supply at MCB Camp Pendleton have indicated that groundwater is not influenced directly by surface water quality within the Santa Margarita River (MCB Camp Pendleton, 2007a). Based on historical water quality data collected at the installation's production wells, the average TDS concentrations in the four groundwater basins are higher than the recommended secondary maximum contaminant level for TDS of 500 mg/L. The TDS levels slightly are higher in the Santa Margarita and Las Flores basins (averages of 729 mg/L and 731 mg/L, respectively) than in the San Mateo and the San Onofre basins (averages of 509 mg/L and 609 mg/L, respectively) (Stetson, 2008). Similarly, the average pH levels are slightly higher in the Santa Margarita and Las Flores Basins (7.33 and 7.32, respectively) compared to the pH levels in the San Mateo and San Onofre basins (7.06 and 7.02, respectively). Several regulated contaminants have been measured above primary drinking water standards, including aluminum, asbestos, fluoride, nickel, and lead in the Santa Margarita basin and radionuclides in the Las Flores and San Onofre basins. As part of the REVA baseline analysis for MCB Camp Pendleton, MC (with the exception of perchlorate) were sampled in production wells located within the Las Flores and the San Onofre groundwater basins. Based on these sampling results, no explosives were detected in the production wells within the Las Flores basin, but 2-nitrotoluene was detected below the laboratory RL and below the DoD drinking water screening value in one well within the San Onofre basin. However, this constituent was not detected when the well was resampled (Malcolm Pirnie, 2009). Additionally, lead was detected below the laboratory RL in one well within the Las Flores basin and in two wells within the San

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Known water quality characteristics (cont.)	Onofre basin. MCB Camp Pendleton conducted a groundwater sampling event in 2006 to examine the presence of perchlorate. Groundwater samples were collected from wells across four watersheds: San Mateo, San Onofre, Las Flores, and Santa Margarita. The results of the study indicated low concentrations of perchlorate were present across all four watersheds, with the maximum concentration (1.580 μg/L) found in the San Mateo watershed.
Discharge location(s)	Depending on seasonal changes in water table elevation, groundwater in the discontinuous and narrow saturated alluvial deposits along the streams in the upland areas can discharge to the streams. Other groundwater discharge includes groundwater flow to production wells located within the San Mateo, San Onofre, Las Flores, and Santa Margarita basins (**Figure 4-3**).

4.7. Human Land Use and Exposure Profile

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
Land use	A variety of land uses occurs at MCB Camp Pendleton; however, the priority of the installation is to provide training and support facilities for active duty and Reserve Marine, Navy, Army, Air Force, and National Guard units, as well as other federal, state, and local agencies. Similar to local municipalities, the installation provides military service members and their families with support facilities and services, including housing, water and sewage service, solid waste disposal, medical and dental services, schools, child care, employment assistance, and recreation opportunities. Mission support activities on MCB Camp Pendleton include natural resources management; fire management; infrastructure, facilities, and grounds maintenance; and morale, welfare,

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
Land use (cont.)	and recreation community services. Drinking water supply wells are found in four of the groundwater basins at MCB Camp Pendleton: San Mateo and Santa Margarita (two major well fields) and San Onofre and Las Flores (two smaller well fields), as shown in **Figure 4-3**. According to the MCB Camp Pendleton Office of Water Resources, over 99% of the installation's water supply is derived from groundwater on base. Included in the recreational services provided on the installation are natural resources–related recreational opportunities, such as beach usage, hunting, fishing, hiking, and camping. These recreational activities are open only to active and retired military and DoD personnel. Permits to hunt, fish, and camp are provided by the installation's Game Warden's office. Several factors, such as scheduled training activities as well as monitored fish and game populations, determine the amount of permits given out each week as well as where the activities can be permitted. Additional land use on MCB Camp Pendleton occurs in the form of leases, easements, and other real estate agreements. Existing real estate agreements include San Onofre State Park, public utilities (including SONGS), and transit corridors (including I-5) (MCB Camp Pendleton, 2007a).
Current human receptors	Streams and other surface water bodies are located in and around MCB Camp Pendleton. These water bodies include coastal lagoons and freshwater lakes. Surface waters on the installation are not used as a potable water supply. Humans potentially use these waters for recreational purposes (such as swimming and fishing); however, because a large majority of the water bodies only contain water during the wet season when rain events occur, the overall recreational use is limited. Freshwater lakes were identified at MCB Camp Pendleton during the initial review of the installation. However, no direct pathways exist between the MC loading areas and freshwater lakes. Streams draining the MC loading areas may recharge alluvial groundwater basins that are used as drinking water sources located in the coastal plain downstream of MC loading areas. The alluvial groundwater basins that are located downstream of primary MC loading areas include the San Mateo, San Onofre, and Las Flores basins. Drinking water supply wells for MCB

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
Current human receptors (cont.)	Camp Pendleton are located in each of these basins. For this reason, non-perennial streams draining from primary MC loading areas have potential human receptors (through drinking water use) (MCB Camp Pendleton, 2007a).
Land use restrictions	Leases and easements—including aboveground utility facilities of SONGS and San Diego Gas & Electric, I-5, and railway lines—reduce the land available for military use, affect the use of aviation assets, and challenge the conduct of realistic military training activities. Constraints exist for amphibious landing exercises along the installation's entire western boundary and create artificial restrictions on land maneuvers. Training is restricted at MCB Camp Pendleton in specified areas, such as designated historical/archeological sites, landfills, cantonment areas, Installation Restoration and National Priorities List environmental cleanup areas, and designated environmentally sensitive areas. The installation has established management programs, protocols, and regulations so that training activities and installation operations avoid and minimize adverse impacts to federally listed species and their habitats, provide compensatory mitigation for impacts that do occur, and ensure that installation actions do not jeopardize the continued survival of the species. Installation lands have been, and continue to be, subject to both direct and indirect pressures from surrounding communities and the region for land use (e.g., leases, easements) and mission restrictions (e.g., noise) (MCB Camp Pendleton, 2007a).

4.8. Natural Resources Profile

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
Ecosystems	Natural resources on MCB Camp Pendleton reflect the rich diversity of species and habitat types formerly present within the greater surrounding region. MCB Camp Pendleton has identified four major ecosystems at the

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
Ecosystems (cont.)	installation and has consolidated planning for and consultation on these ecosystems into three ecosystem conservation plans: estuarine and beach, riparian, and uplands. *Estuarine and Beach* MCB Camp Pendleton's estuarine/beach ecosystem includes 319 acres of habitat associated with beaches along the coastline, coastal lagoons, and river estuaries. This includes the Santa Margarita River Estuary and the coastal lagoons located at Cocklebur, French, Aliso, Las Flores, San Onofre, and San Mateo Creeks. Approximately 17 miles of undeveloped coastline exist within the borders of MCB Camp Pendleton. Habitats of the coast are divided roughly into four zones. The intertidal zone is regularly inundated by the ocean, while the strand or beach is subject to wave action and deposition and removal of sand and gravel. Foredunes are the first line of dunes subject to sand deposition, high winds, and salt deposition but are only rarely subject to wave action or overwash; backdunes may be stable (not subject to deposition or erosion by the wind) or moving (having sand deposited or removed). Where cliffs face the ocean, the exposure to high winds and high salt deposition creates another distinctive habitat—coastal bluffs. *Riparian* Of the approximately 9,800 acres of floodplain at MCB Camp Pendleton, riparian habitats currently cover about 8,200 acres; disturbed/developed lands account for the remaining 1,600 acres of floodplain. Riparian ecosystems contain a wide variety of habitat types, including riparian woodlands, riparian scrublands, freshwater marsh, and open water/gravel, and occur in drainages, seepages, and riverine areas where water availability is high. Riparian ecosystems are dynamic systems, depending upon periodic flooding to provide substrate, nutrients, and physical energy to cycle the community back to earlier successional stages. The stream and river channels that are central to riparian areas are subject to erosion and deposition every year and to periodic major flooding. The Santa Margarita River is the most biologically intact riparian corridor remaining in Southern California (USFWS, 1995). Other areas at the installation that support riparian communities include the drainages of the San Mateo, San Onofre, Las Flores, Aliso, and French watersheds and portions of Pilgrim Creek.

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
Ecosystems (cont.)	*Upland* The upland ecosystem includes the remaining undeveloped areas of MCB Camp Pendleton and, like the riparian ecosystem, contains a wide variety of vegetation types, including vernal pools, shrublands, oak woodlands, and grasslands that occur from just inland of the coastal bluffs to the higher elevations of the Santa Margarita Mountains. Because upland areas in Southern California generally are moisture-limited, receiving almost all of their moisture in the winter, upland vegetation differs distinctly, functionally, and visually from season to season (MCB Camp Pendleton, 2007a).
Vegetation	Vegetation distribution is determined primarily by climate, available moisture, and soil nutrients. Thus, rainfall, temperature, soil type, topographic position, and elevation are all important predictors of vegetation. All of these vary substantially on the installation because of its coastal location, diverse geology, and pronounced topography. Elevation on installation ranges from sea level to 3,189 feet amsl. Precipitation is lowest at the coast, around 10 in/yr average, increasing to the east to a high of 24 in/yr near Case Springs. Most rain, 70%, falls from February to March. Temperature varies from the low 100s ^{o}F in summer to just below freezing in some areas during the winter, with mean temperature decreasing with elevation (MCB Camp Pendleton, 2007a). The coastal communities receive the lowest average rainfall; however, they benefit from frequent fog and the moderating influence of the ocean, which reduces heat and moisture stress during the summer. A unique set of species making up the southern foredune community occupies the actively moving sand dunes at two locations on the beach. Salt marshes are found where low topography combines with freshwater inflow and tidal influence to support salt marsh and brackish marsh. There are coastal sage scrub-covered foothills on the stable drier soils along the coast and a mixture of native and non-native grasslands in the central valleys. Chaparral is found in the higher foothills, back ranges, and open woodlands along the peaks (MCB Camp Pendleton, 2007a).
Fauna	The large natural areas of MCB Camp Pendleton support a variety of fish and wildlife species. In addition to hundreds of invertebrates, the installation has documented the presence of more than 50 mammalian, 30 reptilian, 10 amphibian, 300 avian, and 60 fish species. Also, various

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
Fauna (cont.)	agencies and organizations at the installation have identified state-listed species of special concern. Many wildlife species are resident on the installation and can be found throughout the year. Other wildlife species visit the installation seasonally—such as migratory birds like the least Bell's vireo—or periodically, like mountain lions. MCB Camp Pendleton is involved with regional conservation planning efforts (mostly by providing habitat and some protection for some nonlisted species of special concern). Benefits to nonlisted wildlife species on installation include wildlife corridors that provide linkages between San Diego, Riverside, and Orange Counties' open space (MCB Camp Pendleton, 2007a). The installation implements a game management and migratory bird management plan to manage populations in a scientifically sound manner that supports a recreational hunting program and is consistent with military mission and other species management programs. The game management includes a plan to manage the bison population in a scientifically sound manner that minimizes mission conflicts and impacts to habitat and safety. Management of the bison herd is limited to activities to prevent conflict with the installation's training mission, tracking of herd growth rate, moving bison off active ranges when ranges are in use, and measuring costs and lost time associated with bison range conflicts. In the future, culling the herd may be necessary to limit training stoppages caused by bison wandering onto active firing ranges (USMC, 2011).
Special status species	Management of federally listed T/E species is conducted through the implementation of habitat-based management plans for riparian, estuarine, coastal, and upland areas (MCB Camp Pendleton, 2007a). In December 2009, the U.S. Fish and Wildlife Service removed the brown pelican from the list of T/E species for MCB Camp Pendleton. This delisting action reduce the number of federally listed species on the installation from 17 to 16 species, which include birds, mammals, fish, amphibians, crustaceans, and plants (Marano, 2009). Listed species present at the installation include the arroyo toad (endangered), California least tern (endangered), coastal California gnatcatcher (threatened), Stephens' kangaroo rat (endangered), and thread-leaved brodiaea (threatened) (MCB Camp Pendleton, 2007a).

4.9. Potential Pathways and Receptors

MC accumulated in the MC loading areas potentially can migrate to receptors via the following exposure pathways:

- Surface water runoff including sediment transport
- Leaching to groundwater and subsequent groundwater flow

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. Ecological receptor exposure to sediment, including dermal contact and direction ingestion, also is considered. Other off-range exposure scenarios (e.g., soil ingestion, incidental dermal contact, bioaccumulation and food chain exposure) are not considered in the REVA process. The potential receptors at the MCB Camp Pendleton installation include the following:

- Human receptors utilizing water from the 27 groundwater production wells located in the San Mateo, San Onofre, Las Flores and Santa Margarita groundwater basins
- T/E and California special concern ecological receptors, such as the endangered arroyo toad, the threatened California gnatcatchers, and the threatened Stephens' kangaroo rat, which have habitat areas near major streams, canyons and coastal lagoons
- Human receptors (through contact and noncontact recreation) at the major streams, river and creek mouths, coastal lagoons, and the Pacific Ocean

4.9.1. Surface Water and Sediment Pathways

Surface water runoff is the primary MC transport mechanism at ranges at MCB Camp Pendleton. Although rainstorms are infrequent, the potential for surface runoff is high during storm events. The predominant surface water drainage direction is to the southwest. A significant portion of the installation has steep slopes (with most areas exceeding a slope of 15%); but a majority of the identified MC loading areas have a moderately steep topography (with a slope of 5% to 10%) (MCB Camp Pendleton, 2007a; MCB Camp Pendleton, 2011c).

Most soils at MCB Camp Pendleton are erodible. The steep topography, soil characteristics, fire frequency, and climatic variability at MCB Camp Pendleton make soil erosion and sedimentation quite widespread at the installation (Palmer, 1994). Following rainstorm events, surface drainage occurs by way of natural topographic gradients and drainage directly into canyons. Such drainage systems can transport MC to canyons from soil through dissolution in runoff water or erosion of soil and sediments and transport in runoff. Surface water potentially containing MC transported through canyons can recharge alluvial aquifers downstream of primary MC loading areas. Dissolved and soil-associated MC could be transported in surface drainage to habitats containing ecological receptors (e.g., endangered arroyo toad, threatened California gnatcatchers, threatened Stephens' kangaroo rat) located downstream of MC loading areas at MCB Camp Pendleton. The streams and other surface waters also potentially are used for recreational purposes; however, because most of the streams are non-perennial, the streams infrequently have surface water that could come into contact with recreational users.

MC loading areas are located in six of the seven watersheds draining through MCB Camp Pendleton. Canyons that drain four of these watersheds (San Mateo, San Onofre, Las Flores, and Santa Margarita) potentially recharge alluvium groundwater basins that are used as drinking water sources downstream from MC loading areas. In addition, canyons within all watershed areas containing MC loading areas flow to areas that have been documented to be associated with potential T/E ecological species. Sediment transported in the canyons also potentially can come into contact with ecological receptors. Most streams at MCB Camp Pendleton are non-perennial, and most surface flow infiltrates the channel beds and does not reach the edge of the alluvial basin, coastal lagoons, or the ocean. Some flow to these water bodies may occur during some extreme storm events. However, because of the large distances surface water travels (more than 2 miles to alluvial basins) and the fact that all MC - with the exception of perchlorate - have high rates of decay, many of the MC concentrations in surface water can reduce considerably before reaching the identified receptor locations. Surface water and groundwater sampling conducted as part of the baseline assessment and discussed in the baseline REVA Report indicated minimal to no detections of MC at locations or drinking water wells upstream of coastal lagoons and the ocean.

4.9.2. Groundwater Pathway

Almost all the MC loading areas identified at MCB Camp Pendleton are located in upland areas that are underlain by either the basement complex overlain by a thin alluvial layer or low permeable aquitards also overlain by a thin alluvial layer. A small proportion of precipitation at the MC loading areas may infiltrate the underlying basement complex or aquitards; however, because many of the MC loading areas are located on moderate to steep slopes, most of this water flows overland into the non-perennial streams. In the upland areas, shallow groundwater in the discontinuous and narrow alluvial deposits underlying the streams mostly discharges to streams, depending on seasonal changes in water table elevation. The non-perennial streams and canyons from the upland areas drain toward the Coastal Plain area where they recharge the alluvial aquifers. The alluvial aquifers in the coastal plain are underlain by the San Mateo aquifer, and these two aquifers are the drinking water sources for the installation.

Based on water level maps for the Las Flores basin, groundwater at MCB Camp Pendleton generally parallels the surface topography, flowing in a southwest direction toward the Pacific Ocean (Palmer, 1994).

Potential receptors of groundwater include humans that use it as a drinking water source (as mentioned in **Section 4.8.1**). The installation production wells are located in the San Mateo, San Onofre, Las Flores and Santa Margarita alluvial basins (**Figure 4-3**). Streams draining from the identified MC loading areas potentially containing MC can recharge these alluvial basins. Before directly recharging into the groundwater, MC - with the exception of perchlorate - can undergo reduction in concentration due to decay and sorption with surface sediments. Groundwater potentially containing MC from the up gradient edge of these alluvial basins then can be transported to the down gradient production wells, thus indicating a potential pathway for human receptors from MC entering the alluvial aquifers. However, MC decay which is more pronounced in groundwater because of the longer travel times can significantly reduce the potential for MC - with the exception of perchlorate - to reach the down gradient drinking water wells.

5. Modeling Assumptions and Parameters

As part of the REVA five-year review effort, fate and transport screening-level modeling analyses were conducted for the following 32 MC loading areas at MCB Camp Pendleton:

- Kilo Two Combat Town
- LFAM 706
- PDL Combat Town
- Quebec Impact
- Range 104B
- Range 108
- Range 109
- Range 201
- Range 202
- Range 203
- Range 204B
- Range 207
- Range 208C
- Range 210D
- Range 210E/210F
- Range 211
- Range 215A
- Range 216 House
- Range 217/219
- Range 218A
- Range 221/222
- Range 223B
- Range 227
- Range 301
- Range 307
- Range 314 Complex
- Range 407 Complex
- Range 408
- Range 409A
- Range 600
- Whiskey Impact
- Zulu Impact

The purpose of the fate and transport screening-level analyses was to determine the potential for release of MC in surface water, groundwater, and sediment from the identified MC loading areas. If the results of the screening-level analyses indicated a potential release of MC, additional assessments (such as sampling) were conducted. Otherwise, no further assessment was conducted at this time, but the identified MC loading areas will 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 MCB Camp Pendleton were conducted following the REVA process described in the *REVA Reference Manual* and the *REVA 5-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 could 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 MC loading area, then additional calculations are performed to estimate the potential MC concentrations at a downstream receptor location. Receptor locations assessed at MCB Camp Pendleton include streams recharging down gradient alluvial groundwater basins. Potential MC migration to streams near habitat areas of ecological receptors was not assessed because habitat areas of ecological receptors are located within the installation boundary where associated impacts generally are addressed and managed by Environmental Security. Also, while streams potentially are used for recreational purposes, the use is likely very limited due to the non-perennial nature of most of the streams down gradient of the identified MC loading areas.

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 5-Year Review Manual* (HQMC, 2009; HQMC, 2010).

Table 5-1: REVA Trigger Values for MC

MC	Trigger Value for Water (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 Munitions Constituents 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 transported in surface water runoff and (2) direct dissolution of MC in surface water runoff.

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

5.1.1.1. Estimation of the Annual Average Munitions Constituents Concentrations Leaving Munitions Constituents 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 Revised Universal Soil Loss Equation (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 MCB Camp Pendleton using available information, such as soil types, land use / land cover, and digital elevation data (MCB Camp Pendleton, 2005; MCB Camp Pendleton, 2011c). **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 MC loading area was estimated simply as the product of the average annual precipitation, the MC loading area, and a runoff coefficient. The average annual precipitation of 13.5 in/yr was evaluated from annual precipitation data obtained from National Climatic Data Center for a station in Escondido, California, near MCB Camp Pendleton (for the period 1979–2005) and from MCB Camp Pendleton (for the period 2006–2011). This precipitation rate is the average for the lower coastal plain area, which generally has lower precipitation than the higher (mountain) elevation areas. The lower precipitation rate of the lower coastal plain areas was used as a conservative assumption. Runoff coefficients were estimated from Caltrans highway design manual (Caltrans, 2006) based on soil hydrologic group, slope, and land cover of the MC loading areas being analyzed (**Appendix A**).

ESTIMATION OF MUNITIONS CONSTITUENTS MASS AND CONCENTRATION IN SURFACE WATER RUNOFF

A multimedia partitioning model, CalTOX (DTSC, 1994), 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 is 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-level analysis inherently results in annual average concentrations.

5.1.1.2. Estimation of Munitions Constituents Concentrations Entering Streams Recharging Alluvial Groundwater Basins

MC loading areas within MCB Camp Pendleton drain to streams that ultimately flow to alluvial groundwater basins where they recharge the alluvial aquifers. For MC loading areas where MC concentrations in surface water runoff at the edge of the MC loading area were estimated to be above the REVA trigger value, an additional conservative mixing calculation was carried out to estimate MC concentrations in surface water entering downstream receptor locations. Total drainage areas to the potential downstream receptor locations in streams recharging alluvial groundwater basins were estimated (**Figure 5-1**). The estimated concentrations at the edge of the MC loading areas then were multiplied by the ratio of the MC loading area to the total drainage area of the receptor locations in streams recharging alluvial groundwater basins.

The down gradient, mixed MC concentrations entering the receptor locations in streams recharging alluvial groundwater basins were estimated as area-weighted sums of the concentrations from the individual MC loading areas draining to the water bodies:

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

Where: C_{mixed} = Post-mixed concentrations entering receptor locations in streams recharging alluvial groundwater basins (µg/L)

C_{runoff} = Concentration in runoff from MC loading areas (µg/L)

A_{LA} = Area receiving MC loading (square meters [m^2])

A_{DA} = Total drainage area of receptor locations in streams recharging alluvial groundwater basins (m^2)

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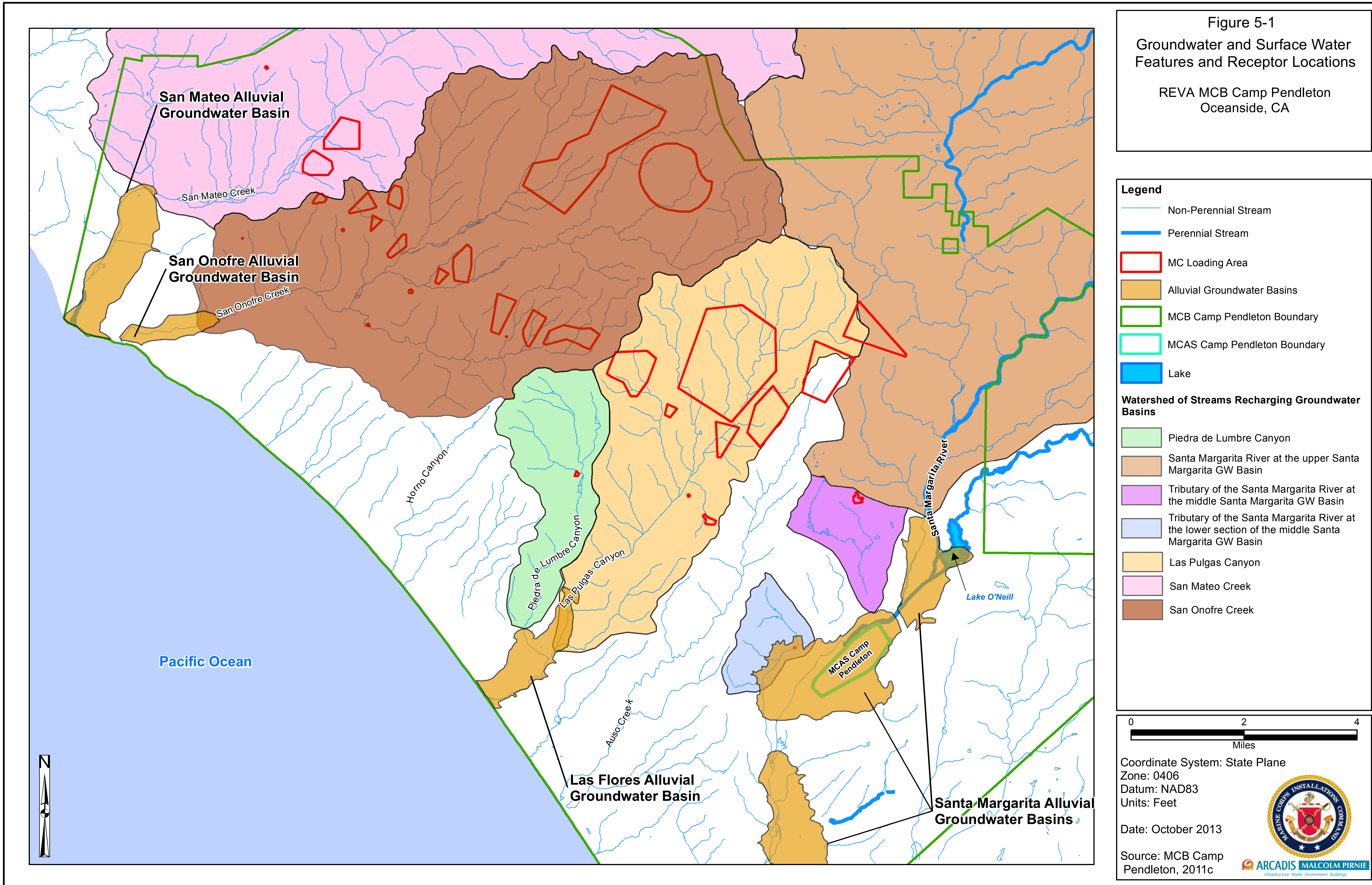
San Mateo Alluvial Groundwater Basin
San Onofre Alluvial Groundwater Basin
San Mateo Creek
San Onofre Creek
Horno Canyon
Piedra de Lumbre Canyon
Las Pulgas Canyon
Auso Creek
Santa Margarita River
Lake O'Neill
MCAS Camp Pendleton
Pacific Ocean
Las Flores Alluvial Groundwater Basin
Santa Margarita Alluvial Groundwater Basins
N
Figure 5-1
Groundwater and Surface Water Features and Receptor Locations
REVA MCB Camp Pendleton
Oceanside, CA
Legend
Non-Perennial Stream
Perennial Stream
MC Loading Area
Alluvial Groundwater Basins
MCB Camp Pendleton Boundary
MCAS Camp Pendleton Boundary
Lake
Watershed of Streams Recharging Groundwater Basins
Piedra de Lumbre Canyon
Santa Margarita River at the upper Santa Margarita GW Basin
Tributary of the Santa Margarita River at the middle Santa Margarita GW Basin
Tributary of the Santa Margarita River at the lower section of the middle Santa Margarita GW Basin
Las Pulgas Canyon
San Mateo Creek
San Onofre Creek
0 2 4
Miles
Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet
Date: October 2013
Source: MCB Camp Pendleton, 2011c
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Table 5-2 shows proportions of MC loading areas draining to streams recharging alluvial groundwater basins. An inherent assumption of this method is that all areas other than MC loading areas contribute runoff that has negligible MC concentrations. This provides the estimated MC concentrations in surface water entering the down gradient streams which recharge alluvial groundwater basins, after accounting for mixing with runoff from non-loading areas. This approach conservatively assumes no reduction of MC through MC decay in surface water.

Table 5-2: Proportions of MC Loading Areas Draining to Receptor Locations

Receptor Location	MC Loading Area Draining to Receptor Location	Approximate Percent of MC Loading Area Draining to Receptor Location
San Mateo Creek at the up gradient edge of the San Mateo alluvial groundwater basin	LFAM 706	100
	Range 314 Complex	100
	Range 307	100
San Onofre Creek in the San Onofre alluvial groundwater basin at point closest to a drinking water well	Whisky Impact	100
	Range 217/219	100
	Range 600	100
	Range 210D	100
	Range 215A	100
	Range 216 House	100
	Range 218A	100
	Range 210E/210F	100
	Range 208C	100
	Range 202	100
	Range 204B	100
	Range 203	100
	Range 201	100
	Quebec Impact	100
	Range 207	100
	Range 301	100
	Range 211	100
Las Flores Creek in the Las Flores alluvial groundwater basin at point closest to a drinking water well	Zulu Impact	100
	Range 407 Complex	100
	Range 227	100

Receptor Location	MC Loading Area Draining to Receptor Location	Approximate Percent of MC Loading Area Draining to Receptor Location
	Range 408	20
	Range 221/222	100
	Range 109	100
	Range 108	100
	Range 223B	100
	Range 409A	30
Unnamed tributary of Las Flores Creek at the up gradient edge of the Las Flores alluvial groundwater basin	PDL Combat Town	100
Santa Margarita River at the up gradient edge of the upper Santa Margarita alluvial groundwater basin	Range 408	5
	Range 409A	70
Unnamed tributary of the Santa Margarita River at the up gradient edge of the middle Santa Margarita alluvial groundwater basin	Kilo Two Combat Town	100
Unnamed tributary of the Santa Margarita River in the middle Santa Margarita alluvial groundwater basin at point closest to a drinking water well	Range 104B	100

5.1.2. Sediment Screening-Level Approach at Munitions Constituents 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 surface 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).

For MC loading areas where MC concentrations in sediment at the edge of the MC loading area were estimated to be above the REVA trigger value, additional screening-level analysis was carried out to estimate MC concentration in sediment at downstream receptor locations in streams recharging alluvial groundwater basins. This involved 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 streams recharging alluvial groundwater basins was estimated to be equivalent to the MC mass in sediment 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 was estimated by taking the sum of the MC mass in sediment leaving the individual MC loading areas and dividing it by the sediment mass eroding to the receptor location as follows:

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

Where: $C_{sed,mixed}$ = Post-mixed MC concentration in sediment entering receptor locations in streams recharging alluvial groundwater basins (µg/kg)
$M_{MC,LA}$ = MC mass in sediment leaving the individual MC loading areas (micrograms per day)
$M_{sed,DA}$ = Sediment mass eroded within the drainage area to the receptor location in streams recharging alluvial groundwater basins (kilograms per day)

This method conservatively assumes that 100% of the sediment leaving the MC loading areas is deposited into downstream surface water (downstream receptor locations). 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 MCB Camp Pendleton 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 (MCB Camp Pendleton Environmental Security GIS data)
- IRP site data
- INRMP
- USGS topographic maps and regional groundwater resource reports
- USDA 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**.

5.2.2. REVA Groundwater Analysis Procedure

The groundwater screening-level analysis was conducted for two alluvial groundwater basins (San Onofre and Las Flores basins) that, based on the surface water screening-level analysis results, were estimated to have MC in the groundwater at concentrations above REVA trigger values. Analysis also was completed for Range 104B MC loading area located within the Santa Margarita alluvial groundwater basin that was selected for quantitative analysis based on the potential for MC migration within the MC loading area to groundwater.

As discussed in **Section 4.8.2**, MC from up gradient MC loading areas primarily migrate to groundwater within the San Onofre and the Las Flores alluvial groundwater basins by stream recharge. As a result, a modified REVA Part I procedure was used for the screening-level analysis conducted for the San Onofre and the Las Flores basins. The Range 104B MC loading area is located within the Santa Margarita alluvial groundwater basin (**Figure 5-1**). In addition to streams recharging the alluvial aquifer, recharge also can occur from the portion of precipitation that falls directly on Range 104B and infiltrates the underlying permeable subsurface material. As a result, the typical REVA Part I procedure was applied in order to assess the potential for MC at the Range 104B MC loading area to migrate vertically from the ground surface through the vadose zone to groundwater and then horizontally through groundwater to potential drinking water receptors.

5.2.2.1. Initial Groundwater Screening Analysis at the Range 104B MC Loading Area

The first step in analyzing groundwater transport at the Range 104B MC loading area 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) are 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 values (**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 Range 104B MC loading area (presented in **Section 6**) and the estimated infiltration rate (recharge) of 0.19 feet per year (ft/yr) at MCB Camp Pendleton (Stetson, 2001). The estimated recharge value of 0.19 ft/yr includes the estimated evapotranspiration rate, which significantly reduces recharge.

The maximum possible concentration of MC in the infiltrating water was calculated by dividing the MC loading rate by the volume of the infiltrating water. The MC estimated to have concentrations above the REVA trigger values at the Range 104B MC loading area were analyzed further for transport through the vadose zone using a screening-level vadose zone model.

5.2.2.2. Vadose Zone Modeling at the Range 104B MC Loading Area

When the results from the initial groundwater analysis for Range 104B MC loading area from **Section 5.2.2.1** indicate a need for further evaluation, the United States Environmental Protection Agency (USEPA) 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-level analysis (**Section 5.2.2.1**) were used to simulate MC transport to the water table. RDX, TNT, and perchlorate were modeled for migration through the vadose zone at the Range 104B MC loading area.

Soils at the Range 104B MC loading area consist of sandy loam and fine sandy loam. 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**.

5.2.2.3. Saturated Zone Modeling

Saturated zone modeling was conducted for MC that were estimated to reach the groundwater within the San Onofre and the Las Flores alluvial groundwater basins and at the Range 104B MC loading area within the Santa Margarita alluvial groundwater basin at concentrations above REVA trigger values. The fate and transport of MC within these groundwater basins were simulated using BIOCHLOR 2.2, a one-dimensional analytical solute transport and fate model (Aziz and Newell, 2002). The model was used to predict the possible movement of MC through the saturated zone to potential receptor locations. It was run on a box grid and assumed a homogeneous aquifer with constant velocity.

Transport within the San Onofre and the Las Flores Alluvial Groundwater Basins: MC from MC loading areas up gradient of these basins are assumed to be released primarily to surface water and transported in streams to the alluvial groundwater basins, where they are assumed to directly recharge the groundwater (**Figure 5-1**). Therefore, results from the surface water screening-level analysis (**Section 5.1.1**) were used to estimate MC concentrations in streams potentially recharging alluvial groundwater basins. Using the estimated MC concentrations in streams recharging the San Onofre and the Las Flores alluvial groundwater basins from the result of the surface water screening-level analysis as input to the BIOCHLOR model, MC concentrations potentially reaching the nearest drinking water production wells were estimated. The relevant aquifer and chemical properties used as input parameters in the BIOCHLOR model are presented in **Appendix A**. **Figure 5-1** shows locations of the alluvial groundwater basins and drinking water supply wells.

Transport from the Range 104B MC Loading Area within the Santa Margarita Alluvial Groundwater Basin: Using MC concentration estimated to reach the water table at the Range 104B MC loading area from the result of the vadose zone modeling as an input to the BIOCHLOR model, MC concentrations potentially reaching the nearest groundwater production well were estimated. This estimated concentration was used to estimate the MC mass transported to the drinking water well by simply multiplying the concentration with the groundwater discharge rate. In order to estimate the cumulative mass transported to the drinking water well (through the vadose zone and MC mass recharged from stream within the Santa Margarita alluvial basin), this mass was added to the estimated MC mass in the tributary stream assumed to recharge the Santa Margarita alluvial basin (from result of the surface water screening analysis). This cumulative mass then was divided by the groundwater discharge rate to estimate MC concentration reaching the drinking water production well located closest to the Range 104B MC loading area. The relevant input parameters used in the BIOCHLOR model are presented in **Appendix A**. **Figure 5-1** shows locations of the Range 104B MC loading area, the Santa Margarita alluvial groundwater basin, and the drinking water production wells within the basin.

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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. The assessment results for the MC loading areas are presented within this section based on the hydrologic watershed areas within which they are located, since multiple MC loading areas fall within each watershed:

- San Mateo watershed (**Section 6.1**)
- San Onofre watershed of (**Section 6.2**)
- Las Flores watershed (**Section 6.3**)
- Santa Margarita watershed (**Section 6.4**)

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

Table 6-1: MC Loading Areas

MC Loading Area	Size of MC Loading Area	
	Acres	1,000 m^2
San Mateo Watershed		
LFAM 706	178	721
Range 302	0.107	0.435
Range 307	0.943	3.82
Range 314 Complex	108	437
San Onofre Watershed		
Quebec Impact	49.4	200
Range 201	17.2	69.4
Range 202	0.796	3.22
Range 203	52.3	212
Range 204B	17.2	69.5

MC Loading Area	Size of MC Loading Area	
	Acres	1,000 m^2
Range 207	0.97	3.94
Range 208C	40.6	164
Range 210D	20.9	84.7
Range 210E/210F	108	436
Range 211	2.35	9.50
Range 215A	108	436
Range 216 House	0.122	0.495
Range 217/219	155	628
Range 218A	86.9	351
Range 301	0.108	0.436
Range 600	727	2,940
Whisky Impact	1,290	5,210
Las Flores Watershed		
PDL Combat Town	2.70	10.9
Range 108	13.5	54.7
Range 109	0.722	2.92
Range 221/222	286	1,160
Range 223B	17.7	71.7
Range 225	4.44	17.98
Range 227	90.2	365
Range 407 Complex	263	1,065
Range 408	359	1,450
Range 409A	263	1,060

MC Loading Area	Size of MC Loading Area	
	Acres	1,000 m^2
Zulu Impact	1,530	6,210
Santa Margarita Watershed		
Kilo Two Combat Town	12.7	51.4
Range 104B	0.245	0.993
Range 401	67.6	274
Range 408	359	1,450
Range 409A	263	1,060

The majority of the identified MC loading areas (32 of the 38) underwent screening-level modeling during the five-year review.

The section for each hydrologic watershed area contains discussions on the operational range areas identified, the site-specific CSM, MC deposition estimates, screening-level modeling results, and additional range information.

Surface Water and Sediment Analyses Summary

The screening-level analyses of MC fate and transport in surface water and sediment were conducted for 32 MC loading areas located within four watershed areas (San Mateo, San Onofre, Las Flores, and Santa Margarita). These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and the presence of surface drainages that lead to potential receptor locations. Annual average MC concentrations in surface water runoff and sediment at the edge of each MC loading area were estimated. MC concentrations in surface water and sediment entering identified downstream receptor locations (streams recharging alluvial groundwater basin used as drinking water sources) also were estimated. Based on these modeling results, as well as previous field monitoring activities, field data collection was conducted at MCB Camp Pendleton (detailed in **Section 8**).

MC concentrations in surface water runoff at the edge of 29 of the 32 MC loading areas analyzed were estimated to be above REVA trigger values, and TNT concentrations in sediment at the edge of 5 of the 32 MC loading areas analyzed were estimated to be above REVA trigger values. Annual average MC concentrations in surface water entering two identified surface water receptor locations were predicted to be above REVA trigger values, while annual average MC concentrations in sediment entering all surface water receptor locations were predicted to be below REVA trigger values.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for two groundwater alluvial basins (the San Onofre and the Las Flores basins) and for the Range 104B MC loading area located within the middle Santa Margarita alluvial basin. These groundwater basins were selected for quantitative transport analysis based on the surface water screening-level analysis results or the potential for MC migration to groundwater and the presence of potential groundwater receptors (drinking water production wells). MC concentrations potentially migrating to the groundwater within the San Onofre and the Las Flores alluvial groundwater basins were predicted to reach drinking water wells at concentrations above REVA trigger values. At the Range 104B MC loading area within the Santa Margarita alluvial groundwater basin, perchlorate was estimated to reach the water table at a concentration above the REVA trigger value. Perchlorate was further estimated to reach a drinking water well within the Santa Margarita alluvial groundwater basin at a concentration above the REVA trigger value. Based on these modeling results, as well as previous field monitoring activities, field data collection was conducted at MCB Camp Pendleton (detailed in **Section 8**).

6.1. San Mateo Watershed

The San Mateo watershed is located on the western edge of MCB Camp Pendleton; it is approximately 85,500 acres, with the majority of the area (approximately 79%) located outside of MCB Camp Pendleton (**Figure 6-1**). The watershed area encompasses a stream network that is non-perennial.

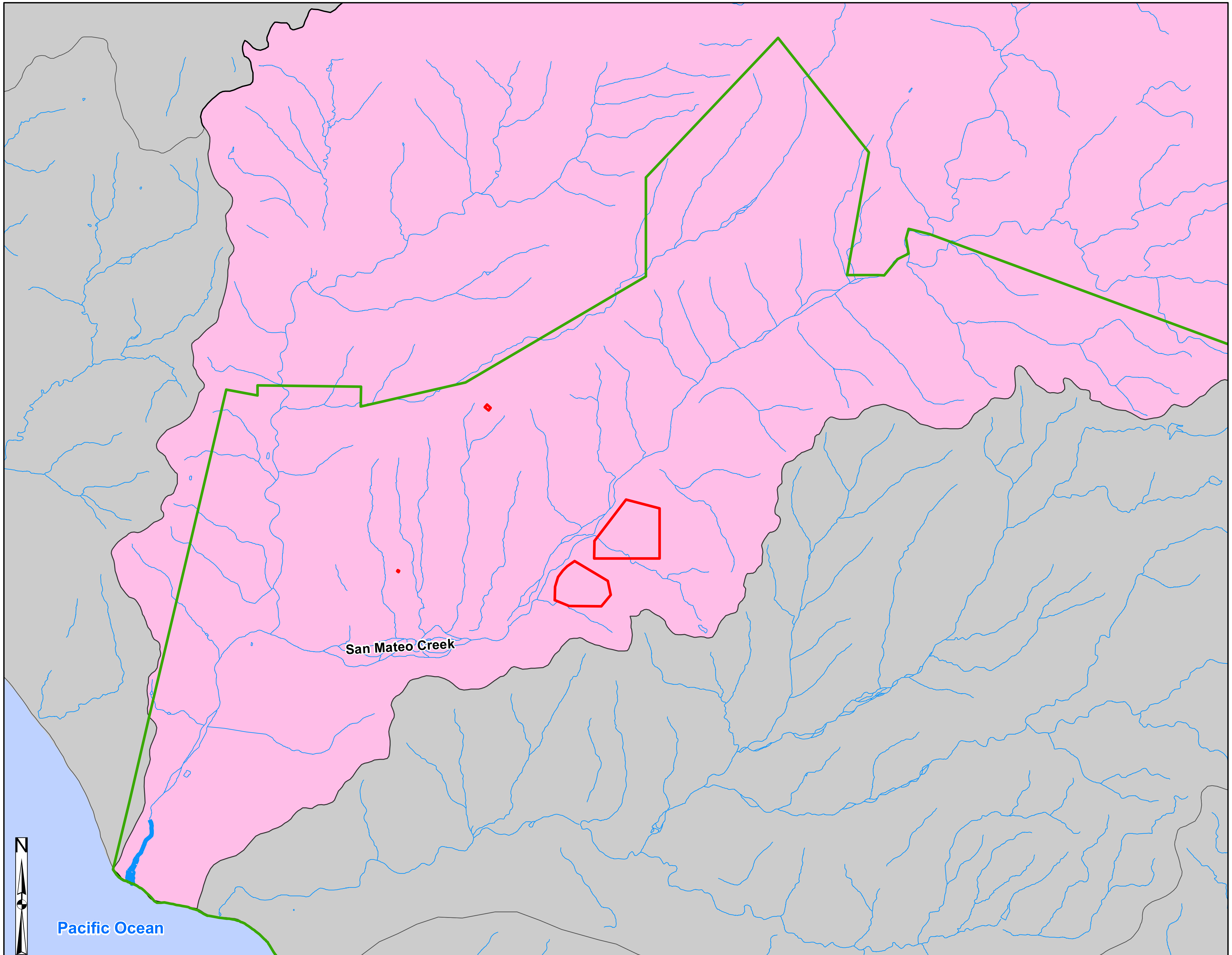
The downstream portion of the watershed contains the San Mateo alluvial groundwater basin that is one of the drinking water sources for the installation. Part or all of 10 training areas and one dud-producing impact area are located within the watershed:

- Charlie Training Area (1,641 acres)
- Delta Training Area (2,635 acres)
- Yankee Training Area (3,806 acres)
- Bravo One Training Area (2,494 acres)
- Bravo Two Training Area (1,986 acres)
- Bravo Three Training Area (2,467 acres)
- Alpha One Training Area (1,100 acres)
- Sierra One Training Area (244 acres)
- Sierra Two Training Area (58 acres)
- Sierra Three Training Area (168 acres)
- Quebec Impact Area (2,710 acres)

Figure 6-1

MC Loading Areas within the San Mateo Watershed

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Non-Perennial Stream
- Perennial Stream
- San Mateo Watershed
- MC Loading Area
- MCB Camp Pendleton Boundary

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

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The majority of the MC deposition in the watershed is anticipated to occur at four MC loading areas located within the Quebec Impact Area, Bravo One Training Area, and Bravo Two Training Area. These four MC loading areas are listed in **Table 6-2**.

Table 6-2: MC Loading Areas in the San Mateo Watershed

MC Loading Area	Size (acres)
LFAM 706	178
Range 302	0.107
Range 307	0.943
Range 314 Complex	108

Military Munitions

Military munitions authorized for use within the MC loading areas located in the San Mateo 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 San Mateo 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, other 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 annually within these MC loading areas (**Table 6-3**); the assumptions used to guide the estimates are detailed in **Section 3**. The analysis suggests that RDX and TNT represent the highest MC loading within the San Mateo watershed. The highest MC loading rate observed at a particular MC loading area during the five-year review period was RDX at the Range 307 MC loading area. Based on the size of the MC loading area and the associated MC loading rates, the most significant loading in the watershed appeared to be RDX and TNT deposition at the Range 307 MC loading area. Compared to estimated baseline average annual MC loading rates, the estimated average annual MC loading rates for this review suggest loading has decreased since the baseline assessment. Estimated HMX and RDX loading decreased across this watershed by an approximate order of magnitude compared to baseline estimates. Estimated TNT loading rate slightly decreased across the watershed, with changes less than an order of magnitude when compared to the baseline estimates. Estimated perchlorate loading decreased by approximately two orders of magnitude across the watershed compared to the baseline estimates.

Table 6-3: Estimated MC Loading Rates for the San Mateo 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)	**Quebec Impact (48.6%)[a]**	**1,482,946**	**2.53E-10**	**1.64E-06**	**9.12E-07**	**1.17E-07**
Five-Year Review (Period F 2006–2011)	LFAM 706	721,341	2.44E-11	1.69E-07	8.88E-08	7.91E-11
	Range 302	435	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Range 307	3,816	0.00E+00	8.19E-05	5.25E-05	1.33E-07
	Range 314 Complex	437,045	0.00E+00	5.74E-08	1.02E-08	1.91E-08
	Total MC loading area in San Mateo (Period F)	**1,162,637**	**1.35E-11**	**3.95E-07**	**2.31E-07**	**7.66E-09**

Notes:
[a] Loading area covers portions of multiple watersheds.
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 conservatively account for potential/actual inconsistent expenditure recordkeeping. Five-year review values cover 2006 to 2011.

Annual lead deposition for the MC loading areas in the San Mateo watershed was estimated during this five-year review (**Table 6-4**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimate of the total amount of lead deposited in a given MC loading area. The baseline assessment did not include such lead loading estimates for MC loading areas. Calculations indicate the Range 314 Complex MC loading area may have the most significant lead deposition rates, estimated at 28,900 lb of lead annually. Accounting for all MC loading areas identified in the San Mateo watershed, it is estimated that a total of 30,600 lb of lead was deposited annually during this review period.

Table 6-4: Estimated Annual Lead Deposition for the San Mateo Watershed

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
LFAM 706	721,341	1.05E-03	1.94E-03	1.68E+03
Range 302	435	1.14E-03	2.10E-03	1.00E+00
Range 307	3,816	3.04E-07	5.60E-07	2.56E-03
Range 314 Complex	437,045	3.00E-02	5.53E-02	2.89E+04
Total MC loading area in San Mateo (Period F)	**1,162,637**	**1.19E-02**	**2.20E-02**	**3.06E+04**

Note: lb/yd^2 – pounds per square yard

6.1.1.2. Geography and Topography

The San Mateo watershed is characterized by various terrain, consisting of sandy shores, coastal plains, rolling hills, canyons, and mountains. The watershed area contains the Santa Margarita Mountains in the central eastern part of the watershed, at the northern boundary of the installation. The terrain generally slopes toward the center of the watershed to San Mateo Canyon, the major non-perennial stream/wash that ultimately flows south toward the Pacific Ocean. Available contour data indicate the elevation of the watershed area within the installation boundary ranges from approximately mean sea level at the coastline to approximately 2,500 feet amsl near the northern boundary of the installation at the Santa Margarita Mountains (MCB Camp Pendleton, 2011c). Based on available spatial data, the slope within the installation boundary of the watershed area can range from nearly level to approximately 90% in the mountain hills, but the majority of the area has a slope ranging from approximately 5% to 58% (MCB Camp Pendleton, 2011c).

6.1.1.3. Surface Water Features

The San Mateo watershed contains a non-perennial stream network with a dendritic drainage pattern. The major stream, the San Mateo Canyon, originates several miles up gradient of the installation boundary and flows southwesterly through the installation and, ultimately, into the Pacific Ocean. Tributaries of the San Mateo Canyon flow southeast and west into the canyon. All of LFAM 706, Range 314 Complex, Range 307 and Range 302 MC loading areas drain within the San Mateo watershed.

Table 6-5 describes the drainage characteristics of the four MC loading areas within the San Mateo watershed.

Table 6-5: Drainage Description for the MC Loading Areas within the San Mateo Watershed

MC Loading Area	Drainage Description
LFAM 706	An unnamed tributary stream of the San Mateo Canyon flows westerly through the southern part of the MC loading area into the San Mateo Canyon. San Mateo Canyon is approximately 370 feet down gradient of the MC loading area.
Range 302	There are no surface water features within the MC loading area, but two tributary streams of the San Mateo Canyon are located approximately 740 feet to the southwest and 1,000 feet to the southeast of the MC loading area. Both tributaries flow to the southeast. San Mateo Canyon is approximately 3,400 feet down gradient of the MC loading area.
Range 307	There are no surface water features within the MC loading area, but a tributary stream of the San Mateo Canyon flows in a southwesterly direction into San Mateo Canyon approximately 690 feet down gradient of the MC loading area. San Mateo Canyon is approximately 2 miles down gradient of the MC loading area.
Range 314 Complex	An unnamed tributary stream of the San Mateo Canyon flows along a small portion of the southern MC loading area boundary. This stream flows in a westerly direction into the canyon. The San Mateo Canyon is approximately 790 feet down gradient of the MC loading area.

6.1.1.4. Soil Characteristics and Land Cover

The predominant soil map symbols of the San Mateo watershed within the installation boundary include RuG, Altmont clay (AtF), and GaF. These soil map units consist of unweathered bedrock, clay, clay loam, weathered bedrock, and fine sandy loam. Many of the soil characteristics of the RuG soil map unit, which only consists of unweathered bedrock, have not been measured. The AtF and the GaF soil map units are well drained and generally have a neutral pH range (6.6 to 8.4) (USDA NRCS, 2007). The organic content for AtF ranges from 0.5% to 3%, and the organic content for GaF ranges from 0.5% to 1%. The inherent soil erodibilities for these soils are low and moderate, with estimated soil erodibility factors of 0.2 for AtF and 0.32 for GaF. All three of the soil map units have relatively high runoff potential.

The San Mateo watershed is largely covered with vegetation, including grass, scrub, chaparral, and some forest, and includes some unvegetated areas.

6.1.1.5. Erosion Potential

The San Mateo watershed area was estimated to have moderate soil erosion potential [RUSLE predicted soil loss value of 5.14E-03 kilograms per square meters per day ($kg/m^2/d$)]. This estimated moderate soil erosion potential is largely a result of the steep topography and moderate inherent soil erodibility factor common within the watershed area.

The LFAM 706 and Range 314 Complex MC loading areas were estimated to have low soil erosion potential, and Range 307 and Range 302 MC loading areas were estimated to have moderate and high soil erosion potential. The moderate and high soil erosion potentials at Range 307 and Range 302 MC loading areas are largely a result of poor vegetation cover at the loading areas. The LFAM 706 and Range 314 Complex MC loading areas, which have a low estimated soil erosion potential, have extensive vegetation cover and have either a lower inherent soil erodibility factor or a flatter slope.

6.1.1.6. Groundwater Characteristics

The San Mateo watershed area includes the San Mateo groundwater basin, one of the drinking water sources for the installation. Within the San Mateo watershed, the groundwater basin is located in the coastal plain area down gradient of the identified MC loading areas. The primary water-bearing units in the San Mateo groundwater basin are the alluvial and San Mateo aquifers. These aquifers are the groundwater-producing units in the San Mateo basin. The aquifers are recharged primarily by streams. Based on the cross-section data presented in Stetson (2007), thickness of the alluvium in the San Mateo groundwater basin can range from 11 to 45 feet. Generally, the alluvium is composed of coarse-grained sediments; although, in most areas, the uppermost layers are composed of finer-grained sediments consisting of clay, silt, sandy clay, and sandy silt. In the San Mateo groundwater basin, the San Mateo Formation, which comprises the San Mateo aquifer, contains a considerable amount of clay, shale, and clay interbedded with shale (Stetson, 2007). Thicker coarse-grained layers consisting of sand, sandstone, gravel, cobbles, silty sand, and clayey sand are found approximately 1.3 miles up gradient of the Pacific Ocean. A grey-colored plastic clay with minor interbedded shale encountered in the boring of a monitoring well located approximately 0.4 miles up gradient of the ocean is most likely representative of a lagoon depositional environment (Stetson, 2007). Thickness of the San Mateo Formation within the San Mateo groundwater basin can range from 65 to more than 200 feet (Stetson, 2007). The hydraulic conductivity of the alluvial and the San Mateo aquifers within the San Mateo groundwater basin has been estimated to range from 0.0083 to 0.27 ft/min (Stetson, 2005).

Based on water level measured in monitoring and production wells, the depth to groundwater in the San Mateo groundwater basin can be 12 to 32 feet bgs.

The MC loading areas are located in the upland areas of the watershed. Based on a geologic map of watersheds presented by Stetson (2008), the LFAM 706 and the Range 307 MC loading areas are located on basement rock that is close to land surface, cropping out to form the Santa Margarita Mountains. Groundwater within the fractures and joints of the basement complex currently is not considered viable for water supply purposes. The Range 314 Complex and the Range 302 MC loading areas are underlain by low permeable aquitards consisting of the Santiago and Williams Formations. These aquitards likely do not contain or transmit substantial quantities of groundwater due to their poor sorting and the high percentage of fine-grained materials.

6.1.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Runoff coefficients at MC loading areas were assumed to range from 0.45 to 0.56. These relatively high runoff potentials are largely attributable to the infrequent torrential storms that occur (often resulting in flash floods), soil types with high runoff potential (hydrologic group D), the sparse vegetation cover at some of the MC loading areas, and the moderately steep topographic slopes at the MC loading areas within the watershed. The primary difference between the MC loading area with the highest runoff coefficient (Range 302) and the lowest coefficient (Range LFAM 706) is the vegetative cover.

As indicated in **Section 6.1.1.5**, the MC loading areas within the watershed have low, moderate, or high soil erosion potential. The moderate and high soil erosion potential that may occur at the Range 302 and Range 307 MC loading areas make soil erosion an important mechanism for MC mobilization into surface water runoff. MC migrated into streams with surface water runoff would drain west, southeast and southwest into San Mateo Canyon, ultimately reaching the Pacific Ocean.

Groundwater Pathways

A small portion of MC deposited on MC loading areas likely will migrate down to the underlying basement complex or low permeable aquitards; however, because the MC loading areas are located on moderately steep slopes, most of the MC deposited on MC loading areas likely will be transported with overland flow into the non-perennial streams. MC recharged to shallow groundwater in the discontinuous and narrow alluvial deposits higher in the watershed mostly discharge to streams, depending on seasonal changes to water table elevations. In these areas, the discontinuous and narrow alluvial deposits underlie the non-perennial streams and overlie the basement complex and aquitards. Groundwater migration downward to the underlying basement complex or aquitards from the alluvium likely is insignificant. The non-perennial streams and canyons from the MC loading areas drain toward the San Mateo alluvial groundwater basin, where they recharge the alluvial aquifer. The alluvial aquifer is continuous throughout the San Mateo groundwater basin and is in direct contact with the underlying San Mateo aquifer.

Groundwater within the San Mateo groundwater basin does not discharge to streams. Without the presence of the production wells, groundwater within the San Mateo groundwater basin flows in a southeast direction toward the Pacific Ocean. However, pumping at the installation production wells results in localized groundwater flow path toward the production wells. The groundwater gradient in San Mateo groundwater basin is estimated to range from less than 0.01 to 0.09 (MCB Camp Pendleton, 2011b). The groundwater velocity within the basin is estimated to range from approximately 5E-06 ft/min to approximately 7.8E-03 ft/min (Stetson, 2005; MCB Camp Pendleton, 2011c; McWhorter and Sunada, 1997).

6.1.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

Habitat areas of the endangered arroyo toad are found within the LFAM 706 and the Range 314 Complex MC loading areas and approximately 1.6 miles down gradient of the Range 307 MC loading area (MCB Camp Pendleton, 2011c). Also, habitat areas of the threatened California gnatcatcher are found within the Range 302 MC loading area. The San Mateo watershed drains to the San Mateo alluvial groundwater basin and recharges the aquifer that is used as a drinking water source (**Figure 6-2**).

Groundwater Receptors

The San Mateo groundwater basin contains six installation production wells that supply potable water to the installation's northern service area. MC potentially transported to groundwater in the San Mateo alluvial groundwater basin may migrate to the installation production wells (**Figure 6-2**). MC recharged to shallow groundwater in upland areas of the watershed near MC loading areas can discharge to streams where there are potential ecological receptors, including endangered arroyo toad and threatened California gnatcatcher (as described above).

6.1.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from three MC loading areas that drain to the San Mateo Creek, which flows to and recharges a groundwater basin that is used as a drinking water source (the San Mateo alluvial groundwater basin). The MC loading areas assessed include LFAM 706, Range 314 Complex, and Range 307. These MC loading areas were selected for quantitative transport analysis based on current use of munitions containing HE and proximity to surface drainages that lead to potential receptor locations.

Some MC loading areas within the San Mateo watershed were partially or wholly excluded from the analysis. The Range 302 MC loading area was not included because it was estimated to have negligible MC loading; the negligible HMX loading associated with the Range 307 and Range 314 Complex MC loading areas was also not included in the analysis.

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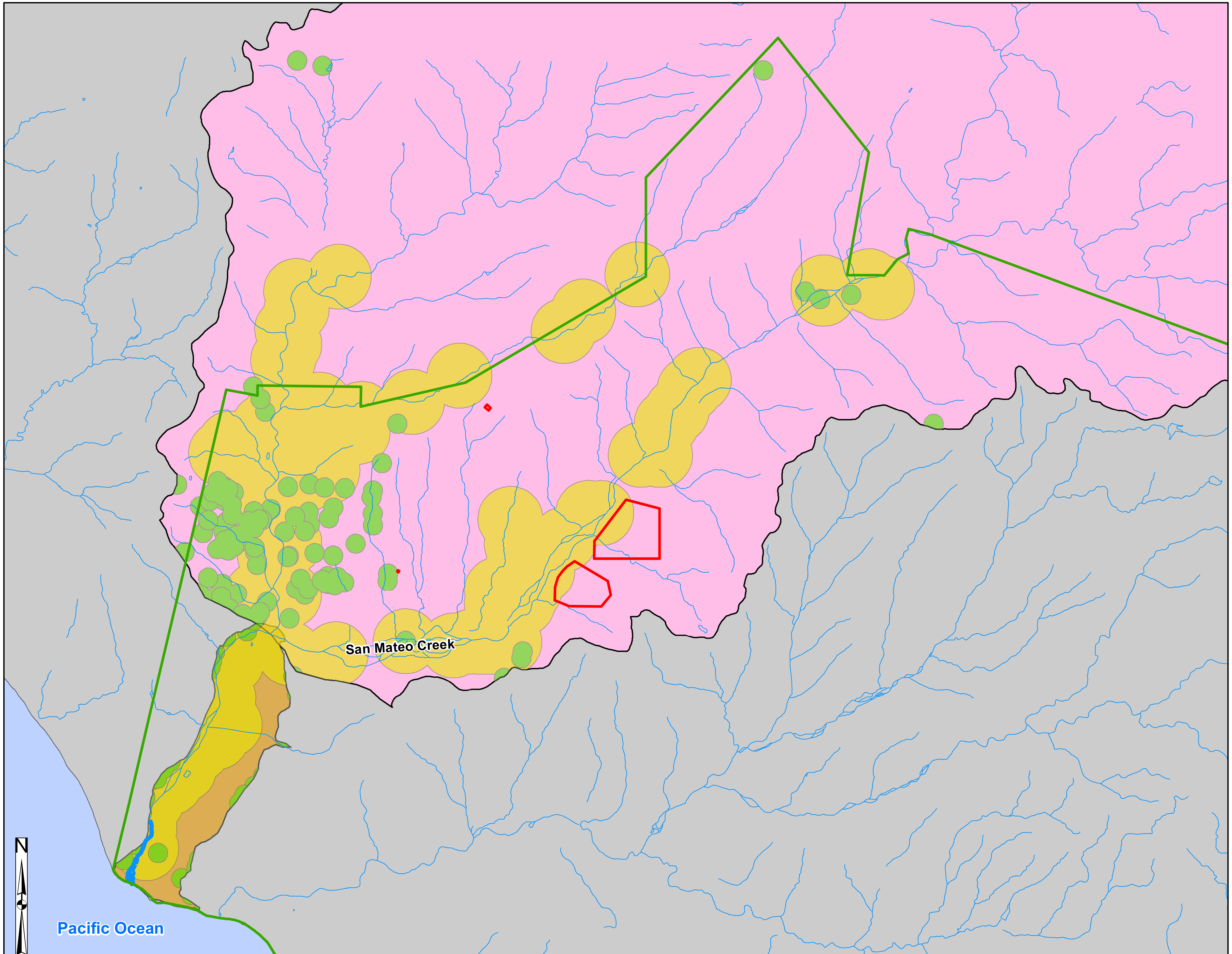


Figure 6-2

Pathways and Potential Receptors in the San Mateo Watershed

REVA MCB Camp Pendleton
Oceanside, CA

Legend

- Non-Perennial Stream
- Perennial Stream
- Alluvial Groundwater Basin
- MC Loading Area
- MCB Camp Pendleton Boundary

Sensitive Species Habitat

- Arroyo Toad
- California Gnatcatcher

Watershed of Streams Recharging Groundwater Basins

- San Mateo Creek

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for the time period matching the estimated MC loading period (2006–2011 [Period F]). The proportions of MC loading areas draining to San Mateo Creek at the up gradient edge of the San Mateo alluvial groundwater basin are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the San Mateo watershed up gradient of the San Mateo alluvial groundwater basin. **Table 6-6** presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to San Mateo Creek at the up gradient edge of the San Mateo alluvial groundwater basin.

Table 6-6: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into San Mateo Creek at the Up Gradient Edge of the San Mateo Alluvial Groundwater Basin

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
LFAM 706	100.0	28.0	30.6	0.640
Range 307	0	64.4	67.3	5.71
Range 314 Complex	0	7.62	2.12	93.7

Table 6-7 presents the estimated annual average edge-of-loading-area concentrations in surface water runoff from individual MC loading areas draining within the San Mateo watershed. Based on the screening-level calculations, the concentration of RDX was predicted to exceed the REVA trigger value at the edge of all three MC loading areas modeled within the San Mateo watershed. Perchlorate was predicted to exceed the REVA trigger value at the edge of the Range 314 Complex and Range 307 MC loading areas, and TNT was predicted to exceed the REVA trigger value at the edge of the LFAM 706 and Range 307 MC loading areas. The concentration of HMX was predicted to be below the REVA trigger value at the edge of all MC loading areas modeled within the San Mateo watershed (**Table 6-7**).

Table 6-7: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the San Mateo Watershed

MC Loading Area	Estimated MC Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
LFAM 706	~0	**0.264**	**0.119**	~0
Range 307	N/A	**103**	**44.7**	**0.746**
Range 314 Complex	N/A	**0.116**	0.013	**0.116**
REVA Trigger Value for Water	0.114	0.110	0.113	0.021

Notes:
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 analyses were conducted to estimate the annual average MC concentrations in surface water entering the San Mateo Creek at the up gradient edge of the San Mateo alluvial groundwater basin where it potentially recharges the groundwater. The estimated drainage area of San Mateo Creek upstream of the up gradient edge of the San Mateo alluvial groundwater basin is equivalent to 82,350.4 acres. The average annual concentrations of MC in surface water entering the San Mateo Creek at the up gradient edge of the San Mateo alluvial groundwater basin were predicted to be below REVA trigger values (**Table 6-8**).

Table 6-8: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Entering San Mateo Creek at the Up Gradient Edge of the San Mateo Alluvial Groundwater Basin

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	~0
RDX	0.110	0.002
TNT	0.113	0.001
Perchlorate	0.021	~0

Table 6-9 presents the estimated annual average edge-of-loading-area concentrations in sediment from individual MC loading areas draining within the San Mateo watershed. Based on the

screening-level calculations, the average annual concentrations of MC in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values (**Table 6-9**).

Table 6-9: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the San Mateo Watershed

MC Loading Area	MC Concentration (µg/kg)			
	HMX	RDX	TNT	Perchlorate
LFAM 706	~0	0.007	0.202	~0
Range 307	N/A	0.863	24.5	~0
Range 314 Complex	N/A	0.003	0.023	~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 San Mateo watershed.

6.1.3. Groundwater Analysis Results

A quantitative groundwater analysis was not conducted for the San Mateo watershed. This is because MC migration to groundwater within the San Mateo alluvial groundwater basin primarily is through non-perennial stream recharge. Based on the surface water screening-level analysis, MC concentrations in San Mateo Creek at the up gradient edge of the alluvial groundwater basin where it potentially recharges the groundwater are predicted to be below REVA trigger values (as discussed in **Section 6.1.2**). As a result, additional screening-level analysis in the saturated zone is not required at this time.

6.1.4. Summary of Lead in the San Mateo Watershed

No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike other MC. Lead is geochemically specific with regards to its mobility in the environment. Site-specific conditions must be known (i.e., geochemical properties) in order to quantitatively assess lead migration. Without site-specific physical and chemical characterization, lead cannot be modeled effectively using fate and transport modeling applied to the other indicator MC in REVA. Therefore, the amount of lead deposited within the MC loading areas within the San Mateo watershed is noted here in order to determine whether additional assessment actions (e.g. monitoring) may be warranted.

Section 6.1.1.1 noted that approximately 30,600 lb of lead were deposited annually across the approximate 287 acres covered by the MC loading areas present in the San Mateo watershed. The Range 314 Complex MC loading area has a notably high annual deposition rate of approximately 28,900 lb. Potential receptors of lead deposited at this MC loading area include human and ecological points. The San Mateo alluvial groundwater basin is down gradient of this MC loading area, though the distance between this MC loading area and the nearest groundwater receptor exposure point is approximately 3.0 miles. Habitat area for the arroyo toad is found within the boundary of the MC loading area.

6.2. San Onofre Watershed

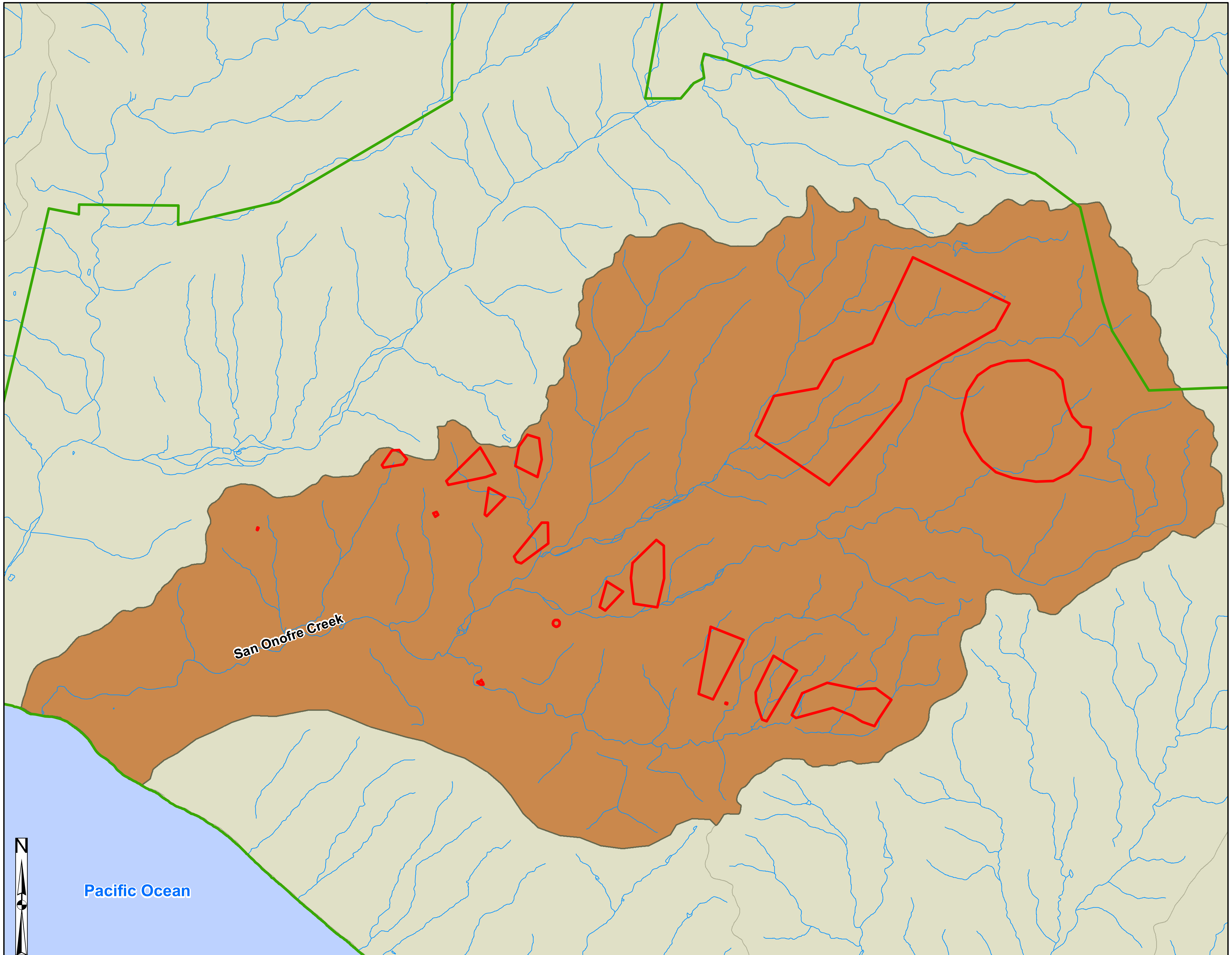
The San Onofre watershed is located on the west and central parts of MCB Camp Pendleton; it is approximately 28,000 acres, with only a small portion of the area (approximately 1%) located outside of MCB Camp Pendleton (**Figure 6-3**). The watershed area encompasses a stream network that is non-perennial. The downstream portion of the watershed contains the San Onofre alluvial groundwater basin, which is one of the drinking water sources for the installation. Part or all of 12 training areas and four impact areas are located within the watershed:

- Alpha One Training Area (1,100 acres)
- Alpha Two Training Area (1,329 acres)
- Alpha Three Training Area (1,265 acres)
- Bravo Three Training Area (2,467 acres)
- Delta Training Area (2,635 acres)
- Echo Training Area (1,704 acres)
- Finch Training Area (1,447 acres)
- Fox Trot Training Area (2,673 acres)
- Jardine Canyon Impact Area (350 acres)
- Romeo One Training Area (1,689 acres)
- Romeo Two Training Area (2,665 acres)
- Romeo Three Training Area (1,172 acres)
- Quebec Impact Area (2,710 acres)
- Whisky Impact Area (13,489 acres)
- Yankee Training Area (3,806 acres)
- Zulu Impact Area (7,390 acres)

Figure 6-3

MC Loading Areas within San Onofre Watershed

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Non-Perennial Stream
- Perennial Stream
- San Onofre Watershed
- MC Loading Area
- MCB Camp Pendleton Boundary

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

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Seventeen MC loading areas located within the impact and training areas, where the majority of MC deposition is anticipated to occur, are listed in **Table 6-10**.

Table 6-10: MC Loading Areas in the San Onofre Watershed

MC Loading Area	Size (acres)
Quebec Impact	49.4
Range 201	17.2
Range 202	0.796
Range 203	52.3
Range 204B	17.2
Range 207	0.97
Range 208C	40.6
Range 210D	20.9
Range 210E/210F	108
Range 211	2.35
Range 215A	108
Range 216 House	0.122
Range 217/219	155
Range 218A	86.9
Range 301	0.108
Range 600	727
Whisky Impact	1,290

Military Munitions

Military munitions authorized for use within the MC loading areas located in the San Onofre Watershed are listed in **Table 3-1**.

6.2.1. Conceptual Site Model

6.2.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the San Onofre watershed are shown in **Figure 6-3**. The boundaries of each MC loading area were selected based on training-specific information (e.g., operational range boundaries, target locations, other GIS data), which does not necessarily capture the complete potential spatial distribution of MC loading. Notably, this approach resulted in a significantly larger size for the Whiskey Impact MC loading area relative to the baseline assessment, partly because it was enlarged to encompass the new CAS urban target area. Additionally, the Quebec Impact MC loading area was notably reduced in size relative to the baseline assessment in order to reflect target and training information.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited annually within these MC loading areas (**Table 6-11**); the assumptions used to guide the estimates are detailed in **Section 3**. The analysis suggests that RDX and TNT represent the highest MC loading within San Onofre watershed. The highest MC loading rate observed at a particular MC loading area during the review period was RDX at the Range 202 MC loading area. However, based on the size of the MC loading area and the associated MC loading rates, the most significant loading appeared to be the RDX and TNT deposition at the much larger Quebec Impact MC loading area. Compared to estimated baseline average annual MC loading rates, the estimated average annual MC loading rates for the five-year review indicate loading has remained relatively stable across the watershed since the baseline assessment. Estimated HMX loading increased slightly, with the change being less than an order of magnitude across the MC loading areas in this watershed. Estimated TNT and RDX loading increased slightly, with the change for both being less than an order of magnitude across the MC loading areas in this watershed. Estimated perchlorate loading increased by an order of magnitude across the MC loading areas in this watershed.

Table 6-11: Estimated Annual MC Loading for the San Onofre 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)	Quebec Impact (51.4%)[a]	1,568,384	2.53E-10	1.64E-06	9.12E-07	1.17E-07
	Whiskey Impact	894,355	3.37E-09	3.54E-06	4.61E-06	1.73E-09
	Total MC loading area in San Onofre (Period E)	**2,462,739**	**1.39E-09**	**2.33E-06**	**2.25E-06**	**7.53E-08**
Five-Year Review (Period F 2006–2011)	Quebec Impact	199,870	1.86E-08	5.20E-05	3.31E-05	2.67E-07
	Range 201	69,428	8.08E-12	3.89E-07	2.07E-08	9.06E-10
	Range 202	3,223	0.00E+00	4.80E-04	3.08E-04	7.78E-07

Assessment	MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)			
			HMX	RDX	TNT	Perchlorate
	Range 203	211,832	0.00E+00	2.82E-07	2.66E-09	0.00E+00
	Range 204B	69,542	0.00E+00	5.65E-05	2.73E-07	5.80E-09
	Range 207	3,935	0.00E+00	1.31E-07	1.15E-07	0.00E+00
	Range 208C	164,287	6.40E-11	3.85E-07	8.20E-08	1.02E-08
	Range 210D	84,743	0.00E+00	1.28E-07	1.61E-09	3.15E-10
	Ranges 210E/210F	436,078	1.13E-11	1.29E-05	8.33E-07	6.41E-09
	Range 211	9,498	0.00E+00	8.06E-05	2.07E-05	1.77E-11
	Range 215A	436,239	2.48E-11	1.59E-06	4.37E-08	1.13E-10
	Range 216 House	495	0.00E+00	2.03E-05	1.23E-05	3.12E-08
	Ranges 217/219	627,869	1.85E-12	6.81E-07	3.63E-07	3.36E-10
	Range 218A	351,495	0.00E+00	5.07E-08	1.15E-08	8.40E-08
	Range 301	436	0.00E+00	0.00E+00	5.89E-12	0.00E+00
	Range 600	2,941,964	1.96E-12	1.70E-07	8.85E-08	7.57E-12
	Whiskey Impact	5,214,386	4.07E-09	6.50E-06	9.78E-06	1.81E-06
	Total MC loading area in San Onofre (Period F)	**10,825,320**	**2.31E-09**	**5.35E-06**	**5.52E-06**	**8.80E-07**

Notes:
[a] Loading area covers portions of multiple watersheds.

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 conservatively account for potential/actual inconsistent expenditure recordkeeping. Five-year review values cover 2006 to 2011.
Estimated MC loading rate based on part or all of individual MC loading areas located within the watershed.

Annual lead deposition for the MC loading areas in the San Onofre watershed was estimated during this five-year review (**Table 6-12**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimate of the total amount of lead deposited in a given MC loading area. The baseline assessment did not include lead loading estimates for MC loading areas. Calculations indicate the Range 210E/210F MC loading area may have the most significant lead deposition rates, estimated at 13,200 lb of lead annually. Accounting for all MC loading areas identified in the San Onofre watershed, it is estimated that a total of 36,400 lb of lead was deposited annually during this review period.

Table 6-12: Estimated Annual Lead Deposition for the San Onofre Watershed

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
Quebec Impact	199,870	4.81E-05	8.87E-05	2.12E+01
Range 201	69,428	1.66E-02	3.06E-02	2.54E+03
Range 202	3,223	1.85E-06	3.41E-06	1.32E-02
Range 203	211,832	2.98E-04	5.49E-04	1.39E+02
Range 204B	69,542	6.94E-05	1.28E-04	1.06E+01
Range 207	3,935	0.00E+00	0.00E+00	0.00E+00
Range 208C	164,287	5.63E-03	1.04E-02	2.04E+03
Range 210D	84,743	9.88E-05	1.82E-04	1.85E+01
Ranges 210E/210F	436,078	1.37E-02	2.53E-02	1.32E+04
Range 211	9,498	1.92E-09	3.55E-09	4.03E-05
Range 215A	436,239	5.44E-03	1.00E-02	5.24E+03
Range 216 House	495	2.62E-06	4.84E-06	2.86E-03
Ranges 217/219	627,869	1.33E-03	2.45E-03	1.84E+03
Range 218A	351,495	6.53E-03	1.20E-02	5.06E+03

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
Range 301	436	3.56E-01	6.57E-01	3.43E+02
Range 600	2,941,964	2.08E-04	3.84E-04	1.35E+03
Whiskey Impact	5,214,386	4.05E-04	7.46E-04	4.65E+03
Total MC loading area in San Onofre (Period F)	**10,825,320**	**1.53E-03**	**2.81E-03**	**3.64E+04**

6.2.1.2. Geography and Topography

The San Onofre watershed is characterized by various terrains, consisting of sandy shores, coastal plains, rolling hills, canyons, and mountains. The northern tip of the watershed area contains the Santa Margarita Mountains, while the southeastern tip of the watershed area contains the San Onofre Mountains. The terrain generally slopes toward the center of the watershed to San Onofre Canyon, the major non-perennial stream/wash, which ultimately flows southwest toward the Pacific Ocean. Available contour data indicate the elevation of the watershed area within the installation boundary ranges from mean sea level at the coastline and in the south central part of the watershed (near the point where the San Onofre Canyon intersects Basilone Road) to 2,900 feet amsl on the northern boundary of the watershed at the Santa Margarita Mountains (MCB Camp Pendleton, 2011c). Based on available spatial data, the slope within the installation boundary of the watershed area can range from nearly level to approximately 87% in the mountain hills, but the majority of the area has a slope ranging from approximately 5.5% to 49% (MCB Camp Pendleton, 2011c).

6.2.1.3. Surface Water Features

The San Onofre watershed contains a non-perennial stream network with a dendritic drainage pattern. The San Onofre Canyon flows southwesterly within the installation boundary, becomes San Onofre Creek, and discharges to the Pacific Ocean just north of the San Onofre Nuclear Generating Station. Tributaries of San Onofre Canyon flow primarily to the south and southwest into the canyon. All of Range 201, Range 202, Range 203, Range 204B, Range 207, Range 208C, Range 210D, Range 210E/210F, Range 211, Range 215A, Range 216 House, Range 217/219, Range 218A, Range 301, Range 600, Quebec Impact, and Whisky Impact MC loading areas are located within the San Onofre watershed. **Table 6-13** describes the drainage characteristics of the 17 MC loading areas within the San Onofre watershed.

Table 6-13: Drainage Description of the MC Loading Areas within the San Onofre Watershed

MC Loading Area	Drainage Description
Quebec Impact	A tributary stream of North Fork San Onofre Creek flows southerly through the southwestern tip of the MC loading area. Another tributary stream flows southwesterly approximately 475 feet east of the MC loading area. The MC loading area is approximately 1 mile up gradient of San Onofre Canyon.
Range 201	An unnamed tributary stream of the San Onofre Canyon flows southwesterly through the southern part of the MC loading area into the San Onofre Canyon. The San Onofre Canyon is approximately 1.9 miles down gradient of the MC loading area.
Range 202	There are no surface water features within the MC loading area, but an unnamed tributary stream of San Onofre Canyon flows southwesterly approximately 530 feet west of the MC loading area. San Onofre Canyon is approximately 1.2 miles down gradient of the MC loading area.
Range 203	A small tributary stream of the North Fork San Onofre Creek flows southeasterly through the MC loading area. North Fork San Onofre Creek flows southwesterly into the San Onofre Canyon approximately 1 mile southeast of the MC loading area.
Range 204B	A small tributary stream of the North Fork San Onofre Creek flows southeasterly through the northern part of Range 204B MC loading area. North Fork San Onofre Creek flows southwesterly into the San Onofre Canyon approximately 3,200 feet southeast of the MC loading area.
Range 207	There are no surface water features within the MC loading area, but the South Fork San Onofre Creek flows southwesterly approximately 50 feet south of the MC loading area into the San Onofre Canyon.
Range 208C	The tributary stream of North Fork San Onofre Creek flows southerly through the MC loading area. North Fork San Onofre Creek flows southwesterly just south of the MC loading area.
Range 210D	There are no surface water features within the MC loading area, but the unnamed tributary stream of San Onofre Canyon flows southwesterly approximately 158 feet northwest of the MC loading area, and the San Onofre Canyon flows southwesterly approximately 260 feet southeast of the MC loading area.

MC Loading Area	Drainage Description
Range 210E/210F	San Onofre Canyon flows southwesterly through the southeastern end of the MC loading area. Two unnamed tributary streams of the San Onofre Canyon flow southwesterly approximately 210 feet west and 370 feet east of the MC loading area.
Range 211	San Onofre Canyon flows southwesterly approximately 530 feet north of the MC loading area.
Range 215A	A tributary stream of South Fork San Onofre Creek flows southwesterly through the northwestern part of the MC loading area. Another tributary stream of South Fork San Onofre Creek flows southwesterly approximately 320 feet east of the MC loading area.
Range 216 House	A tributary stream of South Fork San Onofre Creek flows southwesterly approximately 320 feet south of the MC loading area.
Range 217/219	South Fork San Onofre Creek flows southwesterly through the eastern end of the MC loading area, and two of its tributary streams flow southwesterly through the central and western end of the MC loading area.
Range 218A	Two tributary streams of the South Fork San Onofre Creek flow southwesterly through the MC loading area.
Range 301	A tributary stream of the San Onofre Canyon flows southerly approximately 530 feet east of the MC loading area.
Range 600	San Onofre Canyon and a small tributary stream flow southwesterly within the MC loading area.
Whisky Impact	North Fork San Onofre Creek flows southwesterly through the northern part of the MC loading area. Tributary streams of North Fork San Onofre Creek flow southwesterly through the southern part of the MC loading area.

6.2.1.4. Soil Characteristics and Land Cover

The predominant soil map symbols of the San Onofre watershed within the installation boundary include CmrG, RuG, GaF, and FeE2 (USDA NRCS, 2007). These soil map units consist of coarse sandy loam, weathered and unweathered bedrock, fine sandy loam, sandy loam, loam, and sandy clay loam. Many of the soil characteristics of the RuG soil map unit, which only consists of unweathered bedrock, have not been measured. The other soil map units (CmrG, GaF, and FeE2) can be well to somewhat excessively well drained and have pH ranging from 5.6 to 7.8

(USDA NRCS, 2007). The organic content for CmrG, GaF, and FeE2 ranges from 0.5% to 1%. The inherent soil erodibilities for CmrG, GaF, and FeE2 are relatively low, moderate, and moderate, respectively, with estimated soil erodibility factors of 0.24 for CmrG, 0.32 for GaF, and 0.28 for FeE2. All four of the soil map units have relatively high runoff potential. A significant portion of the San Onofre watershed area is unvegetated. The vegetated areas within the watershed are covered with grass, scrub, chaparral, and forest.

6.2.1.5. Erosion Potential

The San Onofre watershed area was estimated to have moderate soil erosion potential (RUSLE predicted soil loss value of 5.91E-03 $kg/m^2/d$). This estimated moderate soil erosion potential is largely a result of the steep topography and land cover that is primarily unvegetated within the watershed area.

The estimated soil erosion potential of the 17 identified MC loading areas within the San Onofre watershed ranges from low to high. Twelve of the MC loading areas (Quebec Impact, Range 217/219, Range 210D, Range 215A, Range 216 House, Range 218A, Range 210E/210F, Range 208C, Range 204B, Range 203, Range 201, and Whiskey Impact) were estimated to have low soil erosion potential. These MC loading areas have good vegetation cover and/or a flatter slope. Five of the MC loading areas (Range 202, Range 207, Range 211, Range 301, and Range 600) were estimated to have moderate and high soil erosion potential due to steep topography, lack of vegetation cover, and/or the presence of soil types with a moderate inherent soil erodibility factor.

6.2.1.6. Groundwater Characteristics

The San Onofre watershed area includes the San Onofre groundwater basin, which is one of the drinking water sources for the installation. The San Onofre groundwater basin is located in the coastal plain area down gradient of the identified MC loading areas. The primary water-bearing units in the San Onofre groundwater basin are the alluvial and the San Mateo aquifers. These aquifers are the groundwater-producing units within the groundwater basin and are recharged primarily by streams. The alluvium within the San Onofre groundwater basin consists of coarse-grained sand and gravel and/or cobbles interbedded with finer-grained sediments consisting of lean clay and sandy lean clay (Stetson, 2007). Based on cross-section data presented in Stetson (2007), the thickness of the alluvium in the San Onofre groundwater basin can range from 10 to 45 feet. The San Mateo aquifer within the groundwater basin is composed primarily of coarse-grained sand with minor interbedded clay. The Cristianitos Fault is encountered near the northern boundary of the groundwater basin. The San Mateo aquifer does not exist east of the Cristianitos Fault; this is where the San Onofre breccia is first encountered (Stetson, 2007). Based on well screen depth intervals, the four active production wells within the San Onofre groundwater basin are estimated to be screened in both the alluvial and San Mateo aquifers (MCB Camp Pendleton, 2011e). The hydraulic conductivities of the alluvial and San Mateo aquifers within the San Onofre groundwater basin have been estimated to range from 0.049 to 0.412 ft/min (Stetson, 2005). Based on water levels measured in monitoring and production wells, the depth to groundwater in the San Onofre groundwater basin can be 30 to 43 feet bgs.

The identified MC loading areas are located in upland areas of the watershed; some of these MC loading areas, including Range 217/219, Range 218A, Range 600, and Whisky Impact, as well as parts of Range 210E/210F, Range 215A, and Quebec Impact, are located on basement rock, which is close to land surface (Stetson, 2008). Groundwater within the fractures and joints of the basement complex currently is not considered viable for water supply purposes. Other MC loading areas, including Range 201, Range 202, Range 203, Range 204B, Range 207, Range 208C, Range 210D, Range 211, Range 216, and Range 301 and parts of Quebec Impact, Range 210E/210F, and Range 215A , are underlain by low permeable aquitards consisting of the Santiago and Williams Formations. The aquitards likely do not contain or transmit substantial quantities of groundwater.

6.2.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Runoff coefficients at MC loading areas within the San Onofre watershed were estimated to range from 0.43 to 0.57. In addition to the occurrence of infrequent torrential storms at MCB Camp Pendleton, the relatively high runoff potentials are attributable to the moderately steep to steep topography, sparse vegetation cover, and/or the presence of soil types with high runoff potential (hydrologic group D). The MC loading area with the highest runoff coefficient (Range 202) has a moderately steep topographic slope, no vegetation cover, and soil types with a high runoff potential. The MC loading area with the lowest runoff coefficient (Range 210E/210F) has a moderately steep topographic slope, soil types with high runoff potential, but a relatively dense vegetation cover. As indicated in **Section 6.2.1.5**, the MC loading areas within the watershed have low, moderate, or high soil erosion potential. The moderate and high soil erosion potentials that could occur at five of the MC loading areas (Range 202, Range 207, Range 211, Range 301, and Range 600) make soil erosion an important mechanism for MC mobilization into surface water runoff. MC migrating into streams with surface water runoff would drain southwest, south, and southeast into San Onofre Canyon. San Onofre Canyon flows southwesterly and becomes San Onofre Creek, which also flows southwesterly through the San Onofre alluvial groundwater basin into the Pacific Ocean.

Groundwater Pathways

A small portion of MC deposited on MC loading areas likely will migrate down to the underlying basement complex or low permeable aquitards; however, because many of the MC loading areas are located on moderately steep and steep slopes, most of the MC deposited on MC loading areas likely will be transported with overland flow into non-perennial streams. MC recharged to shallow groundwater in the discontinuous and narrow alluvial deposits in the upland areas mostly discharge to streams, depending on seasonal changes to water table elevations. In these areas, the discontinuous and narrow alluvial deposits underlie the non-perennial streams and overlie the basement complex and aquitards. Groundwater migration downward to the underlying basement complex or aquitards from the alluvium likely is insignificant. The non-perennial streams and canyons from the MC loading areas drain toward the San Onofre alluvial groundwater basin, where they recharge the alluvial aquifer. The alluvial aquifer is continuous throughout the San Onofre groundwater basin and is in direct contact with the underlying San Mateo aquifer. Groundwater within the San Onofre groundwater basin does not discharge to streams. Without the presence of the installation production wells, groundwater within the San Onofre groundwater basin flows in a southwest direction toward the Pacific Ocean. However, pumping at the installation production wells results in localized groundwater flow path toward the production wells. The groundwater gradient in San Onofre groundwater basin is conservatively estimated to be approximately equal to 0.028 (MCB Camp Pendleton, 2011b). Based on this estimated gradient, the estimated hydraulic conductivity values (Stetson, 2005) and the estimated effective porosity (MCB Camp Pendleton, 2011c; McWhorter and Sunada, 1997), the groundwater flow velocity was estimated to be approximately equal to 1.2 E-03 ft/min.

6.2.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

Habitat areas of the endangered arroyo toad are found within Range 207, Range 208C, Range 210D, Range 210E/210F, and Range 211 MC loading areas, and arroyo toad habitat is down gradient of all other MC loading areas within the San Onofre watershed (Range 201, Range 202, Range 203, Range 204B, Range 215A, Range 216, Range 217/219, Range 218A, Range 301, Range 600, Quebec Impact, and Whisky Impact MC loading areas) (MCB Camp Pendleton, 2011c). Additionally, habitat areas of the threatened California gnatcatcher are found approximately 150 feet from the Range 301 MC loading area. The San Onofre watershed drains to the San Onofre alluvial groundwater basin and recharges the aquifer which is used as a drinking water source (**Figure 6-4**).

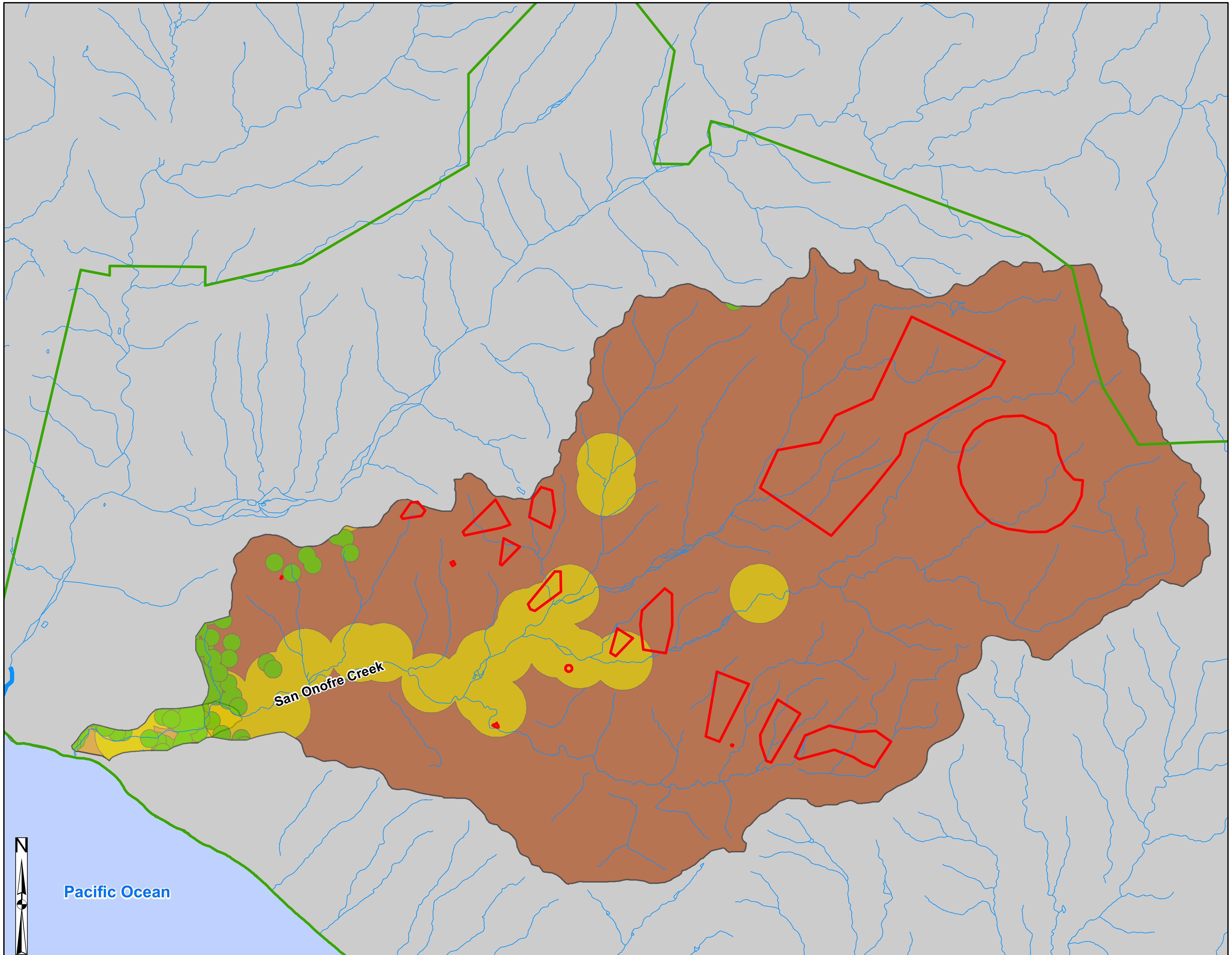
Groundwater Receptors

The San Onofre groundwater basin contains four installation production wells that supply potable water to the installation's northern service area. MC potentially transported to groundwater in the San Onofre alluvial groundwater basin may migrate to the installation production wells (**Figure 6-4**). MC recharged to shallow groundwater in upland areas of the watershed, near MC loading areas, can discharge to streams where there are potential ecological receptors, including the endangered arroyo toad and the threatened California gnatcatcher (as described above).

Figure 6-4

Pathways and Potential Receptors in the San Onofre Watershed

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Non-Perennial Stream
- Perennial Stream
- Alluvial Groundwater Basin
- MC Loading Area
- MCB Camp Pendleton Boundary

Watershed of Streams Recharging Groundwater

- San Onofre Creek

Sensitive Species Habitat

- Arroyo Toad
- California Gnatcatcher

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

6.2.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from 17 MC loading areas that drain to the San Onofre Creek, which flows to and recharges a groundwater basin that is used as a drinking water source (the San Onofre alluvial groundwater basin). **Table 6-14** lists the MC loading areas assessed. The MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and proximity surface drainages that lead to potential receptor locations.

Table 6-14: MC Loading Areas Assessed within the San Onofre Watershed

MC Loading Area	MC Modeled			
	HMX	RDX	TNT	Perchlorate
Quebec Impact	X	X	X	X
Range 201	X	X	X	X
Range 202	--	X	X	X
Range 203	--	X	X	--
Range 204B	--	X	X	X
Range 207	--	X	X	--
Range 208C	X	X	X	X
Range 210D	X	X	X	X
Range 210E/210F	X	X	X	X
Range 211	--	X	X	X
Range 215A	X	X	X	X
Range 216 House	--	X	X	X
Range 217/219	X	X	X	X
Range 218A	--	X	X	X

MC Loading Area	MC Modeled			
	HMX	RDX	TNT	Perchlorate
Range 301	--	--	X	--
Range 600	X	X	X	X
Whisky Impact	X	X	X	X

Of the 17 assessed MC loading areas, eight of these MC loading areas were estimated to have negligible HMX loading. One of these MC loading areas was estimated to have negligible RDX loading. Three of these MC loading areas were estimated to have negligible perchlorate loading. No MC loading areas were estimated to have negligible TNT loading. Therefore, 9, 16, and 14 of the 17 assessed MC loading areas were modeled for HMX, RDX, and perchlorate, respectively. All 17 MC loading areas were modeled for TNT. The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading period (2006–2011 [Period F]). The proportions of MC loading areas draining to San Onofre Creek to a point closest to a drinking water well within the San Onofre alluvial groundwater basin are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the San Onofre watershed up gradient of the alluvial groundwater basin. **Table 6-15** presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to San Onofre Creek within the San Onofre alluvial groundwater basin to a point closest to a drinking water well.

Table 6-15: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into San Onofre Creek at a Point Closest to a Drinking Water Well within the San Onofre Alluvial Groundwater Basin

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Quebec Impact	14.5	17.7	9.19	0.559
Range 201	~0	~0	~0	~0
Range 202	0	2.70	2.01	~0

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Range 203	0	0.105	~0	0
Range 204B	0	6.51	~0	~0
Range 207	0	~0	~0	0
Range 208C	~0	0.110	~0	~0
Range 210D	0	~0	~0	~0
Range 210E/210F	~0	8.26	0.485	~0
Range 211	0	1.22	0.309	~0
Range 215A	~0	1.02	~0	~0
Range 216 House	0	~0	~0	~0
Range 217/219	~0	0.656	0.288	~0
Range 218A	0	~0	~0	0.309
Range 301	0	0	~0	0
Range 600	~0	0.891	0.451	~0
Whisky Impact	85.3	60.7	87.2	99.1

Table 6-16 presents the estimated annual average edge-of-loading-area concentrations in surface water runoff from individual MC loading areas draining within the San Onofre watershed. Based on the screening-level calculations, the average annual concentrations of HMX in surface water runoff would be below the REVA trigger value at the edge of all MC loading areas modeled for HMX. The average annual concentration of RDX in runoff was predicted to be above the REVA trigger value at the edge of 15 of the 16 MC loading areas modeled. RDX was only predicted to be below the REVA trigger value at the edge of the Range 218A MC loading area. The average

annual concentrations of TNT and perchlorate were predicted to be above REVA trigger values at the edge of 9 of the 17 and 8 of the 14 MC loading areas modeled, respectively.

Table 6-16: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the San Onofre Watershed

MC Loading Area	Estimated MC Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
Quebec Impact	0.094	**102**	**32.2**	**1.59**
Range 201	~0	**0.774**	0.020	0.006
Range 202	N/A	**800**	**360**	**3.83**
Range 203	N/A	**0.549**	0.003	N/A
Range 204B	N/A	**111**	**0.309**	**0.035**
Range 207	N/A	**0.179**	**0.129**	N/A
Range 208C	~0	**0.740**	0.108	**0.058**
Range 210D	0	**0.167**	0.001	0.002
Range 210E/210F	~0	**23.9**	**0.852**	**0.042**
Range 211	N/A	**137.1**	**21.0**	~0
Range 215A	~0	**2.77**	0.057	0.001
Range 216 House	N/A	**32.7**	**15.9**	**0.178**
Range 217/219	~0	**1.24**	**0.328**	0.002
Range 218A	N/A	0.080	0.012	**0.500**
Range 301	N/A	N/A	~0	N/A
Range 600	~0	**0.299**	0.092	~0

MC Loading Area	Estimated MC Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
Whisky Impact	0.017	**11.9**	**10.4**	**9.58**
REVA Trigger Value for Water	0.114	0.110	0.113	0.021

Notes:
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 analyses were conducted to estimate the annual average MC concentrations in surface water entering the San Onofre Creek at a point closest to a drinking water well within the San Onofre alluvial groundwater basin where it potentially recharges the groundwater. The estimated drainage area of San Onofre Creek upstream of the point closest to a drinking water well is equivalent to 25,989.8 acres. The average annual concentrations of RDX, TNT, and perchlorate in surface water entering San Onofre Creek at the point closest to a drinking water well within the San Onofre alluvial groundwater basin were predicted to be above REVA trigger values (**Table 6-17**).

Table 6-17: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Entering San Onofre Creek at the Point Closest to a Drinking Water Well within the San Onofre Alluvial Groundwater Basin

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	0.001
RDX	0.110	**1.03**
TNT	0.113	**0.598**
Perchlorate	0.021	**0.480**

Note: **Shading and bold indicate concentration exceeds the REVA trigger value.**

Based on the results of the surface water screening-level analysis, saturated zone groundwater screening-level modeling was conducted to estimate MC concentrations getting to a drinking water well from San Onofre Creek within the San Onofre groundwater basin (**Section 6.2.3**).

Table 6-18 presents the estimated annual average edge-of-loading-area concentrations in sediment from individual MC loading areas draining within the San Onofre watershed. Based on the screening-level calculations, the average annual concentrations of TNT in sediment were predicted to be above the REVA trigger value at the edges of Range 202, Range 211, and Quebec

Impact MC loading areas. The average annual concentrations of HMX, RDX, and perchlorate in sediment were predicted to be below REVA trigger values at the edge of all MC loading areas modeled within the San Onofre watershed.

Table 6-18: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the San Onofre Watershed

MC Loading Area	MC Concentration (µg/kg)			
	HMX	RDX	TNT	Perchlorate
Quebec Impact	0.002	3.87	**81.6**	~0
Range 201	~0	0.029	0.052	~0
Range 202	N/A	23.0	**683.5**	~0
Range 203	N/A	0.021	0.007	N/A
Range 204B	N/A	3.48	0.654	~0
Range 207	N/A	0.006	0.300	N/A
Range 208C	~0	0.019	0.182	~0
Range 210D	~0	0.008	0.004	~0
Range 210E/210F	~0	0.905	2.17	~0
Range 211	N/A	5.00	**50.7**	~0
Range 215A	~0	0.070	0.098	~0
Range 216 House	N/A	0.824	26.9	~0
Range 217/219	~0	0.054	0.971	~0
Range 218A	N/A	0.003	0.030	~0
Range 301	N/A	N/A	~0	N/A
Range 600	~0	0.010	0.211	~0

MC Loading Area	MC Concentration (μg/kg)			
	HMX	RDX	TNT	Perchlorate
Whisky Impact	~0	0.399	23.3	~0
REVA trigger value for sediment	51	32.5	25	0.18

Note: **Shading and bold indicate concentration exceeds the REVA trigger value.**

Additional analyses were conducted to estimate the annual average MC concentrations in sediment entering the San Onofre Creek at the point closest to a drinking water well within the San Onofre alluvial groundwater basin. Average annual MC concentrations in sediment entering the San Onofre Creek at the point closest to a drinking water well within the San Onofre alluvial groundwater basin were predicted to be below REVA trigger values (**Table 6-19**).

Table 6-19: Screening-Level Estimates of Annual Average MC Concentrations in Sediment Entering San Onofre Creek at the Point Closest to a Drinking Water Well within the San Onofre Alluvial Groundwater Basin

MC	REVA Trigger Value (μg/kg)	Concentration (μg/kg)
HMX	51	~0
RDX	32.5	0.008
TNT	25	0.281
Perchlorate	0.18	~0

Based on the results of the sediment screening-level analysis, no additional sediment assessment is required at this time.

6.2.3. Groundwater Analysis Results

A screening-level groundwater analysis was used to assess the potential for MC in streams reaching the San Onofre alluvial groundwater basin to recharge the groundwater and migrate through the groundwater to groundwater receptors (installation drinking water wells). The results from the surface water screening-level analysis were used to estimate MC concentrations in streams potentially recharging the San Onofre alluvial groundwater basin.

Based on the surface water screening-level analysis results, concentrations of RDX, TNT and perchlorate in San Onofre Creek at the point closest to a drinking water well within the San Onofre alluvial groundwater basin (where it can recharge the groundwater) were predicted to exceed REVA trigger values (**Table 6-17**). As a result, saturated zone modeling was conducted for RDX, TNT, and perchlorate to estimate concentrations potentially reaching the nearest drinking water well from the creek (at the assumed point of recharge) within the basin.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through the alluvial and San Mateo aquifers within the San Onofre groundwater basin to potential groundwater receptors (installation drinking water wells). The model was run for a simulation time of 50 years. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the point of San Onofre Creek closest to a drinking water well within the groundwater basin (assumed stream recharge point) and the nearest receptor location (a drinking water well).

Table 6-20 shows results of the saturated zone modeling for MC within the San Onofre groundwater basin (from the point in San Onofre Creek closest to a drinking water well recharging the alluvial aquifer). The distance to a drinking water well from the point on San Onofre Creek that is closest to the well within the alluvial groundwater basin was estimated to be 424 feet. All MC modeled (RDX, TNT and perchlorate) were predicted to reach a drinking water well at concentrations above REVA trigger values. These concentrations were predicted to reach the drinking water well within a time period of less than one year. **Figure 6-4** shows locations of drinking water wells within the San Onofre groundwater basin.

Table 6-20: Model-Estimated MC Concentrations Reaching Groundwater Receptors within the San Onofre Groundwater Basin

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	NP
RDX	0.110	**0.513**
TNT	0.113	**0.389**
Perchlorate	0.021	**0.479**

Notes:
NP – not predicted; MC was estimated to be below the REVA trigger value in the stream recharging the basin
Shading and bold indicate concentration exceeds the REVA trigger value.

Groundwater sampling for MC in drinking water wells within the San Onofre basin was conducted as part of the five-year review in September 2011 and August 2012; a subsequent monitoring event was initiated in December 2012. These results are discussed in **Section 8**. Groundwater sampling analyses for this five-year review included perchlorate, which was not included in the baseline groundwater analyses. The REVA baseline assessment conducted for MCB Camp Pendleton in 2006 did not predict perchlorate to reach drinking water wells within the San Onofre basin at concentrations above the REVA trigger value; however, perchlorate was predicted to exceed the REVA trigger value in this five-year review because of the higher perchlorate loading estimated for the San Onofre watershed in the during the review period. This higher perchlorate loading may be associated with munitions for a new weapon system (HIMARS), which represents a change in training since the baseline assessment. Based on the five-year review screening-level modeling results, perchlorate analysis will be included in future REVA monitoring events conducted within the San Onofre basin at MCB Camp Pendleton.

6.2.4. Summary of Lead in the San Onofre Watershed

No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike other MC. Lead is geochemically specific with regards to its mobility in the environment. Site-specific conditions must be known (i.e., geochemical properties) in order to quantitatively assess lead migration. Without site-specific physical and chemical characterization, lead cannot be modeled effectively using fate and transport modeling applied to the other indicator MC in REVA. Therefore, the amount of lead deposited within the MC loading areas within the San Onofre watershed is noted here in order to determine whether additional assessment actions (e.g. monitoring) may be warranted.

Section 6.2.1.1 noted that approximately 36,400 lb of lead were deposited annually across the approximate 2,675 acres covered by the MC loading areas present in the San Onofre watershed. Ranges 210E/210F MC loading area has the highest annual deposition rate of approximately 13,200 lb. Several other MC loading areas also have significant annual deposition rates given their relatively small size, including Range 201 (2,540 lb), Range 208C (2,040 lb), Range 215A (5,240 lb), and Range 218A (5,060 lb). Potential receptors of lead deposited at these MC loading areas include human and ecological points. The San Onofre alluvial groundwater basin is down gradient of these MC loading areas, though the distance between these MC loading areas and the nearest groundwater receptor exposure point are relatively large. Of the noted MC loading areas, Range 201 is closest at approximately 2.8 miles, while Ranges 210E/210F MC loading area is at approximately 4.5 miles. Habitat area for the arroyo toad is found within the boundary of Range 208 and Ranges 210E/210F MC loading areas.

6.3. Las Flores Watershed

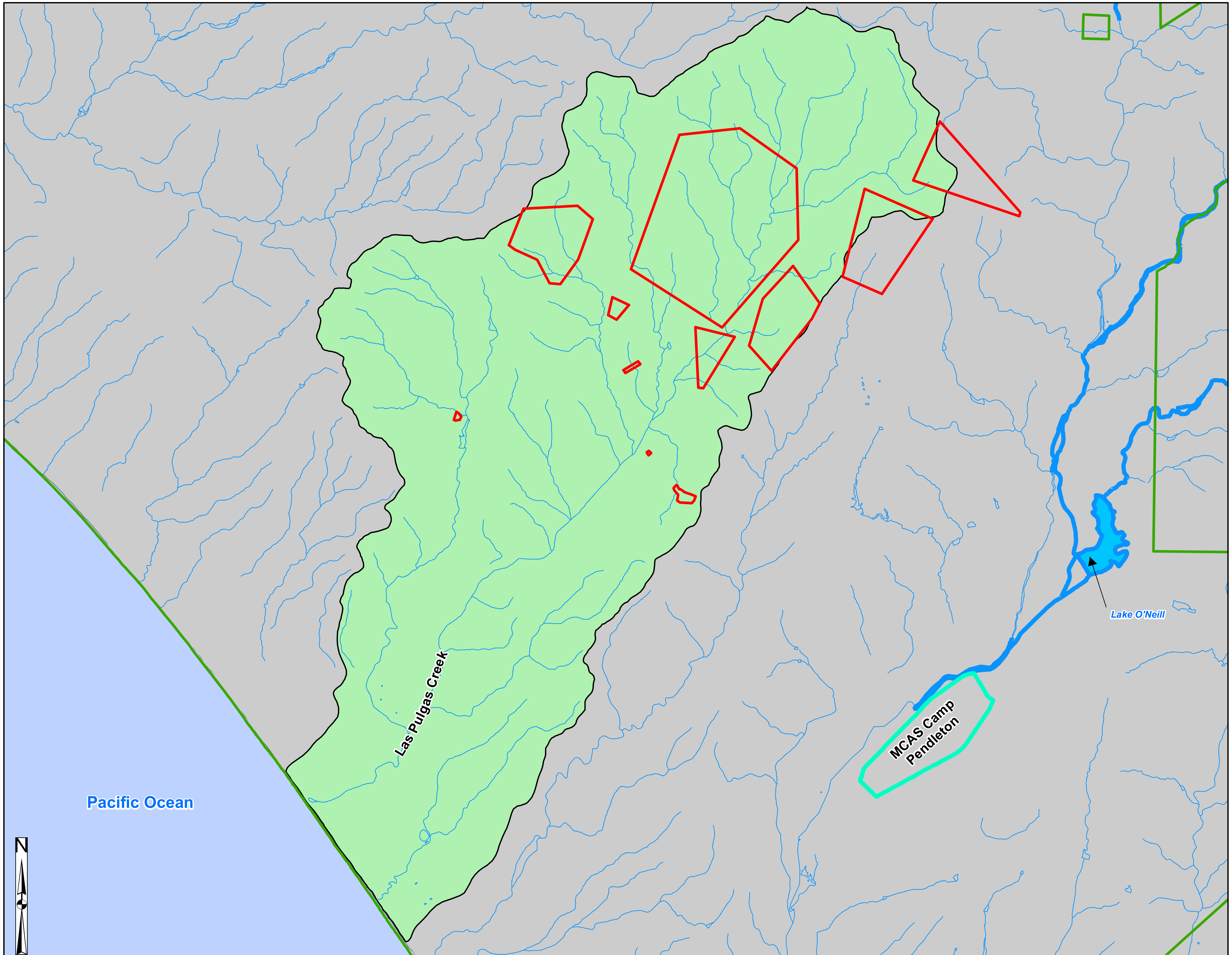
The Las Flores watershed is located on the west and central parts of MCB Camp Pendleton; it is approximately 17,300 acres and is located entirely within the boundary of MCB Camp Pendleton **(Figure 6-5)**. The watershed area encompasses a freshwater lake, coastal lagoons, and a network of non-perennial creeks, including the Las Flores Creek. The downstream portion of the watershed contains the Las Flores alluvial groundwater basin, which serves as one of the drinking water sources for the installation. Part or all of eight training areas and two impact areas are located within the watershed:

- Golf Training Area (2,542 acres)
- Kilo One Training Area (3,125 acres)
- Oscar Two Training Area (5,079 acres)
- Papa One Training Area (2,298 acres)
- Papa Two Training Area (3,606 acres)
- Papa Three Training Area (1,273 acres)
- Red Beach Training Area (274 acres)
- Victor Training Area (323 acres)
- X-Ray Impact Area (4,369 acres)
- Zulu Impact Area (7,390 acres)

Figure 6-5

MC Loading Areas within the Las Flores Watershed

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Non-Perennial Stream
- Perennial Stream
- Lake
- Las Flores Watershed
- MC Loading Area
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

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Eleven MC loading areas partially or fully located within the impact and training areas, where the majority of MC deposition is anticipated to occur, are listed in **Table 6-21**.

Table 6-21: MC Loading Areas in the Las Flores Watershed

MC Loading Area	Size (acres)
PDL Combat Town	2.70
Range 108	13.5
Range 109	0.722
Range 221/222	286
Range 223B	17.7
Range 225	4.44
Range 227	90.2
Range 407 Complex	263
Range 408	359
Range 409A	263
Zulu Impact	1,530

Military Munitions

Military munitions authorized for use within the MC loading areas located in the Las Flores Watershed are listed in **Table 3-1**.

6.3.1. Conceptual Site Model

6.3.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the Las Flores watershed are shown in **Figure 6-5**. The boundaries of each MC loading area were selected based on training-specific information (e.g., operational range boundaries, target locations, other 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 annually within these MC loading areas over time (**Table 6-22**); the assumptions used to guide the estimates are detailed in **Section 3**. The analysis suggests that RDX, TNT, and perchlorate represent the highest MC loading within Las Flores watershed. The highest MC loading rate observed at a particular MC loading area during the review period was RDX at the Range 109

MC loading area. However, based on the size of the MC loading area and the associated MC loading rates, the most significant loading appeared to be RDX and TNT deposition at the much larger Zulu Impact MC loading area. Compared to estimated baseline average annual MC loading rates, the estimated average annual MC loading rates for this review suggest loading has remained relatively steady across the watershed, with the exception of perchlorate. Estimated HMX loading decreased slightly, with the change being less than an order of magnitude in the watershed. Estimated TNT and RDX loading increased slightly, with the change being less than an order of magnitude across the MC loading areas in the watershed. Estimated perchlorate loading increased by approximately three orders of magnitude in the Las Flores watershed.

Table 6-22: Estimated Annual MC Loading for the Las Flores 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)	**Zulu Impact**	**3,225,345**	**6.87E-09**	**3.01E-06**	**2.93E-06**	**2.57E-09**
Five-Year Review (Period F 2006–2011)	PDL Combat Town	10,945	0.00E+00	0.00E+00	6.27E-12	4.11E-12
	Range 108	54,756	8.62E-14	1.23E-06	6.29E-06	1.01E-08
	Range 109	2,922	0.00E+00	8.51E-05	5.46E-05	1.38E-07
	Ranges 221/222	1,158,893	1.17E-10	3.24E-06	8.44E-08	4.62E-09
	Range 223B	71,694	5.49E-10	5.09E-06	9.86E-07	1.25E-06
	Range 225	17,984	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Range 227	364,985	1.59E-12	1.14E-07	7.14E-08	3.03E-09
	Range 407 Complex	1,065,353	2.39E-11	9.12E-06	2.10E-07	2.29E-08
	Range 408 (20%)[a]	290,540	4.65E-11	1.33E-07	6.56E-08	4.24E-09
	Range 409A (30%)[a]	318,641	2.05E-10	6.28E-07	1.82E-07	2.66E-09
	Zulu Impact	6,207,289	6.75E-09	9.81E-06	1.23E-05	1.52E-06

Assessment	MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)			
			HMX	RDX	TNT	Perchlorate
	Total MC loading area in Las Flores (Period F)	**9,564,002**	**4.41E-09**	**7.87E-06**	**8.11E-06**	**1.00E-06**

Notes:
[a] Loading area covers portions of multiple watersheds

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 conservatively account for potential/actual inconsistent expenditure recordkeeping. Five-year review values cover 2006 to 2011.
Estimated MC loading rate based on part or all of individual MC loading areas located within the watershed.

Annual lead deposition for the MC loading areas in the Las Flores watershed was estimated during this five-year review (**Table 6-23**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimate of the total amount of lead deposited in a given MC loading area. The baseline assessment did not include lead loading estimates for MC loading areas. Calculations indicate the Range 407 Complex MC loading area may have the most significant lead deposition rates, estimated at 17,000 lb of lead annually. Accounting for all MC loading areas identified in the Las Flores watershed, it is estimated that a total of 42,900 lb of lead was deposited annually during this review period.

Table 6-23: Estimated Annual Lead Deposition for the Las Flores Watershed

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
PDL Combat Town	10,945	9.26E-09	1.71E-08	2.23E-04
Range 108	54,756	8.48E-04	1.87E-03	1.02E+02
Range 109	2,922	3.03E-07	5.58E-07	1.95E-03
Ranges 221/222	1,158,893	3.61E-03	6.66E-03	9.23E+03
Range 223B	71,694	6.24E-02	1.15E-01	9.86E+03

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
Range 225	17,984	4.17E-03	7.69E-03	1.65E+02
Range 227	364,985	4.59E-03	8.46E-03	3.70E+03
Range 407 Complex	1,065,353	7.23E-03	1.33E-02	1.70E+04
Range 408 (20%)[a]	290,540	1.15E-03	2.12E-03	7.37E+02
Range 409A (30%)[a]	318,641	1.10E-03	2.04E-03	7.76E+02
Zulu Impact	6,207,289	9.61E-05	1.77E-04	1.32E+03
Total MC loading area in Las Flores (Period F)	**9,564,002**	**2.03E-03**	**3.75E-03**	**4.29E+04**

[a] Loading area covers portions of multiple watersheds.

6.3.1.2. Geography and Topography

The Las Flores watershed is characterized by various terrains, consisting of sandy shores, coastal plains, rolling hills, canyons, and mountains. A small part of the northern area of the watershed includes the Santa Margarita Mountains, while a small part of the southwestern area of the watershed, within the Tango training area, includes the Flores Hill. The terrain generally slopes toward the center of the watershed to Las Pulgas Canyon, the major non-perennial stream/wash that flows south toward the Pacific Ocean. Available contour data indicate the elevation of the watershed area within the installation boundary ranges from mean sea level at the coastline to 2,100 feet amsl on the northwestern boundary of the watershed at the Santa Margarita Mountains and on the western boundary of the watershed approximately 1.1 miles west of the Zulu Impact MC loading area (MCB Camp Pendleton, 2011c). Based on available spatial data, the slope within the installation boundary of the watershed area can range from nearly level to approximately 38% in the mountains, but the majority of the area has a slope ranging from approximately 4% to 23% (MCB Camp Pendleton, 2011c).

6.3.1.3. Surface Water Features

The Las Flores watershed contains a non-perennial stream network with a dendritic drainage pattern. The Las Pulgas Canyon flows southwesterly within the installation boundary. This canyon meets with Piedra de Lumbre Canyon and forms the Las Flores Creek, which flows southwesterly and discharges to the Pacific Ocean approximately 2,100 feet south of Interstate Highway 5. Tributaries of the Las Pulgas Canyon and the Las Flores Creek flow south, southeast, west, and southwest into the Las Pulgas Canyon and the Las Flores Creek. All of Range 108, Range 109, Range 223B, Range 221/222, Range 225, Range 227, Range 407 Complex, PDL Combat Town, and Zulu Impact, 20% of Range 408, and 30% of Range 409A MC loading areas drain within the Las Flores watershed.

Table 6-24 describes the drainage characteristics of the 11 MC loading areas within the Las Flores watershed.

Table 6-24: Drainage Description for the MC Loading Areas within the Las Flores Watershed

MC Loading Area	Drainage Description
PDL Combat Town	The tributary stream of Piedra de Lumbre Canyon flows southeasterly approximately 42 feet north of the MC loading area. The confluence point of this tributary stream with Piedra de Lumbre Canyon is approximately 264 feet down gradient of the MC loading area. Pulgas Lake exists just downstream of the confluence point.
Range 108	The unnamed tributary stream of Las Pulgas Canyon flows northwesterly through the northwestern boundary of the MC loading area to the Las Pulgas Canyon.
Range 109	Las Pulgas Canyon flows southwesterly approximately 528 feet west of the MC loading area.
Range 223B	An unnamed tributary stream of Las Pulgas Canyon flows southeasterly approximately 264 feet west of the MC loading area to the Las Pulgas Canyon.
Range 221/222	Tributary streams of Las Pulgas Canyon flow south and southeasterly through the MC loading area. The Las Pulgas Canyon is approximately 1.7 miles down gradient of the MC loading area.
Range 225	An unnamed tributary stream of Las Pulgas Canyon flows southeasterly through the middle section of the MC loading area into the canyon. Las Pulgas Canyon is approximately 3,000 feet down gradient of the MC loading area.
Range 227	Las Pulgas Canyon flows southwesterly through the northwestern part of the MC loading area. Two unnamed tributary streams of the Las Pulgas Canyon also flow northwesterly and westerly within the eastern and southern parts of the MC loading area.

MC Loading Area	Drainage Description
Range 407 Complex	Two unnamed tributaries of the Las Pulgas Canyon flow southwesterly within the northwestern and southwestern parts of the MC loading area. Las Pulgas Canyon is approximately 1,400 feet down gradient of the MC loading area.
Range 408	Tributary streams of Las Pulgas Canyon flow westerly and southwesterly approximately 530 feet north and southeast of the portion of the MC loading area that drains within the Las Flores watershed. The remaining portion of the MC loading area drains within the Aliso (approximately 75%) and the Santa Margarita (approximately 5%) watersheds.
Range 409A	An unknown tributary stream of the Las Pulgas Canyon flows westerly from the southwestern part of the portion of the MC loading area that drains within the Las Flores watershed to the Las Pulgas Canyon. The remaining portion of the MC loading area (approximately 70%) drains within the Santa Margarita watershed.
Zulu Impact	Las Pulgas Canyon and several tributary streams of Las Pulgas Canyon flow southwesterly and southeasterly within the MC loading area.

6.3.1.4. Soil Characteristics and Land Cover

The predominant soil map units of the Las Flores watershed within the installation boundary include GaF, Salinas clay loam (SbC), Cieneba rocky coarse sandy loam (CmE2), HaG, CmrG, Las Flores loamy fine sand (LeC), and Huerhuero loam (HrD). These soil map units consist of fine sandy loam, coarse sandy loam, gravelly clay loam, loamy fine sand, clay, sandy clay, loamy coarse sand, loam, clay loam, stratified sand to sandy loam, and weathered and unweathered bed rock. These soil map units can be moderately well to somewhat excessively well drained and have pH ranging from 5.1 to 8.4 (USDA NRCS, 2007). The organic content for the soil map symbols ranges from 0.5% to 1.5%, with HaG having the highest organic content of 1.5%. The inherent soil erodibilities for the soil map symbols range from low to moderate, with the estimated soil erodibility factors ranging from 0.17 for SbC to 0.37 for LeC and HrD. All seven of the soil map units have relatively high runoff potential. A significant portion of the Las Flores watershed area is unvegetated. The vegetated areas within the watershed are covered with grass, scrub, chaparral, and forest.

6.3.1.5. Erosion Potential

Within the Las Flores watershed, the drainage area of Piedra de Lumbre Canyon upstream of the Las Flores groundwater basin and the drainage area of Las Pulgas Canyon upstream of the point closest to a drinking water well within the groundwater basin were estimated to have moderate soil erosion potential (RUSLE predicted soil loss values of 3.46E-03 and 5.61E-03 kg/m^2/d). These estimated moderate soil erosion potentials are results of moderately steep topographies and land covers that are largely unvegetated.

The identified MC loading areas within the Las Flores watershed, with the exception of the Zulu Impact MC loading area, were estimated to have low soil erosion potential. Zulu Impact MC loading area was estimated to have moderate soil erosion potential. The moderate soil erosion potential at Zulu Impact MC loading area is attributable to moderately steep topography, the presence of unvegetated areas, and the presence of soil types with moderate soil erodibility factor. The MC loading areas with low estimated soil erosion potential generally have good vegetation cover and/or flatter topographic slope.

6.3.1.6. Groundwater Characteristics

The Las Flores watershed area includes the Las Flores groundwater basin, which is one of the drinking water sources for the installation. The Las Flores groundwater basin is located in the coastal plain area down gradient of the identified MC loading areas. The primary water-bearing units in the Las Flores groundwater basin are the alluvial and San Mateo aquifers. These aquifers are the groundwater-producing units within the groundwater basin and are recharged primarily by streams. The alluvium within the Las Flores groundwater mostly consists of fine-grained sediments, consisting of clayey sand and silty sand but also includes coarser-grained sediments consisting of a mix of gravel, sand, and clay or just gravel and sand (Worts and Boss, 1954). Groundwater within the alluvial aquifer is unconfined (Palmer, 1994). One water supply well within the Las Flores groundwater basin is screened within the alluvial aquifer (Palmer, 1994). The San Mateo aquifer within the groundwater basin is composed primarily of coarse-grained sediments consisting of gravel and sand with minor interbedded mix of sandy clay and silty clay (Worts and Boss, 1954). Groundwater within the San Mateo aquifer is primarily unconfined, though a local confining condition does occur adjacent to I-5 at one of the drinking water wells, which is a flowing artesian well (Palmer, 1994). The San Mateo aquifer is the major water-producing aquifer in the Las Flores basin. Many of the water supply wells within the Las Flores alluvial basin are screened within both the alluvial and San Mateo aquifers. Based on aquifer pumping tests conducted at pump wells within the Las Flores groundwater basin, the estimated hydraulic conductivity of the San Mateo aquifers within the Las Flores groundwater basin can range from 0.09 to 0.19 ft/min (Palmer, 1994). Based on water levels measured in monitoring and production wells, the depth to groundwater in the Las Flores groundwater basin can be 10 to 58 feet bgs.

The identified MC loading areas are located in upland areas of the watershed, and some of these MC loading areas, including Range 221/222, Range 408, and Range 409A and parts of Range 223B, Range 407 Complex, and Zulu Impact MC loading areas are located on basement rock that is close to land surface (Stetson, 2008). Groundwater within the fractures and joints of the basement complex currently is not considered viable for water supply purposes. Other MC loading areas, including Range 108, Range 109, Range 225, Range 227, and PDL Combat Town MC loading areas, as well as parts of Range 223B, Range 407 Complex, and Zulu Impact MC loading areas, are underlain by low permeable aquitards consisting of the Santiago and Williams Formations. The aquitards likely do not contain or transmit substantial quantities of groundwater.

6.3.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Runoff coefficients at MC loading areas within the Las Flores watershed were estimated to range from 0.33 to 0.5. In addition to the occurrence of infrequent torrential storms at MCB Camp Pendleton, the moderate to high runoff potentials are attributable to the moderately steep topography, sparse vegetation cover, and/or the presence of soil types with high runoff potential (hydrologic group D). The MC loading area with the highest runoff coefficient (Range 223B) has sparse vegetation cover and soil types with high runoff potential but has a relatively flat topographic slope. The MC loading area with the lowest runoff coefficient (PDL Combat Town) has a flat topographic slope, relatively good vegetation cover, and soil types with relatively low runoff potential (hydrologic group B).

As indicated in **Section 6.3.1.5**, the Zulu Impact MC loading area within the watershed has moderate soil erosion potential, while other MC loading areas within the watershed have low soil erosion potential. The moderate soil erosion potential that could occur at the Zulu Impact MC loading area makes soil erosion an important mechanism for MC mobilization into surface water runoff. MC migrated in streams from surface water runoff would drain southeast, southwest, and west into Las Pulgas Canyon and Las Flores Creek. Las Pulgas Canyon flows southwesterly through the Las Flores alluvial groundwater basin, where it becomes Las Flores Creek after its confluence with Piedra de Lumbre. Las Flores Creek continues to flow southwesterly into the Pacific Ocean.

Groundwater Pathways

A small portion of MC deposited on MC loading areas potentially can migrate down to the underlying basement complex or low permeable aquitards; however, this is likely insignificant within the Las Flores watershed, and most of the MC deposited on MC loading areas likely will be transported with overland flow and/or shallow groundwater to non-perennial streams. MC recharged to shallow groundwater in the discontinuous and narrow alluvial deposits higher in the watershed mostly discharge to streams, depending on seasonal changes to water table elevations. In these areas, the discontinuous and narrow alluvial deposits underlie the non-perennial streams and overlie the basement complex and aquitards. Groundwater migration downward to the underlying basement complex or aquitards from the alluvium likely is insignificant. The non-perennial streams and canyons from the MC loading areas drain toward the Las Flores alluvial groundwater basin, where they recharge the alluvial aquifer. The alluvial aquifer is continuous throughout the Las Flores groundwater basin and is in direct contact with the underlying San Mateo aquifer. Groundwater within the Las Flores groundwater basin does not discharge to streams. Without the presence of the production wells, groundwater within the Las Flores groundwater basin flows in a southwest direction toward the Pacific Ocean. However, pumping at the installation production wells results in localized groundwater flow path toward the production wells. The groundwater gradient in Las Flores groundwater basin is conservatively estimated to be approximately equal to 0.068 (MCB Camp Pendleton, 2011b). Based on this estimated gradient, the estimated hydraulic conductivity values (Stetson, 2005; Palmer, 1994) and the estimated effective porosity (MCB Camp Pendleton, 2011c; McWhorter and Sunada, 1997), the groundwater flow velocity was estimated to be approximately equal to 2.1E-03 ft/min.

6.3.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Habitat areas of the threatened California gnatcatcher are found approximately 530 feet down gradient of the PDL Combat Town MC loading area and approximately 1.7 to 5.7 miles down gradient of all other identified MC loading areas within the watershed (MCB Camp Pendleton, 2011c). The Las Pulgas and Piedra de Lumbre Canyons drain to the Las Flores alluvial groundwater basin recharge the aquifer that is used as a drinking water source (**Figure 6-6**).

Groundwater Receptors

The Las Flores groundwater basin contains four installation production wells that supply potable water to the installation’s southern service area. MC potentially transported to groundwater in the Las Flores alluvial groundwater basin may migrate to the installation production wells (**Figure 6-6**). MC recharged to shallow groundwater in upland areas of the watershed near MC loading areas can discharge to streams where there are potential ecological receptors, including threatened California gnatcatchers (as described above).

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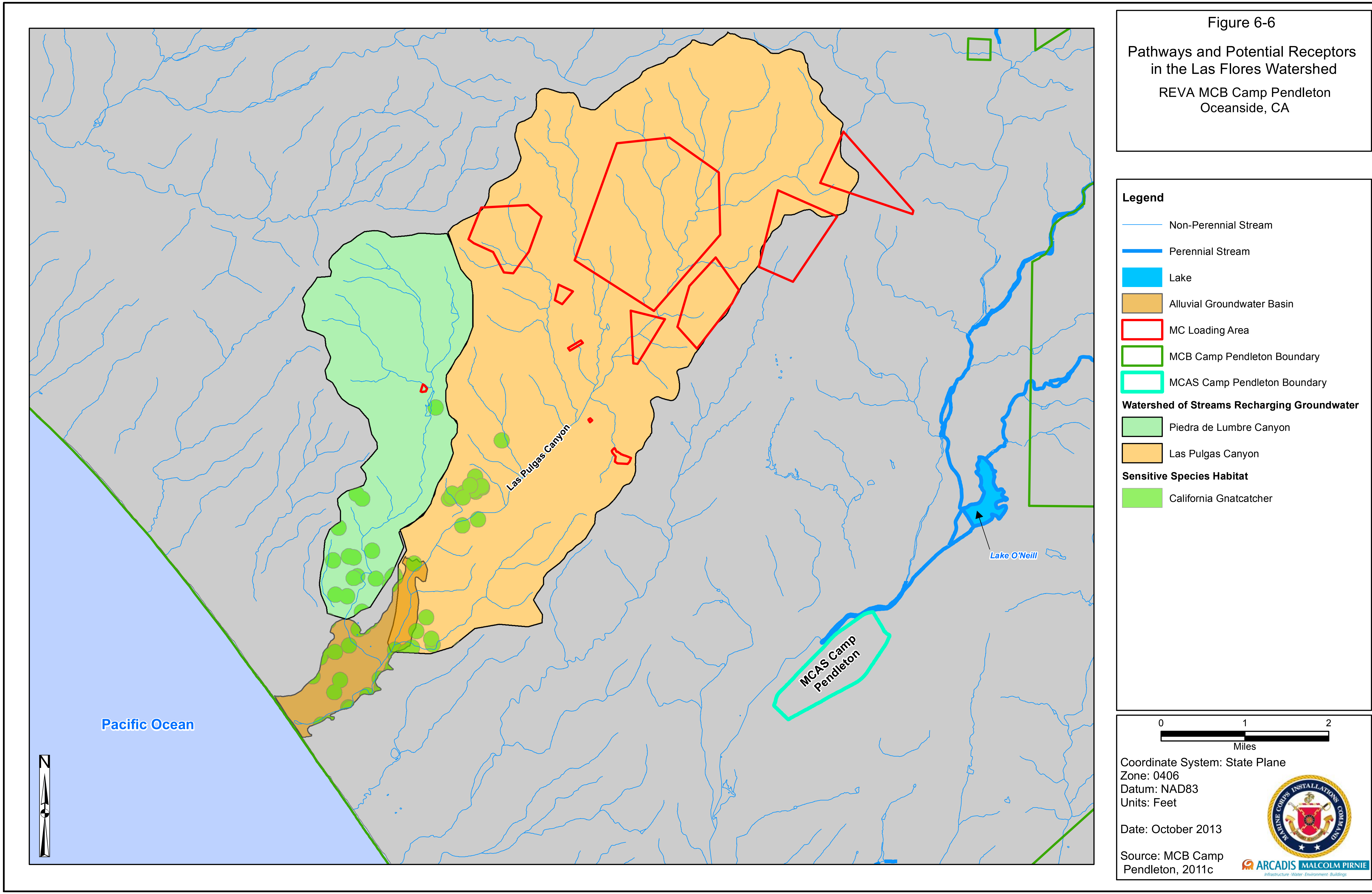
Figure 6-6
Pathways and Potential Receptors in the Las Flores Watershed
REVA MCB Camp Pendleton
Oceanside, CA
Legend
Non-Perennial Stream
Perennial Stream
Lake
Alluvial Groundwater Basin
MC Loading Area
MCB Camp Pendleton Boundary
MCAS Camp Pendleton Boundary
Watershed of Streams Recharging Groundwater
Piedra de Lumbre Canyon
Las Pulgas Canyon
Sensitive Species Habitat
California Gnatcatcher
Las Pulgas Canyon
Lake O'Neill
MCAS Camp Pendleton
Pacific Ocean
N
0
1
2
Miles
Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet
Date: October 2013
Source: MCB Camp Pendleton, 2011c
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6.3.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from 10 MC loading areas that drain to the Las Pulgas Canyon and the Piedra de Lumbre Canyon, which flows to and recharges a groundwater basin that is used as a drinking water source (the Las Flores alluvial groundwater basin). **Table 6-25** lists the MC loading areas assessed. The MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and proximity to surface drainages that lead to potential receptor locations.

Table 6-25: MC Loading Areas Assessed within the Las Flores Watershed

MC Loading Area	MC Modeled			
	HMX	RDX	TNT	Perchlorate
PDL Combat Town	--	--	X	X
Range 108	--	X	X	X
Range 109	--	X	X	X
Range 221/222	X	X	X	X
Range 223B	X	X	X	X
Range 227	X	X	X	X
Range 407 Complex	X	X	X	X
Range 408	X	X	X	X
Range 409A	X	X	X	X
Zulu Impact	X	X	X	X

The Range 225 MC loading area, located within the Las Flores watershed, was not included in the analysis because the MC loading area was estimated to have negligible MC loading. Of the 10 assessed MC loading areas, 3 were estimated to have negligible HMX loading. One of these MC loading areas was estimated to have negligible RDX loading. No MC loading areas were estimated to have negligible TNT or perchlorate loading. Therefore, 7 and 9 of the 10 assessed MC loading areas were modeled for HMX and RDX, respectively. All 10 MC loading areas were modeled for TNT and perchlorate. The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (2006–2011 [Period F]). Only one MC loading area (PDL Combat Town) drains to the Piedra de Lumbre Canyon at the up gradient edge of the Las Flores alluvial groundwater basin. The proportions of MC loading areas draining to Las Pulgas Canyon within the Las Flores alluvial groundwater basin at a point closest to a drinking water well are presented in **Table 5-2**. **Figure 6-6** shows surface water features and MC loading areas analyzed within the Las Flores watershed. **Table 6-26** presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to Las Pulgas Canyon within the Las Flores alluvial groundwater basin at a point closest to a drinking water well.

Table 6-26: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas to Las Pulgas Canyon within the Las Flores Alluvial Groundwater Basin at a Point Closest to a Drinking Water Well

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Range 108	~0	~0	0.354	~0
Range 109	0	0.368	0.173	~0
Range 221/222	0.337	5.60	0.107	~0
Range 223B	~0	0.533	0.106	0.938
Range 227	~0	~0	~0	~0
Range 407 Complex	~0	11.01	0.276	0.253
Range 408	~0	0.261	0.113	~0
Range 409A	0.147	0.758	0.220	~0
Zulu Impact	99.3	81.3	98.6	98.6

Table 6-27 presents the estimated annual average edge-of-loading-area concentrations in surface water runoff from individual MC loading areas draining within the Las Flores watershed. Based

on the screening-level calculations, the average annual concentrations of HMX in surface water runoff would be below the REVA trigger value at the edge of all MC loading areas modeled for HMX. The average annual concentrations of RDX in runoff were predicted to be above the REVA trigger value at the edge of 9 of the 10 MC loading areas for RDX. The average annual concentrations of TNT and perchlorate were predicted to be above REVA trigger values at the edge of 6 of the 10 and 7 of the 10 MC loading areas modeled, respectively.

Table 6-27: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Las Flores Watershed

MC Loading Area	Estimated MC Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
PDL Combat Town	N/A	N/A	~0	~0
Range 108	N/A	**2.41**	**6.13**	**0.061**
Range 109	N/A	**161**	**52.8**	**0.789**
Range 221/222	0.001	**6.18**	0.082	**0.026**
Range 223B	0.003	**9.33**	**1.29**	**7.01**
Range 227	~0	**0.223**	0.072	0.019
Range 407 Complex	~0	**16.2**	**0.283**	**0.159**
Range 408	~0	**0.246**	0.073	**0.026**
Range 409A	0.001	**1.24**	**0.251**	0.020
Zulu Impact	0.033	**17.1**	**14.4**	**8.87**
REVA trigger value for water	0.114	0.110	0.113	0.021

Notes:
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 entering the Las Pulgas Canyon in the Las Flores alluvial groundwater basin at a point closest to a drinking water well. The estimated drainage area of Las Pulgas Canyon upstream of the point in the Las Flores alluvial groundwater basin closest to a drinking water well is equivalent to 12,536 acres. The average annual concentrations of RDX, TNT, and perchlorate in surface water entering Las Pulgas Canyon in the Las Flores alluvial groundwater basin at a point closest to a drinking water well were predicted to be above REVA trigger values (**Table 6-28**). Additional analysis was not conducted to estimate MC concentrations in surface water entering the Piedra de Lumbre Canyon at the up gradient edge of the Las Flores alluvial groundwater basin because the predicted edge-of-loading-area MC concentrations from the PDL Combat Town MC loading area, which is the only MC loading area draining to this receptor location, were below REVA trigger values. Thus, MC concentrations farther downstream in the Piedra de Lumbre Canyon likely would be even less than the predicted edge-of-loading-area MC concentrations that are already below REVA trigger values.

Table 6-28: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Entering Las Pulgas Canyon in the Las Flores Alluvial Groundwater Basin at a Point Closest to a Drinking Water Well

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	0.004
RDX	0.110	**2.61**
TNT	0.113	**1.79**
Perchlorate	0.021	**1.10**

Note: **Shading and bold indicate concentration exceeds the REVA trigger value**.

Based on the results of the surface water screening-level analysis, a saturated zone groundwater screening-level modeling was conducted to estimate MC concentrations getting to the closest drinking water well from Las Pulgas Canyon within the Las Flores groundwater basin (**Section 6.3.3**).

Table 6-29 presents the estimated annual average edge-of-loading-area concentrations in sediment from individual MC loading areas draining within the Las Flores watershed. Based on the screening-level calculations, the average annual concentrations of TNT in sediment were predicted to be above the REVA trigger value at the edge of Range 109 and Zulu Impact MC loading areas. The average annual concentrations of HMX, RDX, and perchlorate in sediment were predicted to be below REVA trigger values at the edge of all MC loading areas modeled within the Las Flores watershed.

Table 6-29: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Las Flores Watershed

MC Loading Area	MC Concentration (µg/kg)			
	HMX	RDX	TNT	Perchlorate
PDL Combat Town	N/A	N/A	~0	~0
Range 108	N/A	0.091	15.5	~0
Range 109	N/A	6.09	**133**	~0
Range 221/222	~0	0.234	0.209	~0
Range 223B	~0	0.235	2.18	~0
Range 227	~0	0.008	0.185	~0
Range 407 Complex	~0	0.409	0.481	~0
Range 408	~0	0.008	0.185	~0
Range 409A	~0	0.031	0.428	~0
Zulu Impact	~0	0.503	**28.3**	~0
REVA trigger value for sediment	51	32.5	25	0.18

Notes:
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 sediment entering the Las Pulgas Canyon at a point closest to a drinking water well within the Las Flores alluvial groundwater basin. Average annual MC concentrations in sediment entering the Las Pulgas Canyon at a point closest to a drinking water well were predicted to be below REVA trigger values (**Table 6-30**). The predicted edge-of-loading-area MC concentrations at the PDL Combat Town MC loading area were below REVA trigger values. As a result, no additional analysis was conducted to estimate MC concentrations in sediment entering the identified downstream receptor location (Piedra de Lumbre Canyon at the up gradient edge of the Las Flores alluvial groundwater basin).

Table 6-30: Screening-Level Estimates of Annual Average MC Concentrations in Sediment Entering the Las Pulgas Canyon at a Point Closest to a Drinking Water Well within the Las Flores Alluvial Groundwater Basin

MC	REVA Trigger Value (µg/kg)	Concentration (µg/kg)
HMX	51	~0
RDX	32.5	0.037
TNT	25	1.95
Perchlorate	0.18	~0

Based on the results of the sediment screening-level analysis, no additional sediment assessment is required at this time.

6.3.3. Groundwater Analysis Results

A screening-level groundwater analysis was used to assess the potential for MC in streams reaching the Las Flores alluvial groundwater basin to recharge the groundwater and migrate through the groundwater to groundwater receptors (installation drinking water wells). The results from the surface water screening-level analysis were used to estimate MC concentrations in streams potentially recharging the Las Flores alluvial groundwater basin.

Based on the surface water screening-level analysis results, concentrations of RDX, TNT, and perchlorate in Las Pulgas Canyon at the point closest to a drinking water well within the Las Flores alluvial groundwater basin (potentially recharging the basin) were predicted to exceed REVA trigger values (**Table 6-28**). As a result, saturated zone modeling was conducted for RDX, TNT, and perchlorate to estimate concentrations potentially reaching the nearest drinking water production well from Las Pulgas Canyon within the basin.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through the alluvial and San Mateo aquifers within the Las Flores groundwater basin to potential groundwater receptors (installation drinking water wells). The model was run for a simulation time of 50 years. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone in Las Pulgas Canyon at a point closest to a drinking water well within the Las Flores groundwater basin (the assumed stream recharge point) and the nearest receptor location (a drinking water well).

Table 6-31 shows results of the saturated zone modeling for MC within the Las Flores alluvial groundwater basin (from the Las Pulgas Canyon recharging the alluvial aquifer at a point closest to a drinking water well). Distance of the nearest drinking water well from Las Pulgas Canyon within the alluvial groundwater basin was estimated to be 1,056 feet. All MC modeled (RDX, TNT, and perchlorate) were predicted to reach the nearest drinking water well to Las Pulgas Canyon at concentrations above REVA trigger values. These concentrations were predicted to reach the drinking water well within a time period of less than one year. **Figure 6-6** shows locations of drinking water wells within the Las Flores groundwater basin.

Table 6-31: Model-Estimated MC Concentrations Reaching Groundwater Receptors within the Las Flores Groundwater Basin

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	NP
RDX	0.110	**0.866**
TNT	0.113	**0.610**
Perchlorate	0.021	**0.725**

Notes:
NP – not predicted; MC were estimated to be below the REVA trigger value in the stream recharging the basin
Shading and bold indicate concentration exceeds the REVA trigger value.

Groundwater sampling for MC in two drinking water wells closest to the Las Pulgas Canyon within the Las Flores basin has been conducted as part of the five-year review in September 2011, October 2011, and August 2012; a subsequent monitoring event was initiated in December 2012. These results are discussed in **Section 8**. The groundwater sampling conducted as part of the REVA baseline assessment did not include perchlorate analyses, as the baseline REVA assessment did not predict perchlorate to reach drinking water wells within the Las Flores basin at a concentration above the REVA trigger value. Perchlorate was included as part of the groundwater analyses for this five-year review because perchlorate was predicted to exceed the REVA trigger value due to the higher perchlorate MC loading estimated for the Las Flores watershed in the five-year review period. This higher perchlorate loading may be associated with munitions for a new weapon system (HIMARS), which represents a change in training since the baseline assessment. Based on the five-year review screening-level modeling results, perchlorate analysis will be included in future REVA monitoring programs conducted within the Las Flores basin at MCB Camp Pendleton.

6.3.4. Summary of Lead in the Las Flores Watershed

No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike other MC. Lead is geochemically specific with regards to its mobility in the environment. Site-specific conditions must be known (i.e., geochemical properties) in order to quantitatively assess lead migration. Without site-specific physical and chemical characterization, lead cannot be modeled effectively using fate and transport modeling applied to the other indicator MC in REVA. Therefore, the amount of lead deposited within the MC loading areas within the Las Flores watershed is noted here in order to determine whether additional assessment actions (e.g. monitoring) may be warranted.

Section 6.3.1.1 noted that approximately 42,800 lb of lead were deposited annually across the approximate 2,363 acres covered by the MC loading areas present in the Las Flores watershed. The Range 407 Complex MC loading area has the highest annual deposition rate of approximately 17,000 lb. The Range 223B MC loading area also has a notable annual deposition rate given its relatively small size, approximately 9,860 lb. Potential receptors of lead deposited at these MC loading areas include human points. The Las Flores alluvial groundwater basin is down gradient of these MC loading areas, though the distance between these MC loading areas and the nearest groundwater receptor exposure point are relatively large, with Range 223B at approximately 4.4 miles and Range 407 Complex at approximately 5.0 miles. Neither of these MC loading areas are known to contain habitat for sensitive or protected species.

6.4. Santa Margarita Watershed

The Santa Margarita watershed runs through the eastern portion of MCB Camp Pendleton, extending from the Cleveland National Forest to the Pacific Ocean; it is approximately 99,074 acres, with a large part of the area (over 50%) located outside of the installation boundary **(Figure 6-7)**. The watershed area encompasses most of the developed area of MCB Camp Pendleton and all of MCAS Camp Pendleton. It also contains the Santa Margarita River. The downstream portion of the watershed contains the Santa Margarita alluvial groundwater basins, which serve as one of the drinking water sources for the installation. Part or all of nine training areas and two impact areas are located within the watershed:

- Foxtrot Training Area (2,673 acres)
- Golf Training Area (2,542 acres)
- Hotel Training Area (3,746 acres)
- India Training Area (3,736 acres)
- Kilo One Training Area (3,125 acres)
- Kilo Two Training Area (1,064 acres)
- Mike Training Area (1,776 acres)
- November Training Area (3,245 acres)
- Oscar One Training Area (3,093 acres)
- X-Ray Impact Area (4,369 acres)

- Zulu Impact Area (7,390 acres)

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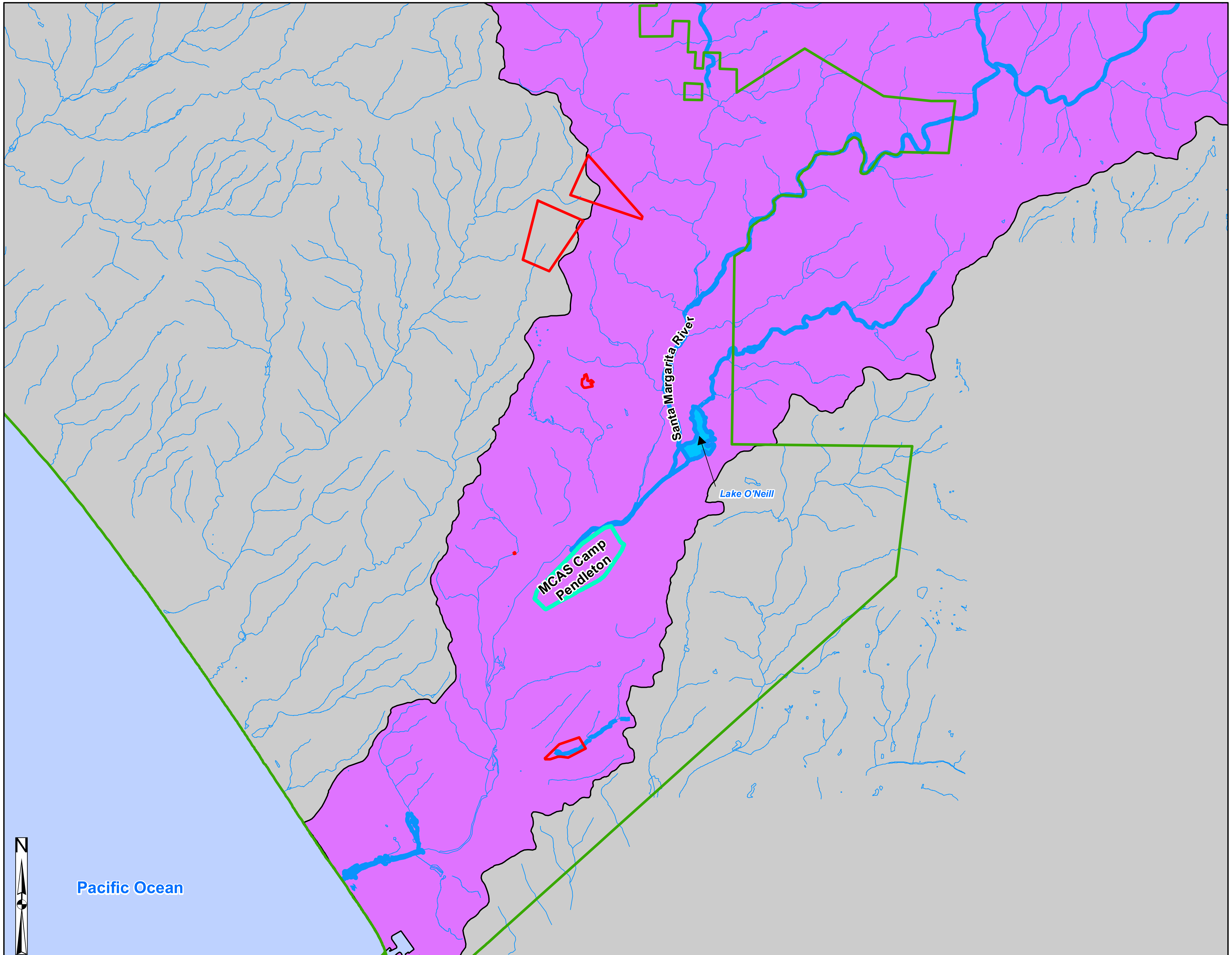
Figure 6-7

MC Loading Areas within the Santa Margarita Watershed

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Non-Perennial Stream
- Perennial Stream
- Lake
- Santa Margarita Watershed
- MC Loading Area
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

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Five MC loading areas partially or fully located within the impact and training areas, where the majority of MC deposition is anticipated to occur, are listed in **Table 6-32**.

Table 6-32: MC Loading Areas in the Santa Margarita Watershed

MC Loading Area	Size (acres)
Kilo Two Combat Town	12.7
Range 104B	0.245
Range 401	67.6
Range 408	359
Range 409A	263

Military Munitions

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

6.4.1. Conceptual Site Model

6.4.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the Santa Margarita watershed are shown in **Figure 6-7**. The boundaries of each MC loading area were selected based on training-specific information (e.g., operational range boundaries, target locations, other 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 annually within these MC loading areas (**Table 6-33**); the assumptions used to guide the estimates are detailed in **Section 3**. The analysis suggests that RDX and TNT represent the highest MC loading within Santa Margarita watershed. The highest MC loading rate observed at a particular MC loading area during the five-year review period was TNT at the Range 401 MC loading area. Based on the size of the MC loading area and MC loading rate, TNT deposition at the Range 401 MC loading area represented the most significant loading in the watershed. Compared to estimated baseline average annual MC loading rates, the estimated average annual MC loading rates for this review suggest MC loading generally has increased across the watershed, with the exception of perchlorate. Estimated RDX, HMX, and TNT loading increased across the watershed, with the changes being one, two, and three orders of magnitude, respectively.

Estimated perchlorate loading decreased by an order of magnitude across the MC loading areas in the watershed.

Table 6-33: Estimated Annual MC Loading for the Santa Margarita Watershed

Assessment	MC Loading Area	Assumed MC Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)			
			HMX	RDX	TNT	Perchlorate
Baseline (Period E 1989–2005)	Edson Range Impact (0.5%)[a]	88,150	1.11E-10	1.12E-06	1.22E-06	3.38E-07
	X-Ray Impact (28.2%)[a]	889,936	0.00E+00	4.79E-10	3.04E-11	2.45E-10
	Range 401	56,200	0.00E+00	2.15E-09	5.27E-08	1.15E-11
	Range 409 Impact (74.9%)[a]	2,008,818	0.00E+00	1.33E-08	8.71E-09	1.04E-08
	Total MC loading area in Santa Margarita (Period E)	**3,043,104**	**3.22E-12**	**4.14E-08**	**4.20E-08**	**1.68E-08**
Five-Year Review (Period F 2006–2011)	Kilo 2 Combat Town	51,438	0.00E+00	0.00E+00	1.27E-13	9.35E-10
	Range 104B	993	0.00E+00	1.10E-05	7.09E-06	1.79E-08
	Range 401	273,699	3.56E-12	2.46E-07	9.02E-05	2.03E-09
	Range 408 (0.5%)[a]	72,635	4.65E-11	1.33E-07	6.56E-08	4.24E-09
	Range 409A (70%)[a]	743,496	2.05E-10	6.28E-07	1.82E-07	2.66E-09

Assessment	MC Loading Area	Assumed MC Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)			
			HMX	RDX	TNT	Perchlorate
	Total MC loading area in Santa Margarita (Period F)	**1,142,261**	**1.38E-10**	**4.86E-07**	**2.17E-05**	**2.54E-09**

Note:
[a] Loading area covers portions of multiple watersheds.

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 conservatively account for potential/actual inconsistent expenditure recordkeeping. Five-year review values cover 2006 to 2011.
Estimated MC loading rates are based on part or all of individual MC loading areas located within the watershed.

Annual lead deposition for the MC loading areas in the Santa Margarita watershed was estimated during this five-year review (**Table 6-34**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimate of the total amount of lead deposited in a given MC loading area. The baseline assessment did not include lead loading estimates for MC loading areas. Calculations indicate the Range 409A MC loading area may have the most significant lead deposition rate, estimated at 1,810 lb of lead annually. Accounting for all MC loading areas identified in the Santa Margarita watershed, it is estimated that a total of 2,060 lb of lead was deposited annually during this review period.

Table 6-34: Estimated Annual Lead Deposition for the Santa Margarita Watershed

MC Loading Area	Size (m^2)	Lead Deposition		
		kg/m^2	lb/yd^2	Total lb
Kilo 2 Combat Town	51,438	5.40E-06	9.96E-06	6.12E-01
Range 104B	993	3.13E-02	5.77E-02	6.86E+01
Range 401	273,699	1.23E-08	2.26E-08	7.41E-03
Range 408 (0.5%)*	72,635	1.15E-03	2.12E-03	1.84E+02
Range 409A (70%)*	743,496	1.10E-03	2.04E-03	1.81E+03

MC Loading Area	Size (m²)	Lead Deposition		
		kg/m²	lb/yd²	Total lb
Santa Margarita (Period F)	**1,142,261**	**8.20E-04**	**1.51E-03**	**2.06E+03**

[a] Loading area covers portions of multiple watersheds.

6.4.1.2. Geography and Topography

The Santa Margarita watershed ranges from the San Bernardino Mountains north of MCB Camp Pendleton to the Pacific Ocean at MCB Camp Pendleton, near the city of Oceanside, California (Stetson, 2008). The northern area of the watershed within the installation boundary includes the Santa Margarita Mountains. The lower part of the watershed has a relatively flat alluvial floodplain that drains the watershed from the northeast to the southwest. Terraces and gently to steeply sloping hillsides border the watershed on the installation, guiding the Santa Margarita River as it meanders through the coastal mountains to the coastal floodplain, which begins approximately 7 miles from the coast (Stetson, 2008). Land surface elevations within the watershed range from sea level at the ocean to 6,817 feet in the upper reaches of the watershed outside of the installation boundary (Stetson, 2008). Available contour data indicate the maximum land surface elevation of the watershed area within the installation boundary is approximately 2,500 feet at the Santa Margarita Mountains (MCB Camp Pendleton, 2011c). Based on available spatial data, the slope within the installation boundary of the watershed area can range from nearly level to approximately 42% in the mountain hills, but the majority of the area has a slope ranging from approximately 3% to 24% (MCB Camp Pendleton, 2011c).

6.4.1.3. Surface Water Features

The Santa Margarita watershed contains a stream network that flows perennially and non-perennially with a dendritic drainage pattern. The Santa Margarita River, the major drainage feature within the watershed, is 27 miles long and originates at the confluence of the Murrieta and Temecula Creeks upstream of the MCB Camp Pendleton installation boundary. The Santa Margarita River flows southwesterly to the Pacific Ocean from the Palomar Mountains, Santa Ana Mountains, Santa Margarita Mountains, and the Santa Rosa Plateau. Segments of the Santa Margarita River within the installation boundary that have perennial flow include the segment between the installation boundary and approximately 3,540 feet south of Basilone Road and the segment between Stuart Mesa Road and the Pacific Ocean. The tributary stream of the Santa Margarita River on the east that flows through O'Neill Lake has a perennial flow. Also, a short stream that flows east of the Santa Margarita River toward the lower Santa Margarita alluvial basin has a perennial flow. Other segments of the Santa Margarita River within the installation, as well as all its other tributary streams, have non-perennial flows. The named tributary streams of the Santa Margarita River within the installation include De Luz Creek, Roblar Creek, and

Wood Canyon, which all flow west of the Santa Margarita River. Tributaries of the Santa Margarita River generally flow southeast and southwest into the river. All of Kilo Two Combat Town, Range 104B, and Range 401, 5% of Range 408, and 70% of Range 409A MC loading areas drain within the Santa Margarita watershed.

Table 6-35 describes the drainage characteristics of the five MC loading areas within the Santa Margarita watershed.

Table 6-35: Drainage Description of the MC Loading Areas within the Santa Margarita Watershed

MC Loading Area	Drainage Description
Kilo Two Combat Town	Wood Canyon flows southeasterly approximately 1,500 feet north of the MC loading area, and an unnamed tributary stream also flows southeasterly approximately 740 feet south of the MC loading area. Both streams flow into the Santa Margarita River, which is approximately 1.5 miles down gradient of the MC loading area.
Range 104B	An unnamed tributary stream of the Santa Margarita River flows southeasterly within the MC loading area to the Santa Margarita River.
Range 401	A short, unnamed perennial stream flows southwesterly within the MC loading area. Flow in this stream ends in a small pond upstream of the southwestern boundary of the MC loading area.
Range 408	Wood Canyon flows southeasterly to the Santa Margarita River approximately 2,640 feet southeast of the portion of the MC loading area draining within the watershed. The majority of the MC loading area drains within the Aliso and Las Flores watersheds.
Range 409A	Tributaries of Roblar Creek flow northeasterly to Roblar Creek just north of the portion of the MC loading area draining within the watershed. Roblar Creek flows to De Luz Creek. A tributary stream of the Santa Margarita River flows southeasterly just south of the portion of the MC loading area draining within the watershed. The remaining portion of the MC loading area drains within the Las Flores watershed.

6.4.1.4. Soil Characteristics and Land Cover

The predominant soil map units of the Santa Margarita watershed within the installation boundary include CmrG, GaF, Linne clay loam (LsF), and Tujunga sand (TuB). These soil map units consist of coarse sandy loam, fine sandy loam, clay loam, sand, find sand, loamy sand, stratified gravelly sand to gravelly loamy sand, and weathered and unweathered bedrock. These soil map units can be well to somewhat excessively well drained and have pH ranging from 5.6 to 8.4.

The CmrG soil has an acidic characteristic (pH of 5.6 to 6), and the other soils have neutral or basic characteristics (pH of 6.6 to 8.4) (USDA NRCS, 2007). The organic content of the soil map units ranges from 0.5% to 1%, with the LsF soil having the higher range. The inherent soil erodibilities of three of the four soil map units are low (factor ranging from 0.15 to 0.24). The GaF soil has a moderate soil erodibility factor of 0.32. Three of the four soil map units have relatively high runoff potentials, but the TuB soil has a low runoff potential.

Approximately 40% of the Santa Margarita watershed within the installation boundary is unvegetated. The part of the watershed that is covered with vegetation includes grass, scrub, chaparral, and some forest.

6.4.1.5. Erosion Potential

Within the Santa Margarita watershed, the drainage areas of 1) Santa Margarita River upstream of the upper Santa Margarita groundwater basin, 2) a tributary stream of the Santa Margarita River upstream of the middle Santa Margarita groundwater basin, and 3) a tributary stream of the Santa Margarita River upstream of the point closes to a drinking water well within the middle Santa Margarita groundwater basin were estimated to have moderate, low, and moderate soil erosion potentials, respectively (RUSLE predicted soil loss values of 4.43E-03, 2.39E-03, and 3.70E-03 $kg/m^2/d$). The estimated moderate soil erosion potentials at two of the three drainage areas are results of moderately steep topographies and land covers that have unvegetated areas.

The identified MC loading areas within the Santa Margarita watershed were estimated to have low soil erosion potentials. These low soil erosion potentials are the result of flat topographic slopes, fairly good vegetation covers, and/or the presence of soil types with low erodibility factors.

6.4.1.6. Groundwater Characteristics

The Santa Margarita watershed area includes the Santa Margarita groundwater basins (the upper, middle and lower basins). The upper and middle Santa Margarita groundwater basins currently serve as drinking water sources for the installation. These groundwater basins are located down gradient of the identified MC loading areas. The primary water-bearing units in these groundwater basins are the alluvial aquifers. The alluvial aquifers are the groundwater-producing units within the groundwater basins and are recharged primarily by streams. The water supply wells present within the upper and middle Santa Margarita groundwater basins are screened within the alluvial aquifer. The alluvium in the lower Santa Margarita groundwater basin is largely fine-grained sediments consisting of sandy clay, silt and clay interbedded with coarse-grained materials, including sand, gravel, cobbles, and a mix of sand and gravel (Law and Crandall, 1995). The alluvium in the southern part of the middle Santa Margarita groundwater basin consists of finer-grained sediments (clay, sandy clay, and silty clay) underlain by coarser-grained ones (sand, gravel cobbles, and gravel and sand); however, the alluvium in the northern part of the middle Santa Margarita groundwater basin generally consists of coarse-grained sediments, including sand, gravel and sand, and cobbles. The alluvium in the upper Santa Margarita groundwater basin largely consists of gravel and sand interbedded with thin layers of clay. Based on a geologic cross section presented by Law and Crandall (1995), the alluvium aquifer within the Santa Margarita groundwater basins can have a thickness of 200 feet. Based on aquifer pumping tests within the Santa Margarita groundwater basins, the estimated hydraulic conductivity of the alluvial aquifer within the Santa Margarita groundwater basin can range from 0.00056 to 0.313 ft/min (Stetson, 2001). Based on water levels measured in monitoring and production wells, the depth to groundwater in the Santa Margarita groundwater basins can be 3 to 58 feet bgs (Stetson, 2001).

With the exception of the Range 104B MC loading area, which is located within the middle Santa Margarita groundwater basin, the identified MC loading areas are located in upland areas of the watershed. Some of these MC loading areas, including Range 408 and Range 409A, are located on basement rock that is close to land surface (Stetson, 2008). Groundwater within the fractures and joints of the basement complex currently is not considered viable for water supply purposes. Other MC loading areas, including Kilo Two Combat Town and Range 401, are underlain by low permeable aquitards consisting of the Santiago and Williams Formations. The aquitards likely do not contain or transmit substantial quantities of groundwater.

6.4.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Runoff coefficients at MC loading areas within the Santa Margarita watershed were estimated to range from 0.34 to 0.52. The higher runoff coefficients of 0.46 and 0.52 estimated at Range 408 and Kilo Two Combat Town are results of moderate topographic slope, the presence of soil types with high runoff potential, and/or the presence of sparse vegetation cover. As indicated in **Section 6.4.1.5**, the identified MC loading areas within the Santa Margarita watershed have low soil erosion potentials. These low soil erosion potentials make soil erosion a less important mechanism for MC mobilization into surface water runoff, indicating a low potential for MC migration in sediment. MC migrated into streams with surface water runoff would drain southeast and southwest into the Santa Margarita River. Santa Margarita River flows southwesterly through the upper, middle, and lower Santa Margarita alluvial groundwater basins to the Pacific Ocean.

Groundwater Pathways

MC from the Range 104B MC loading area, located above an alluvial aquifer within the middle Santa Margarita alluvial groundwater basin, can migrate down to the groundwater with recharge from the portion of precipitation that directly falls on the MC loading area and infiltrate the underlying permeable subsurface material. MC from the Range 104B MC loading area also can migrate to groundwater through stream recharge.

Other MC loading areas within the Santa Margarita watershed are located on basement complex or low permeable aquitards that are both overlain by discontinuous and narrow alluvial deposits. A small portion of MC deposited on these MC loading areas potentially can migrate down to the underlying basement complex or low permeable aquitards; however, this likely is insignificant, and most of the MC deposited on MC loading areas likely will be transported with overland flow and/or shallow groundwater to non-perennial streams. MC recharged to shallow groundwater in the discontinuous and narrow alluvial deposits mostly discharge to streams, depending on seasonal changes to water table elevations. The discontinuous and narrow alluvial deposits underlie the non-perennial streams and overlie the basement complex and aquitards. Groundwater migration downward to the underlying basement complex or aquitards from the alluvium likely is insignificant. The non-perennial and perennial streams drain from the MC loading areas toward the Santa Margarita alluvial groundwater basins, where they recharge the alluvial aquifer. The alluvial aquifer is continuous throughout the Santa Margarita groundwater basin. Groundwater within the Santa Margarita basin does not discharge to streams.

Without the presence of production wells, groundwater within the Santa Margarita groundwater basins flows in a southwest direction toward the Pacific Ocean. However, pumping at the installation production wells results in localized groundwater flow path toward the production wells. The groundwater gradient in Santa Margarita groundwater basin is conservatively estimated to be approximately equal to 0.023 (MCB Camp Pendleton, 2011b). Based on this estimated gradient, the estimated hydraulic conductivity values (Stetson, 2001) and the estimated effective porosity (MCB Camp Pendleton, 2011c; McWhorter and Sunada, 1997), the groundwater flow velocity was estimated to be approximately equal to 1.2 E-03 ft/min.

6.4.1.8. Potential Surface Water and Groundwater Receptors

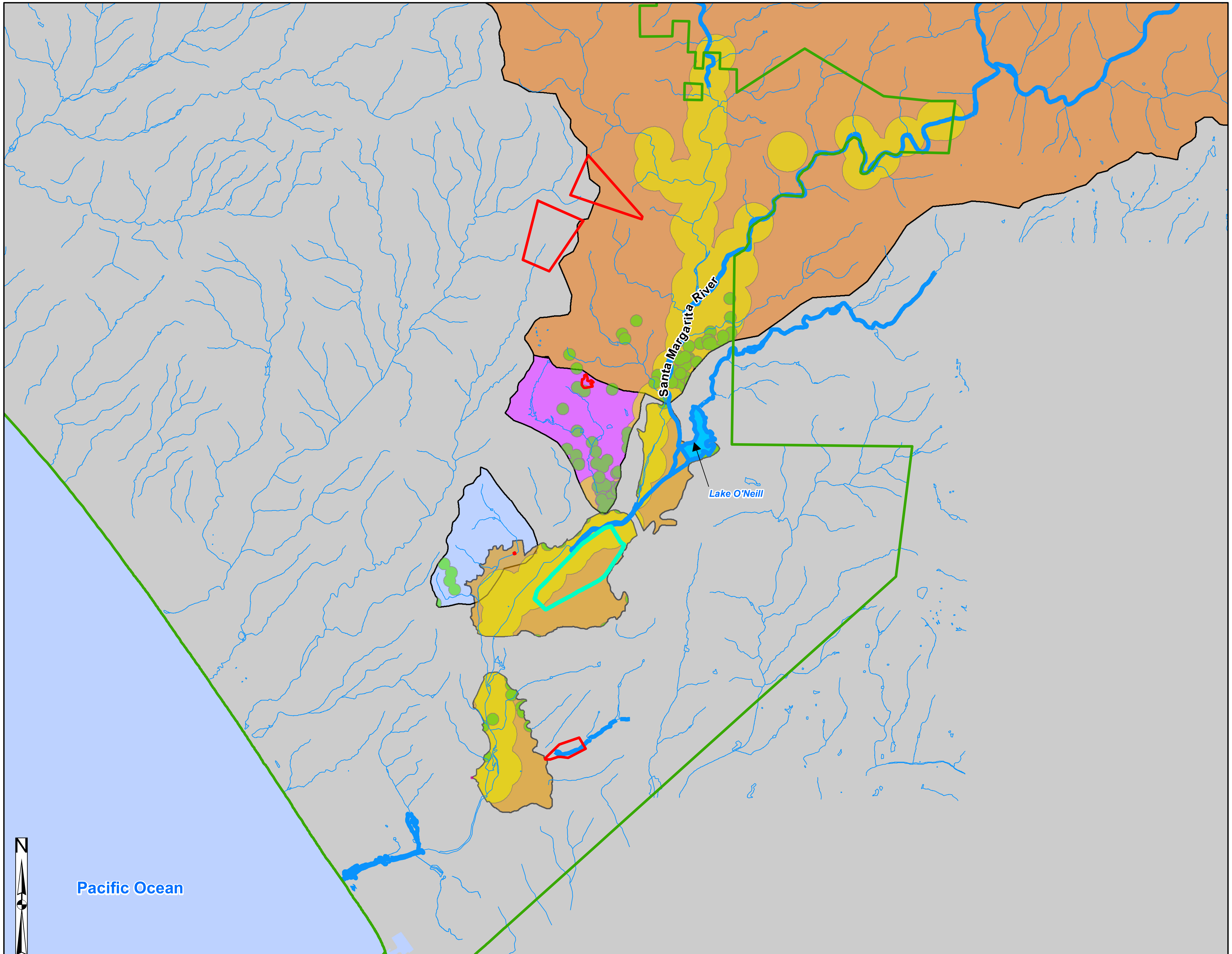
Surface Water and Sediment Receptor

Habitat areas of the threatened California gnatcatcher are found within the Kilo Two Combat Town MC loading area and approximately 1.6 miles down gradient of the Range 408 MC loading area (MCB Camp Pendleton, 2011c). Habitat areas of the endangered arroyo toad are found approximately 840 feet, 1,950 feet and 1,580 feet down gradient of the Range 104B, Range 401, and Range 409A MC loading areas, respectively. Habitat areas of the endangered Pacific Pocket Mouse are found approximately 5,800 feet and 18,500 feet down gradient from Range 401 and Range 104B MC loading areas, respectively. The Santa Margarita River and two of its unnamed tributary streams drain to the upper and middle Santa Margarita alluvial groundwater basins and recharge the aquifers that are used as a drinking water source (**Figure 6-8**).

Figure 6-8

Pathways and Potential Receptors in the Santa Margarita Watershed

REVA MCB Camp Pendleton
Oceanside, CA



Legend

- Non-Perennial Stream
- Perennial Stream
- Lake
- Alluvial Groundwater Basin
- MC Loading Area
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundary

Watershed of Streams Recharging GWBasins

Watershed of Streams Recharging Groundwater Basins

- Tributary of the Santa Margarita River at the Middle Santa Margarita GW Basin
- Tributary of the Santa Margarita River at the Lower Section of the Middle Santa Margarita GW Basin

Sensitive Species Habitat

- Arroyo Toad
- California Gnatcatcher
- Pacific Pocket Mouse

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

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Groundwater Receptors

The upper and middle Santa Margarita alluvial groundwater basins contain 13 installation production wells that supply potable water to the installation's southern service area. MC potentially transported to groundwater in the Santa Margarita alluvial groundwater basins may migrate to the installation production wells (**Figure 6-8**). MC recharged to shallow groundwater in upland areas of the watershed near MC loading areas can discharge to streams where there are potential ecological receptors, including threatened California gnatcatchers and endangered arroyo toad (as described above).

6.4.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from four MC loading areas that drain to the Santa Margarita River and two of its tributaries, which flow to and recharge groundwater basins that are used as a drinking water source (the upper and middle Santa Margarita alluvial groundwater basins). **Table 6-36** lists the MC loading areas assessed. The MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and proximity to surface drainages that lead to potential receptor locations.

Table 6-36: MC Loading Areas Assessed within the Santa Margarita Watershed

MC Loading Area	MC Modeled			
	HMX	RDX	TNT	Perchlorate
Kilo Two Combat Town	--	--	X	X
Range 104B	--	X	X	X
Range 408	X	X	X	X
Range 409A	X	X	X	X

The Range 401 MC loading area, located within the Santa Margarita watershed, was not included in the analysis because this MC loading area does not drain to an existing drinking water source (it drains to the lower Santa Margarita alluvial groundwater basin, but this basin currently is not used as a drinking water source by the installation). Of the four assessed MC loading areas, two were estimated to have negligible HMX loading. One was estimated to have negligible RDX loading. No MC loading areas were estimated to have negligible TNT or perchlorate loading.

Therefore, two and three of the four assessed MC loading areas were modeled for HMX and RDX, respectively. All four MC loading areas were modeled for TNT and perchlorate. The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (2006–2011 [Period F]). The proportions of MC loading areas draining to the Santa Margarita River at the up gradient edge of the upper Santa Margarita alluvial groundwater basin are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Santa Margarita watershed up gradient of the upper and middle Santa Margarita alluvial groundwater basin. **Table 6-37** presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to Santa Margarita River at the up gradient edge of the upper Santa Margarita alluvial groundwater basin. Single MC loading areas drain upstream of the other two identified receptor locations within the Santa Margarita watershed (Kilo Two Combat Town upstream of the middle Santa Margarita alluvial basin and Range 104B upstream of the tributary stream within the lower portion of the middle Santa Margarita alluvial basin).

Table 6-37: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the Santa Margarita River at the Up Gradient Edge of the Upper Santa Margarita Alluvial Groundwater Basin

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Range 408	24.7	25.7	33.8	68.8
Range 409A	75.3	74.3	66.2	31.2

Table 6-38 presents the estimated annual average edge-of-loading-area concentrations in surface water runoff from MC loading areas draining within the Santa Margarita watershed. The estimated annual average edge-of-loading-area concentrations in surface water runoff from Range 408 and Range 409A MC loading areas also are presented in **Table 6-27** and **Section 6.3.2**, which discusses surface water screening-level analysis of the Las Flores watershed, where these MC loading areas partially drain. Based on the screening-level calculations, the average annual concentrations of HMX in surface water runoff would be below the REVA trigger value at the edge of all MC loading areas modeled for HMX (**Table 6-38**). The average annual concentration of RDX in runoff was predicted to be above the REVA trigger value at the edge of all three of the MC loading areas modeled for RDX. The average annual concentrations of TNT and perchlorate were predicted to be above REVA trigger values at the edge of two of the four MC loading areas.

Table 6-38: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Santa Margarita Watershed

MC Loading Area	MC Concentration (µg/L)			
	HMX	RDX	TNT	Perchlorate
Kilo Two Combat Town	N/A	N/A	~0	0.005
Range 104B	N/A	**19.1**	**5.61**	**0.102**
Range 408	~0	**0.246**	0.073	**0.026**
Range 409A	0.001	**1.24**	**0.251**	0.020
REVA trigger value for water	0.114	0.110	0.113	0.021

Notes:
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 analyses were conducted to estimate the annual average MC concentrations in surface water entering 1) the Santa Margarita River at the up gradient edge of the upper Santa Margarita alluvial groundwater basin, 2) the tributary stream of the Santa Margarita River at the up gradient edge of the middle Santa Margarita alluvial basin, and 3) the tributary stream of the Santa Margarita River at a point closest to a drinking water well within the middle Santa Margarita alluvial groundwater basin, where the river and streams potentially recharge the groundwater. The estimated drainage areas of these three down gradient receptor locations are presented in **Table 6-39**. The average annual concentrations of all MC in surface water entering the three receptor locations were predicted to be below REVA trigger values.

Table 6-39: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Entering Identified Downstream Receptor Locations within the Santa Margarita Watershed

Surface Water Receptor Location	Drainage Area (acres)	Concentration Entering Receptor Location (µg/L)			
		HMX	RDX	TNT	Perchlorate
Santa Margarita River at the up gradient edge of the upper Santa Margarita alluvial groundwater basin	75,572	~0	0.003	0.001	~0
Unnamed tributary of the Santa Margarita River at the up gradient edge of the middle Santa Margarita alluvial groundwater basin	1,638	~0	~0	~0	~0
Unnamed tributary of the Santa Margarita River in the middle Santa Margarita alluvial groundwater basin at point closest to a drinking water well	1,255	~0	0.004	0.001	~0
REVA trigger value for water		**0.114**	**0.110**	**0.113**	**0.021**

Table 6-40 presents the estimated annual average edge-of-loading-area concentrations in sediment from MC loading areas draining within the Santa Margarita watershed. The estimated annual average edge-of-loading-area concentrations in sediment from Range 408 and Range 409A MC loading areas also are presented in **Table 6-29**. Based on the screening-level calculations, the average annual concentrations of MC in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values.

Table 6-40: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Santa Margarita Watershed

MC Loading Area	MC Concentration (µg/kg)			
	HMX	RDX	TNT	Perchlorate
Kilo Two Combat Town	N/A	N/A	~0	~0

MC Loading Area	MC Concentration (µg/kg)			
	HMX	RDX	TNT	Perchlorate
Range 104B	N/A	0.961	19.1	~0
Range 408	~0	0.008	0.155	~0
Range 409A	~0	0.031	0.428	~0
REVA trigger value for sediment	51	32.5	25	0.18

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 Santa Margarita watershed.

6.4.3. Groundwater Analysis Results

Based on the surface water screening-level analysis discussed above, none of the streams draining to the Santa Margarita alluvial groundwater basins were predicted to reach the Santa Margarita groundwater basins at concentrations above REVA trigger values. Therefore, the groundwater pathway resulting from stream recharge at the upper and the middle Santa Margarita alluvial groundwater basins was eliminated.

The Range 104B MC loading area is located above the middle Santa Margarita alluvial groundwater basin (**Figure 6-8**). In addition to stream recharge within the alluvial groundwater basin, recharge also can occur from the portion of precipitation that falls directly on the Range 104B MC loading area and infiltrates the underlying permeable subsurface material. As a result, the typical REVA Part I procedure was applied to assess the potential for MC at the Range 104B MC loading area to migrate vertically from the ground surface through the vadose zone to groundwater and then horizontally through the groundwater to potential receptors. The methodology applied is discussed in **Section 5.2**.

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the Range 104B MC loading area. In doing this, the estimated MC loading rate for the MC loading area (**Table 6-33**) was divided by a recharge rate of 0.19 ft/yr estimated for MCB Camp Pendleton (Stetson, 2001). **Table 6-41** shows the predicted infiltration MC concentrations at the Range 104B MC loading area. RDX, TNT, and perchlorate were estimated to exceed REVA trigger values at the MC loading area. For this reason, these MC were modeled for migration through the vadose zone.

Table 6-41: Maximum MC Concentrations in Infiltrating Water at the Range 104B MC Loading Area

MC	REVA Trigger Value (µg/L)	Predicted Maximum Infiltration Concentration (µg/L)
HMX	0.114	N/A
RDX	0.110	**189**
TNT	0.113	**122**
Perchlorate	0.021	**0.307**

Notes:
N/A – 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 simulation times ranging from 100 to 2,000 years.

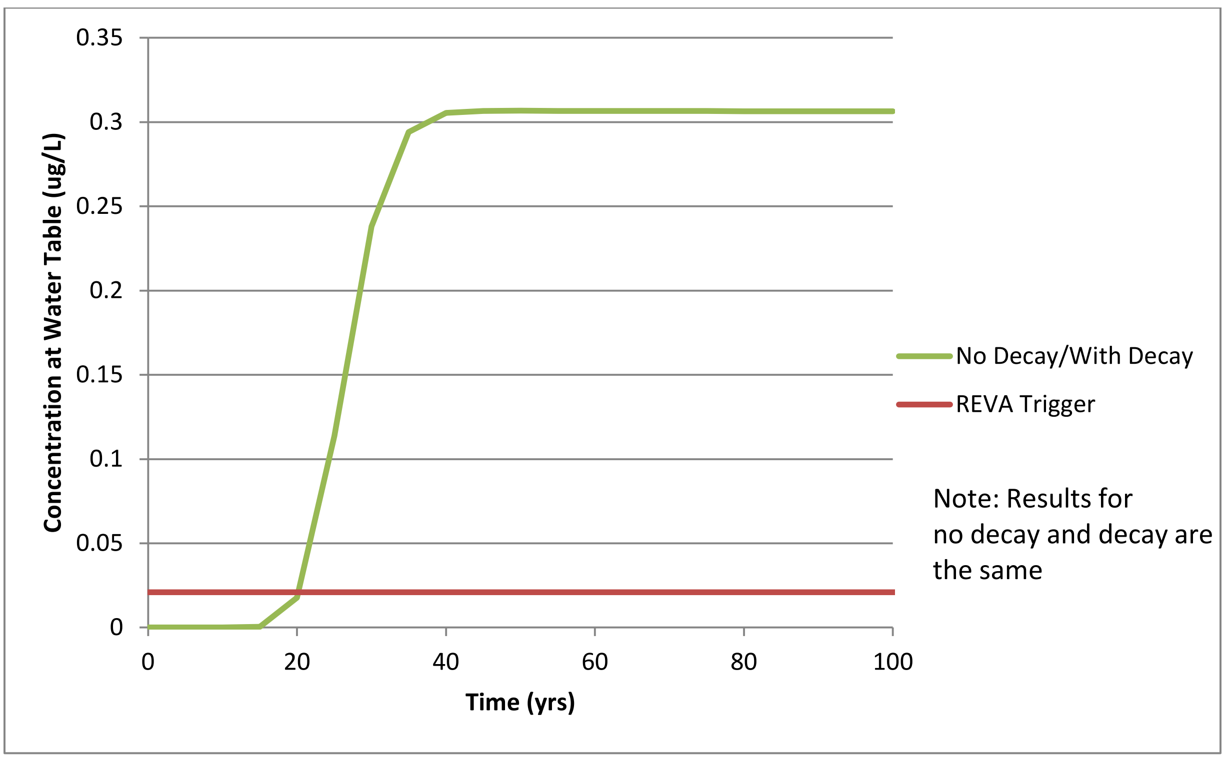
Modeling results with and without decay are presented in **Table 6-42** for comparison. Based on the estimated infiltration rate of 0.19 ft/yr and a depth to groundwater of approximately 21 feet bgs, the minimum travel time for MC to reach the water table at concentrations equal to the respective MC trigger values is 16 years. When decay is included, RDX and TNT are predicted to fully degrade before reaching the water table. The perchlorate concentration is estimated to exceed the REVA trigger value after a travel time of 20 years (**Figure 6-9**). The perchlorate concentration is estimated to reach a steady-state concentration of 0.306 µg/L, which exceeds the REVA trigger value for perchlorate of 0.021 µg/L. As a result, a saturated zone modeling was conducted for perchlorate at the Range 104B MC loading area to estimate the concentration potentially reaching the nearest drinking water well to the MC loading area.

Table 6-42: Estimated MC Concentrations Reaching the Water Table at the Range 104B 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)
RDX	0.110	**187**	16	~0	--
TNT	0.113	**122**	202	~0	--
Perchlorate	0.021	**0.307**	20	**0.306**	20

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

Figure 6-9: VLEACH Vadose Zone Model Perchlorate Results for the Range 104B MC Loading Area



The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through the alluvial aquifer to potential groundwater receptors (installation drinking water wells). The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading area and the nearest receptor location (drinking water well). The model was run for a simulation time of 50 years. The cumulative mass transport (through stream and vadose zone) was considered in estimating the MC concentration reaching the drinking water well closest to the Range 104B MC loading area (as discussed in **Section 5.2.2**).

Table 6-43 shows results of the saturated zone modeling for perchlorate from the Range 104B MC loading area. **Figure 6-8** shows locations of drinking water wells within the Santa Margarita alluvial groundwater basins. Perchlorate was predicted to reach the nearest drinking water well at a concentration above the REVA trigger value. This concentration was predicted to reach the drinking water well within a time period of less than one year.

Table 6-43: MC Concentration Reaching Groundwater Receptors within the Santa Margarita Alluvial Groundwater Basin

Groundwater Basin	Distance to Nearest Drinking Water Well (feet)	Predicted Concentration at Nearest Drinking Water well (µg/L)		
		RDX	TNT	Perchlorate
Santa Margarita[a]	3,694	NP	NP	**0.189**
REVA trigger value (µg/L)		0.110	0.113	0.021

Notes:
NP – not predicted; MC was estimated to be below the REVA trigger value at water table
[a] From Range 104B MC loading area
Shading and bold indicate concentration exceeds the REVA trigger value.

Groundwater sampling for perchlorate in three drinking water wells within the middle Santa Margarita basin has been conducted as part of the five-year revie in August 2012; a subsequent monitoring even was initiated in December 2012. These results are discussed in **Section 8**. The groundwater sampling conducted as part of the REVA baseline assessment did not include any sampling activities in the middle Santa Margarita basin because the baseline REVA assessment did not predict MC to reach drinking water wells in this basin at a concentration above the REVA trigger value. Sampling and analysis for perchlorate was included for this five-year review because perchlorate was predicted to exceed REVA trigger values due to updated assumptions regarding MC loading locations in the Santa Margarita watershed. Based on the groundwater screening-level analysis result, groundwater sampling will be conducted in the drinking water wells closest to the Range 104B MC loading area within the middle Santa Margarita alluvial groundwater basin in future REVA monitoring events conducted at MCB Camp Pendleton.

6.4.4. Summary of Lead in the Santa Margarita Watershed

No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike other MC. Lead is geochemically specific with regards to its mobility in the environment. Site-specific conditions must be known (i.e., geochemical properties) in order to quantitatively assess lead migration. Without site-specific physical and chemical characterization, lead cannot be modeled effectively using fate and transport modeling applied to the other indicator MC in REVA. Therefore, the amount of lead deposited within the MC loading areas within the San Mateo watershed is noted here in order to determine whether additional assessment actions (e.g. monitoring) may be warranted.

Section 6.4.1.1 noted that approximately 2,060 lb of lead were deposited annually across the approximate 282 acres covered by the MC loading areas present in the Santa Margarita watershed. Deposition associated with the Range 409A MC loading area represents the majority of this total, with an annual deposition of approximately 1,810 lb, which is relatively low compared to MC loading areas elsewhere within the installation. Potential receptors of lead deposited at this MC loading area include human points. The Santa Margarita alluvial groundwater basins are down gradient of this MC loading area, though the distance between this MC loading area and the nearest groundwater receptor exposure point is approximately 3.6 miles. The MC loading area is not known to contain habitat for sensitive or protected species.

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7. Small Arms Range Assessments

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. Training areas and ranges that use only small arms ammunition that are .50 cal or smaller are qualitatively assessed. 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) – The 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 prevent a greater or future concern.
- 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 in **Appendix B**, which contains the range-specific assessments of the operational SARs at MCB Camp Pendleton. Where warranted, key range-specific considerations not captured by the SARAP were taken into account during the assessments, and ratings were modified accordingly.

The approximate locations of the SARs are shown in **Figure 7-1.** **Table 7-1** provides the results of the assessment completed for each range. Although a total of 34 SARs were identified at MCB Camp Pendleton, six of these were inactive during this review period and, therefore, were not evaluated. Four rifle ranges (Edson rifle ranges) with similar characteristics and near one another were grouped for their assessment; two multipurpose bays (Range 130 bays 1 and 2) with similar characteristics and adjacent to one another were grouped for their assessment. Consequently, 28 SARs were evaluated for this review through the completion of 24 SARAPs. Thirteen of the SARs were evaluated for this review were not evaluated in the baseline assessment (Edson Rifle A, Edson Rifle C, Edson Rifle D, Range 110, Range 112A, Range 116C, Range 117A, Range 127, Range 210G, Range 216 BZO, Range 223A [200-Yard], Range 303, and Range 501).

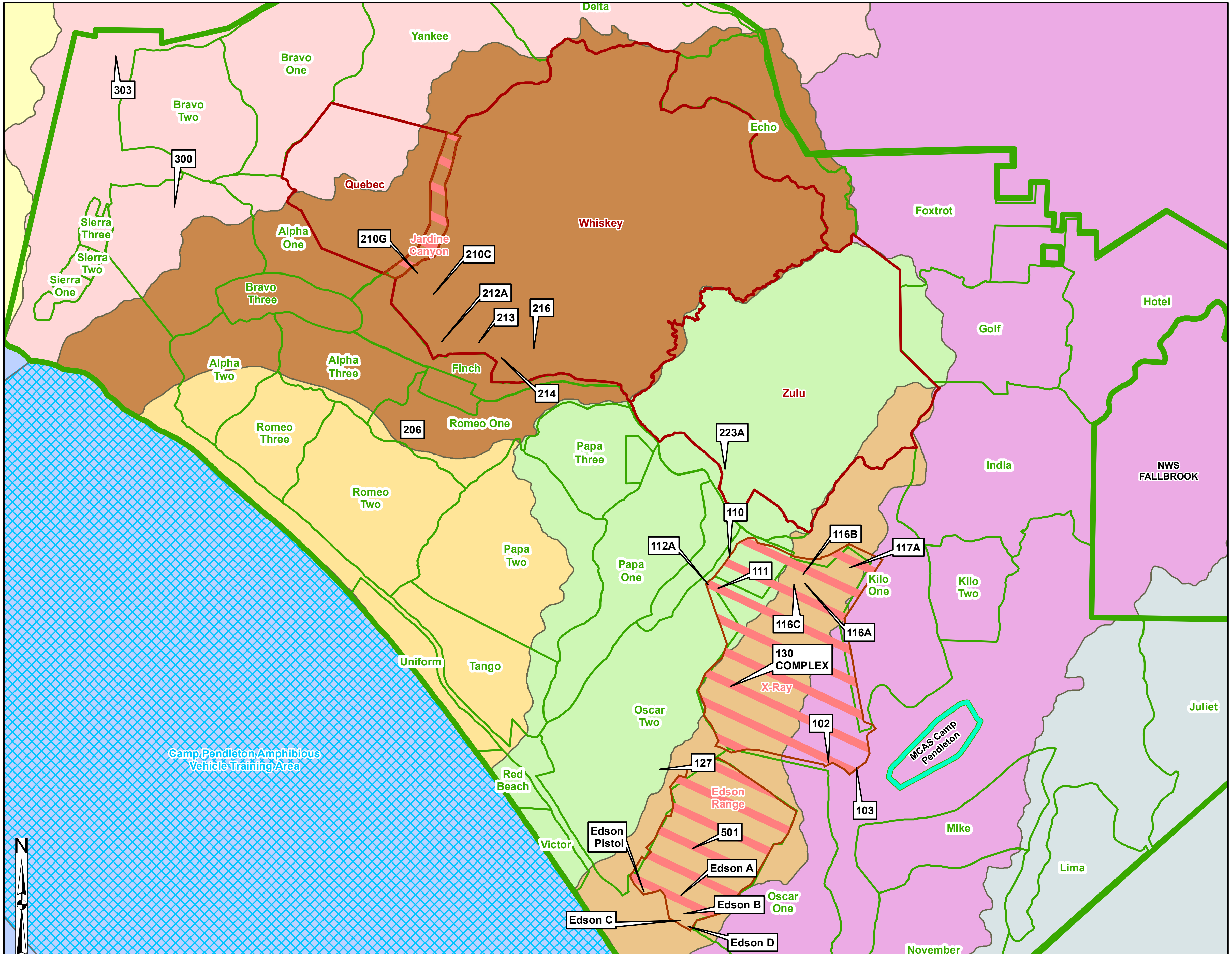

Figure 7-1

Small Arms Ranges Evaluated with SARAP

REVA MCB Camp Pendleton
Oceanside, CA

Legend

- Dud-Producing Impact Area
- Non-Dud Producing Impact Area (Limited Access)
- Training Area, Land
- Training Area, Water
- MCB Camp Pendleton Boundary
- MCAS Camp Pendleton Boundaray
- Aliso Watershed
- Horno/Coastal Watershed
- Las Flores Watershed
- San Luis Rey Watershed
- San Mateo Watershed
- San Onofre Watershed
- Santa Margarita Watershed

0 1 2
Miles

Coordinate System: State Plane
Zone: 0406
Datum: NAD83
Units: Feet

Date: October 2013

Source: MCB Camp Pendleton, 2011c

ARCADIS MALCOLM PIRNIE

Table 7-1: Summary of SAR Prioritizations

Range Name	Range Type	Surface Water Score	Groundwater Score
Edson Pistol Range	KD Pistol Range	Moderate	Minimal[a]
Edson Rifle Complex	KD Rifle Range	Moderate	Minimal[a]
Range 102	KD Pistol Range	Moderate	Moderate
Range 103	KD Rifle Range	Moderate	Moderate
Range 110[b]	Familiarization Range	Moderate	Moderate
Range 111	Transition Rifle BZO/EMP/CMP Range	Moderate	Moderate
Range 112A[b]	BZO/CMP Range	Moderate	Moderate
Range 116A	Navy SEAL KD Rifle Range	Moderate	Minimal
Range 116B	Navy SEAL BZO Range	Moderate	Moderate
Range 116C[b]	Navy SEAL Multi-Target Combat Engagement RETS Range	Moderate	Minimal[a]
Range 117A[b]	KD Sniper Range	Minimal[a]	Minimal[a]
Range 127[b]	Scaled Gunnery Range	Minimal[a]	Moderate
Range 130 Bays	Rifle/Pistol and Sniper Training Ranges	Moderate	Moderate
Range 206	BZO Familiarization Range	Moderate	Minimal[a]
Range 210C	Automatic Rifle Range	Moderate	Minimal
Range 210G[b]	Squad Defense Range	Minimal[a]	Minimal
Range 212A	KD Rifle/Pistol Range	Moderate	Minimal[a]
Range 213	KD Pistol Range	Moderate	Minimal

Range Name	Range Type	Surface Water Score	Groundwater Score
Range 214	KD Rifle Range	Moderate	Minimal[a]
Range 216[b]	SACON House/EMP/Sniper Range	Moderate	Minimal
Range 223A[b]	Shoot House and Turning Target Range	Moderate	Moderate
Range 300	BZO/EMP Range	Moderate	Moderate
Range 303[b]	Pistol BZO Range	Minimal[a]	Minimal
Range 501[b]	Automated Field Firing Range	Moderate	Moderate

Notes:
CMP – Civilian Marksmanship Program
[a] Rating was modified based on consideration of additional range-specific factors.
[b] Indicates a SAR that was not assessed during the baseline assessment.

As discussed in **Section 3.2**, estimation of average annual lead loading at each SAR was based upon approximately 20 months of recent expenditure data. All historical loading was estimated for the 10 SARs that were not evaluated in the baseline assessment.

Following the baseline REVA assessment, soil and surface water sampling were conducted at Range 214 as part of a study to determine potential lead migration from SARs. The results of this sampling are described in **Section 7.2**.

7.2. Small Arms Ranges

SARs are located throughout MCB Camp Pendleton, as seen in **Figure 7-1**. For many of the SARs, the general information used to document soil characteristics, groundwater characteristics, fate and transport pathways, potential receptors, and T/E species is the same. Information applicable across the installation is further detailed in **Section 4.3**. Site-specific information, if available, was used to complete the SARAPs for each SAR and is provided in **Appendix B**.

7.2.1. Edson Pistol Range

7.2.1.1. Site Background

Edson Pistol Range is a KD pistol range located in the southwest portion of the Edson Range Impact Area. It is used to train in pistol firing at targets at a known distance and as a pistol qualification range. The range is equipped with 54 firing points, pneumatically powered target frames, an earthen berm with an approximate 2:1 slope, and firing lines marked at 7, 15, and 25 yards. It has been operational since 1990 and, during the five-year review period, had a lead loading rate of approximately 3,255 lb/yr based on the available expenditure data.

7.2.1.2. Assessment Results

The evaluation of Edson Pistol Range resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Edson Pistol Range was evaluated in the baseline assessment, which resulted in a minimal ranking for surface water and a moderate ranking for groundwater. The surface water ranking was increased from minimal to moderate based upon review of recent Environmental Security GIS Department files depicting the locations of designated riparian habitat area near the range (MCB Camp Pendleton, 2011c). According to the INRMP produced by MCB Camp Pendleton, these habitats may support special status species, such as the threatened California gnatcatcher and the endangered arroyo toad (MCB Camp Pendleton, 2007a). The groundwater ranking was decreased from moderate to minimal due to the lack of potential groundwater receptors. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.2. Edson Rifle Complex

7.2.2.1. Site Background

Edson Rifle Complex is made up of four adjacent ranges (Edson Rifle Ranges A–D) located in the Edson Range Impact Area and is the most heavily used facility at MCB Camp Pendleton. It is used to train in rifle firing at targets at a known distance and alternately is used as a rifle familiarization and qualification range. Small arms munitions and pyrotechnic munitions are permitted to be fired at these ranges. Edson A and B are equipped with 50 firing points each, an earthen berm with an approximate 3:1 slope, and firing lines at 25, 50, 100, 200, 300, and 500 yards. Edson C and D have similar firing point and earthen berm characteristics, with firing lines at 25, 50, 100, 200, 300, 500, and 600 yards. These ranges have been operational since 1990; during the five-year review period, they had a total combined lead loading rate of approximately 42,812 lb/yr based on the available expenditure data.

7.2.2.2. Assessment Results

The evaluation of the grouped rifle ranges of the Edson Rifle Complex resulted in a moderate ranking potential for surface water and a minimal ranking for groundwater. Edson Rifle Complex was assessed in the baseline assessment, which resulted in a minimal-moderate ranking for surface water and a moderate ranking for groundwater. The slight increase in ranking for the surface water was based upon the presence of designated riparian habitat area near the complex (MCB Camp Pendleton, 2011c). These habitats may support special status species, such as the threatened California gnatcatcher and the endangered arroyo toad. The groundwater ranking was decreased from moderate to minimal due to the lack of potential groundwater receptors. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.3. Range 102

7.2.3.1. Site Background

Range 102, also known as the Wilcox Pistol Range, is a KD pistol range located in the southeast portion of the X-Ray Impact Area. It is used to train in pistol firing at targets at a known distance and has been operational since 1961. The range is equipped with 90 firing points, an earthen berm with an approximate 2:1 slope, pneumatically powered target frames, and firing line markers at 10, 15, 25, and 50 yards. Permitted munitions on this range include small arms munitions. During the five-year review period, Range 102 had a lead loading rate of approximately 15,389 lb/yr based on the available expenditure data.

7.2.3.2. Assessment Results

The evaluation of Range 102 resulted in a moderate ranking for both surface water and groundwater. Range 102 was evaluated in the baseline assessment, which resulted in a ranking of minimal to moderate for surface water and moderate for groundwater. The slight increase in ranking for the surface water was due to the considerable lead loading occurring at Range 102, as well as the identification of sensitive species downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The moderate ranking for groundwater remained the same. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.4. Range 103

7.2.4.1. Site Background

Range 103, also known as the Wilcox Rifle Range, is a KD rifle range located in the southeast portion of the X-Ray Impact Area. It is used for rifle training at known target distances and has been operational since 1942. The range is equipped with 146 firing points, an earthen berm with an approximate 2:1 slope, and firing lines at 3, 25, 100, 200, 300, 500, and 600 yards. Small arms munitions and pyrotechnic munitions are permitted to be fired at this range. During the five-year review period, Range 103 had a lead loading rate of approximately 25,048 lb/yr based on the available expenditure data.

7.2.4.2. Assessment Results

Range 103 was determined to have a moderate ranking for both surface water and groundwater. Range 103 was evaluated in the baseline assessment, which resulted in a minimal to moderate ranking for surface water and a moderate ranking for groundwater. The slight increase in ranking for the surface water was due to heavy lead loading occurring at Range 103, as well as the identification of sensitive species have been identified downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The moderate ranking for groundwater remained the same. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.5. Range 110

7.2.5.1. Site Background

Range 110 is a familiarization and field firing range located in the northern portion of the Oscar Two Training Area. It has been operational as a rifle range since 1951; a separate portion of the range accommodated 40 mm HE use until 2009. Range 110 was not evaluated as a SAR during the baseline assessment due to the use of HE rounds. Currently, use of this range is primarily small arms. It contains firing lines from 3 to 100 yards and permits the use of small arms munitions and practice rifle grenade munitions. R-110 is not equipped with an earthen berm, as all the rounds fired at the range are deposited into a hillside immediately behind the target line. During the five-year review period, Range 110 had a lead loading rate of approximately 2,774 lb/yr based on the available expenditure data.

7.2.5.2. Assessment Results

This range was determined to have a moderate ranking for both surface water and groundwater. The moderate ranking for surface water was based on the combination of the considerable lead loading and sensitive species identified downstream of the range as noted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The moderate ranking for groundwater also was based on the considerable lead loading as well as the presence of installation-operated drinking water wells within the same watershed. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.6. Range 111

7.2.6.1. Site Background

Range 111 is a transition rifle and BZO firing range that also is used for the EMP and CMP. It is located in the northwestern portion of the X-Ray Impact Area and has been operational since 1961. The firing distances at Range 111 are between 3 and 350 meters, and it is equipped with a 33-yard (25-meter) BZO firing line and an earthen berm. Permitted munitions on Range 111 include small arms munitions and target practice rifle grenade munitions, as well as non-lethal hand grenades (pepperball and stun grenade). During the five-year review period, Range 111 had a lead loading rate of approximately 6,606 lb/yr based on the available expenditure data.

7.2.6.2. Assessment Results

Range 111 was determined to have a moderate ranking for both surface water and groundwater. It was evaluated in the baseline assessment, which resulted in a moderate ranking for surface water and a moderate to high ranking for groundwater. The moderate ranking for the surface water remained the same for Range 111 during the five-year review. The slight decrease in ranking for the groundwater since the baseline assessment primarily was due to re-evaluation of the proximity of Range 111 to an alluvial basin, which is used as a source of drinking water. The nearest groundwater production well is approximately 3.1 miles southwest in the Las Flores alluvial basin (MCB Camp Pendleton, 2011b). Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.7. Range 112A

7.2.7.1. Site Background

Range 112A is a BZO firing range that also is utilized for the CMP and is located in the northern portion of the Oscar Two Training Area. It has been operational since 1998 and is equipped with 12 firing points, an earthen berm, multiple cover positions along the perimeter, and firing lines marked by signs and concrete at 3, 7, 15, 25, 50, and 100 yards. The range floor is covered with gravel, except for the firing lines that are concrete. SONGS security forces are among the most frequent users of Range 112A. Permitted munitions at Range 112A include small arms munitions. During the five-year review period, Range 112A had a lead loading rate of approximately 2,351 lb/yr based on the available expenditure data.

7.2.7.2. Assessment Results

The Range 112A SARAP evaluation resulted in a moderate ranking for both surface water and groundwater. The moderate ranking for the surface water was based upon the considerable lead loading occurring at Range 112A and the identification of sensitive species downstream of the range based on recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). In addition to the considerable lead loading, the moderate ranking for the groundwater was based on the presence of installation-operated drinking water wells within the same watershed. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.8. Range 116A

7.2.8.1. Site Background

Range 116A is located in the northeastern portion of the X-Ray Impact Area and has been operational since 1997. Primarily, U.S. Navy SEALs and other members of Naval Special Warfare use it as a KD rifle range. The range is equipped with 72 firing points, an earthen berm with an approximate 1.5:1 slope, and firing line markers at 100, 200, 300, 500, 600, 700, and 800 yards. Permitted munitions at Range 116A include small arms munitions and pyrotechnic cartridges. During the five-year review period, Range 116A had a lead loading rate of approximately 1,918 lb/yr based on the available expenditure data.

7.2.8.2. Assessment Results

The Range 116A SARAP evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Range 116A was evaluated in the baseline assessment, which resulted in a minimal ranking for both surface water and groundwater. The moderate ranking for the surface water was based upon the considerable amount of lead loading along with the identification of sensitive species habitats on the range based on recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). While there is a high rate of lead loading at this range, the low precipitation and neutral pH of the groundwater reduce the potential for lead migration into and through groundwater. Additionally, there is a lack of potential groundwater receptors near this range. Considering these factors, the groundwater ranking for this range was determined to be minimal. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.9. Range 116B

7.2.9.1. Site Background

Range 116B is located in the northeastern portion of the X-Ray Impact Area and has been operational since 1997. Primarily, U.S. Navy SEALs and other members of Naval Special Warfare use it as a BZO firing and EMP range. The range is equipped with 30 firing points, pneumatically powered target systems, an earthen berm with an approximate 1.5:1 slope, and firing lines marked at 3, 7, 15, 25, and 50 yards. Permitted munitions at Range 116B include small arms munitions. During the five-year review period, Range 116B had a lead loading rate of approximately 4,520 lb/yr based on the available expenditure data.

7.2.9.2. Assessment Results

The Range 116B SARAP evaluation resulted in a moderate ranking for both surface water and groundwater. Range 116B was assessed in the baseline assessment, which concluded that there was a minimal ranking for surface water and a minimal to moderate ranking for groundwater. The increase in ranking for surface water was due primarily to the combination of the high lead loading occurring at Range 116B and the sensitive species habitat identified adjacent to the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The slight increase in ranking for groundwater was based on the lead loading amounts as well as pH data suggesting that there is low to moderate potential for lead dissolution. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.10. Range 116C

7.2.10.1. Site Background

Range 116C is located in the northeastern portion of the X-Ray Impact Area and has been operational since 1998. Primarily, U.S. Navy SEALs and other members of Naval Special Warfare use it as a multi-target combat engagement RETS range. The targets at this range are oriented in an arc of 270 degrees from distances between 10 and 25 meters and are designed to pop up and move. There are 30 stationary targets and three moving infantry targets for various training scenarios. Range 116C is not equipped with a berm; however, small arms munitions used at this range typically impact into surrounding hillsides set back from the range. Permitted munitions at Range 116C include small arms munitions. During the five-year review period, Range 116C had a lead loading rate of approximately 191 lb/yr based on the available expenditure data.

7.2.10.2. Assessment Results

The Range 116C SARAP evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. The moderate ranking for surface water was based on the presence of sensitive species downstream of the range as well as the lack of containment of small arms munitions due to the absence of a berm. Upon initial evaluation, the ranking for groundwater was scored as moderate. Based on range specific factors, including moderate lead loading, the lack of potential groundwater receptors, and the pH levels in the groundwater that are not conducive to lead migration, the groundwater ranking for Range 116C was adjusted to minimal. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.11. Range 117A

7.2.11.1. Site Background

Range 117A is located in the northeastern portion of the X-Ray Impact Area and has been operational since 1993. The Marine Scout Sniper School primarily uses it as a sniper field fire range. The range supports both KD and unknown-distance firing from a maximum distance of 1,400 meters and a minimum distance of 100 meters as well as nontraditional training scenarios developed by the sniper school (MCB Camp Pendleton, 2008). Range 117A also is equipped with several structures containing targets at various distances downrange as well as an earthen berm. Permitted munitions at Range 117A include small arms munitions. During the five-year review period, Range 117A had a lead loading rate of approximately 170 lb/yr based on the available expenditure data.

7.2.11.2. Assessment Results

The Range 117A SARAP evaluation resulted in a minimal ranking for both surface water and groundwater. The initial evaluation of this range resulted in both the surface water and groundwater rankings scoring as moderate. However, based on range-specific factors, both rankings were adjusted to minimal. The adjustment to the surface water ranking was due primarily to the low lead loading, which has been occurring over a relatively short period of time. Additionally, precipitation is low, and opportunities for surface water transport are very limited. Low lead loading and low precipitation also contributed to the adjustment of the groundwater ranking. Additionally, the anticipated neutral pH of the groundwater in the area reduces the potential for lead migration into and through groundwater. Further details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.12. Range 127

7.2.12.1. Site Background

Range 127 is located in the eastern portion of Oscar Two Training Area and has been operational since 1981. It is categorized as a scaled gunnery range, which is designed to meet training requirements of armor crews. Only small arms munitions are permitted to be fired at this range. The range is designed with undetermined firing positions and an earthen berm; the maximum firing distance on the range is 25 meters. During the five-year review period, Range 127 had a lead loading rate of approximately 2 lb/yr based on the available expenditure data.

7.2.12.2. Assessment Results

The evaluation of Range 127 using the SARAP resulted in a minimal ranking for surface water and a moderate ranking for groundwater. The initial evaluation of this range resulted in a moderate surface water ranking. This ranking was reduced to minimal based on range-specific factors, including minimal lead loading and low precipitation. Similarly, initial evaluation during the five-year assessment scored the groundwater ranking as moderate. Due to the minimal lead loading occurring at the range, professional judgment was used to adjust the ranking from moderate to minimal. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.13. Range 130 Complex (Bays 1 and 2)

7.2.13.1. Site Background

The Range 130 complex contains two adjacent SARs (Bay 1 and Bay 2) located in the southwestern portion of the X-Ray Impact Area. Range 130 Bay 1 is a BZO firing range that has been operational since 1993. It is equipped with 30 firing points, overhead covering for a portion of the range, an earthen berm with an approximate 2.5:1 slope, and firing lines marked at 3, 5, 7, 10, 15, 25, and 50 yards. Permitted munitions on Range 130 Bay 1 include small arms munitions. Range 130 Bay 2 is also a BZO firing range that has been operational since 1993. It is equipped with 50 firing points, an earthen berm with an approximate 2:1 slope, and firing lines marked at 3, 7, 10, 15, 25, and 50 yards. Permitted munitions on Range 130 Bay 2 are identical to those permitted in Bay 1. Earthen side berms separate the two bays and are moderately vegetated. During the five-year review period, Range 130 (Bays 1 and 2) had a combined lead loading rate of approximately 2,383 lb/yr based on the available expenditure data.

7.2.13.2. Assessment Results

The Range 130 Complex (Bays 1 and 2) SARAP evaluation resulted in a moderate ranking for both surface water and groundwater. Range 130 Bay 1 and Bay 2 were assessed together in the baseline assessment, which resulted in a minimal ranking for surface water and a minimal to moderate ranking for groundwater for both bays. The surface water ranking was increased to moderate due the combination of the high lead loading at Bays 1 and 2 and the identification of sensitive species downstream of the ranges, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The moderate ranking for groundwater is due primarily to the high lead loading at the complex. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.14. Range 206

7.2.14.1. Site Background

Range 206 is located in the northern portion of the Romeo One Training Area. It is utilized as a BZO firing range and has been operational since 1968. This range is equipped with a maximum distance firing line marked at 25 meters and an earthen berm with an approximate 1.5:1 slope. A rocky cliff wall beyond the berm was observed to have substantial bullet impact damage on the surface. Permitted munitions on Range 206 include small arms munitions as well as non-lethal grenades. During the five-year review period, Range 206 had a lead loading rate of approximately 1,783 lb/yr based on the available expenditure data.

7.2.14.2. Assessment Results

The Range 206 SARAP evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Range 206 was assessed in the baseline assessment, which resulted in a minimal to moderate ranking for surface water and a moderate to high ranking for groundwater. The slight increase in the surface water ranking since the baseline assessment primarily is due to the increased lead loading occurring at the range since the baseline assessment. Based on the SARAP, the initial ranking for groundwater was moderate. This ranking was reduced to minimal based on several range-specific factors, including the lack of groundwater receptors, low precipitation, and neutral groundwater pH. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.15. Range 210C

7.2.15.1. Site Background

Range 210C is located in the southwestern portion of the Whiskey Impact Area. It is utilized as an automatic rifle range and has been operational since 1971. The range is designed for training target engagement techniques with rifles and the M-249 squad automatic weapon. The range is equipped with an earthen backstop berm that was built into a hillside. The range allows for a minimum firing distance of 5 yards and a maximum firing distance of 50 yards. Permitted munitions on Range 210C include small arms munitions and mines. During the five-year review period, Range 206 had a lead loading rate of approximately 3,219 lb/yr based on the expenditure data provided by MCB Camp Pendleton.

7.2.15.2. Assessment Results

The SARAP evaluation of Range 210C resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Range 210C was evaluated in the baseline assessment, which resulted in a moderate ranking for both surface water and groundwater. The moderate ranking for the surface water at Range 210C is due to the high lead loading rate and the identification of sensitive species downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The decrease in the groundwater ranking since the baseline assessment from moderate to minimal is due to the lack of potential groundwater receptors near the range. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.16. Range 210G

7.2.16.1. Site Background

Range 210G is located in the southwestern portion of the Whiskey Impact Area. It is utilized as a squad defense range and has been operational since 1998. All the targets at this range are fully automated, and the event-specific target scenario is computer-driven and scored from the range operations center (MCB Camp Pendleton, 2008). Range 210G is equipped with 16 firing points that are composed of four firing positions: prone, window, rooftop, and around simulated walls. It also is equipped with 168 stationary infantry targets and 16 moving infantry targets. Permitted munitions on the range include small arms munitions and pyrotechnic cartridges. Range 210G is not used regularly due to its orientation, which conflicts with operations at surrounding ranges. No use of the range was noted in the expenditure data provided for 2010 or 2011. Due to the lack of information and the limited range use, a low loading rate is assumed.

7.2.16.2. Assessment Results

The Range 210G SARAP evaluation resulted in a minimal ranking for both surface water and groundwater. The initial surface water ranking from Range 210G was moderate. Based on range-specific factors, including a low lead loading rate, low precipitation, and the neutral pH of the surface water, which reduces the potential for lead migration, the moderate ranking for surface water was reduced to minimal. The minimal groundwater ranking also was due primarily to the low lead loading and low precipitation levels. As with the surface water, the neutral pH of the groundwater reduces the potential for lead migration into or through the groundwater. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.17. Range 212A

7.2.17.1. Site Background

Range 212A is located just inside the southwestern portion of the Whiskey Impact Area and has been operational since 1971. It is utilized as BZO firing range, as well as a non-lethal familiarization firing range. The range is equipped with 30 firing positions, an earthen berm with an approximate 1.5:1 slope ratio, and firing lines marked at 7, 10, 15, 25, and 36 yards. Targets at Range 212A are placed in front of the impact berm. Permitted munitions on the range include small arms munitions. During the five-year review period, Range 212A had a lead loading rate of approximately 2,772 lb/yr based on the available expenditure data.

7.2.17.2. Assessment Results

The Range 212A evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Range 212A was assessed in the baseline assessment, which resulted in a minimal to moderate ranking for surface water and a moderate to high ranking for groundwater. The moderate ranking for surface water was primarily due to high lead loading and the identification of sensitive species directly adjacent to the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). Based on the SARAP, the initial groundwater ranking was moderate. The ranking was reduced to minimal based on range-specific factors, including low precipitation, neutral groundwater pH, and lack of potential groundwater receptors near the range. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.18. Range 213

7.2.18.1. Site Background

Range 213, also known as the Horno Pistol Range, is located just inside the southwestern portion of the Whiskey Impact Area and has been operational since 1968. It is utilized as a KD pistol range for pistol qualification and familiarization firing. The range is equipped with 24 firing positions, pneumatically powered targets, an earthen berm with an approximate 2:1 slope, and firing lines marked at 7, 15, and 25 yards. Permitted munitions at Range 213 include small arms munitions. During the five-year review period, Range 213 had a lead loading rate of approximately 8,819 lb/yr based on the expenditure data provided by MCB Camp Pendleton.

7.2.18.2. Assessment Results

The Range 213 evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Range 213 was assessed in the baseline assessment, which resulted in a minimal to moderate ranking for surface water and a moderate to high ranking for groundwater. The moderate ranking for surface water was due primarily to the significant lead loading and the identification of rare plant species downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The ranking for groundwater decreased since the baseline assessment primarily due to lack of potential groundwater receptors near the range, low precipitation, and the anticipated neutral pH of the groundwater. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.19. Range 214

7.2.19.1. Site Background

Range 214, also known as the Horno Rifle Range, is located just inside the southwestern portion of the Whiskey Impact Area. It is utilized as a KD rifle range and has been operational since 1961. The range is equipped with 73 firing positions, an earthen berm with an approximate 2:1 slope, and firing lines marked at 100, 200, 300, and 500 yard firing lines. Permitted munitions at Range 214 include small arms munitions and pyrotechnic cartridges. During the five-year review period, Range 214 had a lead loading rate of approximately 14,246 lb/yr based on the available expenditure data.

Soil and surface water sampling at Range 214 occurred following the baseline REVA assessment (ARCADIS/Malcolm Pirnie, 2011a). A total of seven soil samples were collected in July 2010; five first-flush surface water samples were collected in October 2010, and four surface water samples were collected in February 2011. Sampling locations primarily were selected to examine metal (i.e., lead and copper) concentrations in unlined drainage pathways on and around the range; all locations were up gradient of the southern fork of the San Onofre Creek.

The highest soil concentrations of lead and copper were observed immediately down gradient of the impact berm (19,000 and 98,000 milligrams per kilogram [mg/kg], respectively). Lead and copper in soil decreased dramatically farther down gradient of the range, with concentrations of 20 mg/kg and 12 mg/kg, respectively, at the farthest down gradient sample location approximately 120 m west of the rear firing line. These down gradient concentrations were below applicable USEPA Region 9 screening levels as well as California Human Health Screening Levels.

Surface water samples collected in October 2010 also reflected a similar pattern, with maximum concentrations of lead (3,700 μg/L total and 910 μg/L dissolved) and copper (630 μg/L total and 210 μg/L dissolved) immediately down gradient of the impact berm. However, concentrations decreased farther down gradient: at the farthest down gradient location (approximately 120 m west of the rear firing line), estimated concentrations of lead were 2,500 μg/L total and 680 μg/L dissolved, while estimated concentrations of copper were 480 μg/L and 200 μg/L dissolved. The sampling network was expanded, and the four most down gradient locations were resampled in February 2011. The highest concentrations were found at a sampling location along the west side of the range, with lead concentrations of 29 μg/L total and 23 μg/L dissolved and copper concentrations of 25 μg/L total and 29 μg/L dissolved. At the farthest down gradient location (approximately 620 m southwest of the rear firing line), lead concentrations dropped to 6.8 μg/L total and an estimated 1.1 µg/L dissolved, while copper concentrations dropped to 16 µg/L total and 13 µg/L dissolved. These down gradient concentrations were below applicable DoD screening values of copper and lead (24.2 µg/L and 8.7 µg/L, respectively).

7.2.19.2. Assessment Results

The Range 214 evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. Range 214 was assessed in the baseline assessment, which resulted in a minimal ranking for surface water and a moderate to high ranking for groundwater. The increase in ranking for the surface water since the baseline assessment may be attributed to the identification of rare plant species downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). Based on the SARAP, the initial ranking for groundwater from Range 214 was scored as moderate. However, despite the considerable lead loading, the groundwater ranking was reduced to a minimal ranking based on the low precipitation, the anticipated neutral pH of the groundwater, and the lack of groundwater receptors nearby. There are also no groundwater production wells near Range 214, and the nearest alluvial basin is the San Onofre alluvial basin, located approximately 4.5 miles away (MCB Camp Pendleton, 2011b). The sampling results confirmed the SARAP evaluation: metals associated with SAR use were detected within the soil and surface water on and immediately adjacent to the range; however concentrations decreased rapidly to below the applicable standards at sampling locations farther down gradient of the range. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.20. Range 216 BZO

7.2.20.1. Site Background

Range 216 BZO is located just inside the southern boundary of the Whiskey Impact Area and has been operational since 1952. In addition to the BZO range, Range 216 also is equipped with a SACON house, which is used by Marines to hone their skills in entering and clearing rooms. The only range being evaluated under the SARAP is the BZO range. This is a 50-yard range equipped with an earthen berm cut from the surrounding hillside with an approximate slope of 2:1. There is also an unlined depressed channel between the berm and the target line, which drains toward a vegetated area adjacent to the range. Permitted munitions at Range 216 BZO include small arms munitions. During the five-year review period, Range 216 BZO had a lead loading rate of approximately 409 lb/yr based on the available expenditure data.

7.2.20.2. Assessment Results

The Range 216 BZO evaluation resulted in a moderate ranking for surface water and a minimal ranking for groundwater. The moderate ranking for surface water was due to the moderate lead loading at the range and the sensitive plant species that have been identified downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp

Pendleton, 2011c). The minimal ranking for the groundwater primarily was due to the lack of potential groundwater receptors near the range. There are no groundwater production wells near Range 216 BZO, and the nearest alluvial basin is the San Onofre alluvial basin located approximately 4.5 miles away (MCB Camp Pendleton, 2011b). Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.21. Range 223 (200-Yard)

7.2.21.1. Site Background

Range 223 (200-Yard) is part of Range 223A, which is located just within the southwestern boundary of the Zulu Impact Area and has been operational since the 1960s. Range 223A is equipped with a shoot house, turning target range, and the 200-yard range, which is utilized as a BZO range. The 200-yard BZO range is the only range being evaluated using the SARAP. It is equipped with an earthen berm and firing lines ranging from 1 yard to 200 yards. During the five-year review period, Range 223 (200-Yard) had a lead loading rate of approximately 2,694 lb/yr based on the available expenditure data.

7.2.21.2. Assessment Results

The Range 223 (200-Yard) evaluation resulted in a moderate ranking for both surface water and groundwater. The moderate ranking for surface water was due to the high rate of lead loading and the identification of sensitive species downstream of the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The moderate ranking for groundwater was based primarily on the high rate of lead loading despite the low precipitation and anticipated neutral groundwater pH. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.22. Range 300

7.2.22.1. Site Background

Range 300 is located in the northern portion of the Bravo Three Training Area and has been operational since 1968. It is designated as a BZO range that also is used for familiarization firing. It is equipped with an earthen berm with an approximate 2:1 slope cut from the adjacent hillside and firing lines marked at 7, 10, 15, 25, and 36 yards. Permitted munitions on Range 300 include small arms munitions. During the five-year review period, Range 300 had a lead loading rate of approximately 2,448 lb/yr based on the available expenditure data.

7.2.22.2. Assessment Results

The Range 300 evaluation resulted in a moderate ranking for both surface water and groundwater. Range 300 was assessed in the baseline assessment, which resulted in a moderate ranking for surface water and a moderate to high ranking for groundwater. The surface water ranking remained the same since the baseline due to significant lead loading and the potential presence of multiple sensitive species within the riparian habitat directly adjacent to the range (MCB Camp Pendleton, 2011c). The groundwater ranking at Range 300 slightly decreased from moderate to high to only moderate because of the anticipated neutral groundwater pH in the area. It was not reduced further than moderate because of the considerable lead loading occurring and the presence of an alluvial basin used as a source of drinking water situated within 1 mile of the range. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.23. Range 303

7.2.23.1. Site Background

Range 303 is located northwest of the Bravo Two Training Area and has been operational since 2009. It is designated as a pistol BZO range and is operated by the Navy. It is equipped with an earthen impact berm with an approximate 3:1 slope, approximately 15 firing positions, and available firing distances from 7 to 50 meters. It also contains a lined drainage system, which directs runoff from the berm to an old culvert adjacent to the north side of the range. Permitted munitions on Range 303 include small arms munitions. During the five-year review period, Range 303 had a lead loading rate of approximately 301 lb/yr based on the expenditure data provided by MCB Camp Pendleton.

7.2.23.2. Assessment Results

The Range 303 evaluation resulted in a minimal ranking for both surface water and groundwater. The initial ranking for the surface water was moderate. It was reduced to minimal based on the following range-specific factors: a short period of operation with only moderate lead loading, low precipitation, and the anticipated neutral pH of the surface water. The minimal groundwater ranking at Range 303 also primarily was due to the previously noted short operational history with moderate lead loading and the low precipitation levels. An additional factor contributing to the minimal groundwater ranking was the anticipated neutral pH of the groundwater. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.2.24. Range 501

7.2.24.1. Site Background

Range 501 is located in the center of the Edson Impact Area and has been operational since 1961. It is designated as an automated field firing range and is used to train Marines to identify, engage, and hit stationary targets. Range 501 is equipped with fully automated target systems and 16 firing points that are divided into three different types of shooting positions. Permitted munitions at Range 501 include small arms munitions and pyrotechnic cartridges. During the five-year review period, Range 501 had a lead loading rate of approximately 1,786 lb/yr based on the expenditure data provided by MCB Camp Pendleton.

7.2.24.2. Assessment Results

The Range 501 evaluation resulted in a moderate ranking for both surface water and groundwater. The moderate ranking for surface water primarily was due to the considerable amount of lead loading occurring on the range, in addition to the identification of sensitive species on the range, as depicted in recent Environmental Security GIS Department files (MCB Camp Pendleton, 2011c). The moderate groundwater ranking primarily was based on the considerable lead loading as well as the shallow groundwater. Additional details regarding the rankings can be found in the SARAP tables in **Appendix B**.

7.3. Small Arms Range Assessment Protocol Surface Water Assessments

The surface water assessment is the sum of three component scores in the SARAP: range use and range management, surface water pathways, and surface water receptors. Of the 24 surface water assessments completed, none were ranked as high, 20 were ranked as moderate, and 4 were ranked as minimal. SARAPs are provided in **Appendix B**.

7.3.1. Small Arms Ranges with Moderate Surface Water Ranking

SARs designated as having a moderate ranking are those in which the components in the surface water evaluation totaled 30–49 points. **Table 7-2** lists those ranges receiving this rating with a summary of the scores.

Table 7-2: Scores for SARs with Moderate Concern for Surface Water Receptors

Range Name	Annual Lead Use (lb)	Range Use/ Range Management	Surface Water Pathways	Surface Water Receptors	Total Score
Edson Pistol Range	3,255	13	10	13	**36**
Edson Rifle Complex	42,812	13	10–12	13	**36-38**
Range 102	15,389	15	13–15	13	**41–43**
Range 103	25,048	15	8	13	**36**
Range 110	2,774	15	13	13	**41**
Range 111	6,606	15	8–10	13	**36–38**
Range 112A	2,351	13	15	13	**41**

Range Name	Annual Lead Use (lb)	Range Use/ Range Management	Surface Water Pathways	Surface Water Receptors	Total Score
Range 116A	1,918	15	12	13	**40**
Range 116B	4,520	15	17	13	**45**
Range 116C	191	11	15–17	13	**39–41**
Range 130 Complex	2,383	13	15	8	**36**
Range 206	1,783	15	15	8	**38**
Range 210C	3,219	15	12	13	**40**
Range 212A	2,772	15	13–15	8	**36–38**
Range 213	8,819	15	10–12	8	**33–35**
Range 214	14,246	15	8	8	**31**
Range 216 BZO	409	13	11–13	8	**32–34**
Range 223A	2,695	15	13–15	8	**36–38**
Range 300	2,448	15	17	13	**45**
Range 501	1,786	15	11–13	13	**39–41**

Several ranges with moderate surface water rankings received the maximum range use / range management score of 15 due to considerable and prolonged use, lack of bullet capture technology, and infrequent range maintenance. All but two of the ranges with a moderate surface water ranking receive more than 1,000 lb/yr of lead. Most of the ranges have been operational for more than 30 years, and all have been without bullet capture technology (other than earthen impact berms) during their periods of operation.

All of the ranges with moderate surface water rankings received similar scores regarding surface water pathways. The pH values of surface water for off-range areas at MCB Camp Pendleton are estimated to range from 6.24 to 8.07, based on sampling conducted at the installation (Malcolm Pirnie, 2009). In general, moderate scores were given for pH due to the potential for pH to drop below 6.5. Precipitation levels at MCB Camp Pendleton are low, with an average of 11.3 in/yr from 2006 to 2011 (MCB Camp Pendleton, 2011a). This, in conjunction with the relatively minimal vegetation coverage due to the low precipitation and frequent brush fires, contributed most significantly to the moderate scores associated with the surface water pathways.

Many of the ranges with moderate surface water rankings scored higher for the surface water receptor component due to nearby riparian and T/E or protected species. Such species at MCB Camp Pendleton included the arroyo toad, California least tern, coastal California gnatcatcher, Stephens' kangaroo rat, and the thread-leaved brodiaea. Ranges with or near sensitive habitat or species include the Edson Pistol Range, Edson Rifle Complex, Range 102, Range 103, Range 116A, Range 116B, Range 116C, Range 210C, Range 300, and Range 501.

7.3.2. Small Arms Ranges with Minimal Surface Water Concern

SARs designated as having a minimal ranking are those in which the components in the surface water evaluation totaled 0–29 points. **Table 7-3** lists the four ranges receiving this rating with a summary of the scores.

Table 7-3: Scores for SARs with Minimal Concern for Surface Water Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Surface Water Pathways	Surface Water Receptors	Total Score
Range 117A	170	11	11–13	8	**30–32**[a]
Range 127	2	11	8–10	13	**32–34**[a]
Range 210G	--	9	8	13	**30**[a]
Range 303	301	9	8	13	**30**[a]

[a] Site-specific factors were used to decrease the concern from moderate to minimal. See SARAP Tables in **Appendix B**.

All four of the ranges with minimal surface water rankings originally scored as having moderate rankings. However, these ranges were adjusted to a minimal ranking based on site-specific factors, such as low levels of lead loading. In the cases of Ranges 117A and 303, shorter operational histories (19 and 3 years, respectively) contributed to the ranking adjustment. In all cases, the low precipitation levels and anticipated pH not conducive to lead dissolution contributed to the minimal surface water ranking at these ranges.

7.4. Groundwater Assessments

The groundwater assessment is the sum of three component scores in the SARAP: range use and range management, groundwater pathways, and groundwater receptors. Of the 24 groundwater assessments completed, none were ranked high, 11 were ranked as moderate, and 13 were ranked as minimal. SARAPs are provided in **Appendix B**.

7.4.1. Small Arms Ranges with Moderate Groundwater Concern

SARs designated as having a moderate ranking are those in which the components in the groundwater evaluation totaled 30–49 points. **Table 7-4** lists those ranges receiving this rating with a summary of the scores.

Table 7-4: Scores for SARs with Moderate Concern for Groundwater Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
Edson Pistol Range	3,255	13	16	4	**33**
Range 102	15,389	15	14	12	**41**
Range 103	25,048	15	14	12	**41**
Range 110	2,774	15	16	4	**35**
Range 111	6,606	15	16	4	**35**
Range 112A	2,351	13	16	4	**33**
Range 116B	4,520	15	16	4	**35**
Range 130 Complex	2,383	13	22	4	**39**
Range 223A	2,695	15	16	4	**35**
Range 300	2,448	15	10	7	**32**
Range 501	1,786	15	16	4	**35**

Eleven SARs were given a moderate groundwater ranking. Each of these ranges receives at least 1,000 lb of lead annually. Half of the ranges with a moderate groundwater ranking have been operational for more than 30 years.

The moderate groundwater ranking is attributed largely to the groundwater pathway: infiltration to groundwater may be elevated due to the sand content in the soils, presence of a relatively shallow water table, and soil pH that ranges from 5.3 to 8.2. Given the range of the pH and the potential for it to be below 6.5, a condition favorable to lead dissolution, the soil pH was given a moderate score in most cases. Despite the shallow groundwater levels in the immediate area, the groundwater pathway score for Range 300 was significantly lower than for the other SARs due to neutral pH in the soil and groundwater, as well as soils which permit slow infiltration rates.

Generally, most of the SARs with moderate groundwater rankings scored low regarding groundwater receptors. Only Ranges 102 and 103 scored higher in this category. This is due to both ranges being situated over an alluvial basin used as a source of drinking water. There are also six water wells, of which four are currently used for water production, within a 1-mile radius of each range (MCB Camp Pendleton, 2011c). Based on available sampling data from the drinking water system, concentrations of lead do not exceed drinking water standards (MCB Camp Pendleton, 2007a).

7.4.2. Small Arms Ranges with Minimal Groundwater Concern

SARs designated as having a minimal ranking are those in which the components in the groundwater evaluation totaled 0–29 points. **Table 7-5** lists those ranges receiving this rating with a summary of the scores.

Table 7-5: Scores for SARs with Minimal Concern for Groundwater Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
Edson Rifle Complex	42,812	13	16	4	**33**[a]
Range 116A	1,918	15	10	4	**29**
Range 116C	191	11	16	4	**31**[a]
Range 117A	170	11	16	4	**31**[a]
Range 127	2	11	16	7	**34**[a]

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
Range 206	1,783	15	14	4	**33**[a]
Range 210C	3,219	15	8	4	**27**
Range 210G	--	9	8	4	**21**
Range 212A	2,772	15	12	4	**31**[a]
Range 213	8,819	15	8	4	**27**
Range 214	14,246	15	14	4	**33**[a]
Range 216	409	13	12	4	**29**
Range 303	301	9	16	4	**29**

[a] Site-specific factors were used to decrease the concern from moderate to minimal. See SARAP Tables in **Appendix B**.

Some of the higher scores for these SARs are attributed to the range use / range management category; more than half of these ranges were scored high due to long operational history and significant use (more than 1,000 lb/yr of lead). Higher scores also are evident in the groundwater pathways category due to the sand content in the soils, relatively shallow water table, and soil pH that ranges from 5.3 to 8.2. The drivers for these ranges being scored as having minimal groundwater concern include low precipitation levels at MCB Camp Pendleton, anticipated neutral pH of the groundwater that is unfavorable to lead dissolution, and the lack of groundwater receptors near the ranges. Low scores in the groundwater receptors category generally reflect the lack of human or ecological receptor points near the ranges.

Six of the 13 SARs that are listed as having minimal groundwater rankings originally scored as moderate and were adjusted based on site-specific factors. The critical factor in most of these cases was the lack of groundwater receptors near the ranges. In all such cases, the low precipitation levels at MCB Camp Pendleton as well as the anticipated neutral pH of the groundwater not being conducive to lead dissolution contributed to the adjustment to a minimal groundwater ranking.

8. Field Data Collection Results

A field sampling program was implemented for MCB Camp Pendleton based on the findings made during the baseline REVA assessment. The field study was repeated concurrent with the REVA five-year review. Sampling and analysis of surface water and groundwater samples were performed in Las Flores and San Onofre watersheds to compare to prior field findings and determine whether MC are actually migrating to off-range areas. Additional groundwater sampling in both the San Mateo and Santa Margarita alluvial groundwater basins also was conducted in accordance with the *Sampling and Analysis Plan* (SAP) *(Field Sampling Plan / Quality Assurance Project Plan)* (QAPP) *for the 5-Year Review Range Environmental Vulnerability Assessment of the San Onofre and Las Flores Watersheds, Marine Corps Base Camp Pendleton* (ARCADIS/Malcolm Pirnie, 2011b).

Analytical results were compared to applicable DoD screening levels (**Appendix C**). Additionally, the California Maximum Contaminant Level (MCL) for perchlorate in drinking water was used for comparison purposes (CDPH, 2012). A subsequent field study was initiated during the preparation of this review in November 2012 and December 2012, based upon the study performed during the five-year review. The preliminary findings are presented here.

8.1. Monitoring Plan

The collection of field data to support the REVA five-year review process for MCB Camp Pendleton was conducted in accordance with the SAP/QAPP (ARCADIS/Malcolm Pirnie, 2011b). The SAP/QAPP initially was prepared to identify sample locations and procedures for voluntary sampling of surface water and drinking water supply wells in the Las Flores and San Onofre watersheds.

The scope of the five-year field study does not include assessing background or hardness fluctuations over time, rather only assessing changes of analytical non-detect/detections since the baseline sampling event. However, as part of the subsequent 2012-2013 field study, background samples from the upper reaches of the San Mateo watershed were collected to supplement similar data collected in 2007 during the REVA baseline sampling event. Further, samples collected during the 2012-2013 field study were analyzed for hardness, supplementing similar data gathered during the baseline assessment. The collective data was used to interpret sampling results. **Table 8-1** lists the samples, associated watershed, and media.

Table 8-1: Watersheds and Corresponding Sample Identification Labels

Type of Sample	Associated Watershed (Surface Water) or Alluvial Basin (Groundwater)	Sample Date	Sample ID Label
Surface Water	San Mateo	19-Nov-2012	BG01-SW01 (background sample)
			BG01-SW02 (duplicate)
	San Onofre	26-Sep-2011	SO4-SW01
			SO4-SW02 (duplicate)
	Las Flores	26-Sep-2011	LF1-SW01
			LF1-SW02 (duplicate)
		23-Jan-2012	LF1-SW04
			LF2-SW01
			LF2-SW02 (duplicate)
		19-Nov-2012	LF1-SW01
			LF1-SW02 (duplicate)
Groundwater	San Onofre	27-Sep-2011	SOW1-GW02
			SOW2-GW03
			SOW2-GW04 (duplicate)
			SOW3-GW05
			SOW4-GW06
		07-Aug-2012	SOW1-GW12
			SOW2-GW13
			SOW4-GW15
			SOW4-GW16 (duplicate)
			SOW3-GW17
		11-Dec-2012	SOW3-GW07
			SOW1-GW08
			SOW1-GW09 (duplicate)
			SOW4-GW10

Type of Sample	Associated Watershed (Surface Water) or Alluvial Basin (Groundwater)	Sample Date	Sample ID Label
Groundwater	Las Flores	27-Sep-2011	LFW1A-GW01
		24-Oct-2011	LFW3-GW08
		07-Aug-2012	LFW1A-GW09
			LFW3-GW10
			LFW1A-GW11 (duplicate)
		11-Dec-2012	LFW1A-GW04
			LFW1A-GW05 (duplicate)
			LFW3-GW06
	San Mateo	07-Aug-2012	SMW1-GW18
			SMW1-GW19 (duplicate)
			SMW2-GW20
	Santa Margarita	08-Aug-2012	SRW4-GW21
			SRW4-GW22 (duplicate)
			SRW5-GW23
			SRW3-GW24
			SRW2-GW25
			SRW2-GW26 (duplicate)
			SRW1-GW27
		11-Dec-2012	SRW5-GW01
			SRW5-GW02 (duplicate)
			SRW3-GW03

Note: ID – identification

8.2. Methods and Observations

Field activities conducted concurrently with the five-year review (referred to as the 2011-2012 study) included sampling of off-range surface water and groundwater at the following locations:

- Two surface water locations, off range and down gradient of operational ranges in the Las Flores and San Onofre watersheds, at the beginning of the 2011–2012 rainy season
- Two surface water locations, off range and down gradient of operational ranges in the Las Flores watershed, following one rain event during the 2011–2012 rainy season

- Raw groundwater from 13 operational or proposed drinking water supply wells (2 wells in the Las Flores alluvial basin, 4 wells in the San Onofre alluvial basin, 2 wells in the San Mateo alluvial basin, 5 wells in the Santa Margarita alluvial basin)

Field sampling locations for the 2011-2012 study were established during the REVA baseline assessment based on the baseline modeling results for HE transport. These locations were selected again for this REVA five-year review and later were expanded during the study to include additional groundwater wells based on information and analysis regarding perchlorate collected during this five-year review. Samples were collected 26–28 September 2011, 24 October 2011, 23 January 2012, and 7–8 August 2012.

The same locations served as the basis for the initiation of the subsequent field study (referred to as the 2012-2013 study), with addition of a background surface water location, and the exception of two drinking water supply wells in the upper Santa Margarita alluvial basin. Data presented here include sampling at the following locations:

- One surface water background location, off range near the northern boundary of the installation in the upper San Mateo watershed, at the beginning of the 2012-2013 rainy season
- One surface water location, off range and down gradient of operational ranges in the Las Flores watershed, at the beginning of the 2012-2013 rainy season
- Raw groundwater from 7 operational or proposed drinking water supply wells (2 wells in the Las Flores alluvial basin, 3 wells in the San Onofre alluvial basin, and 2 wells in the Santa Margarita alluvial basin)

The locations for the 2012-2013 study were selected based on preliminary REVA five-year modeling results (described in **Section 6**) and analytical results from the 2011-2012 study. Samples were collected 19 November 2012 and 11 December 2012.

8.2.1. Surface Water Sampling

Surface water grab samples were collected on the following dates at the following locations:

- 26 September 2011 in the Las Flores watershed at location LF1 (sample ID LF1-SW01) and in the San Onofre watershed at location SO4 (sample ID SO4-SW01). Duplicate samples also were collected at each location (sample IDs LF1-SW02 and SO4-SW02, respectively).
- 23 January 2012 in the Las Flores watershed at locations LF1 (sample ID LF1-SW04) and LF2 (sample ID LF2-SW01). A duplicate sample was collected at location LF2 (sample ID LF2-SW02).
- 19 November 2012 in the Las Flores watershed at location LF1 (sample ID LF1-SW01); a duplicate sample was also collected (sample ID LF1-SW02). A background sample was also collected in the upper San Mateo watershed at location BG1 (sample ID BG01-SW01); a duplicate sample was also collected (sample ID BG01-SW02).

During the baseline field study, sampling data were collected at the start of the winter or rainy season as well as at subsequent times during the same season in order to evaluate possible changes over the course of the season. The streams present at MCB Camp Pendleton are predominantly non-perennial and require significant precipitation to generate flow. However, during the 2011–2012 season, precipitation was unusually low; consequently, samples were collected whenever surface water was available. The lack of significant precipitation events during the 2011–2012 season contributed to an inability to collect several samples in the San Onofre watershed, with only a single sample being collected at location SO4 in September 2011. During the collection of SO4, surface water flow terminated at the sampling location. Base surface water flow was only observed at location LF1 in the Las Flores watershed during the sampling period. During the 2012-2013 season, precipitation has also been lower than the historical average, and this has similarly contributed to an inability to collect samples in the San Onofre and Las Flores watershed; only the base surface water flow at location LF1 has been sampled during the 2012-2013 study. Reduced precipitation also resulted in the collection of background samples form standing water at location BG1, whereas flow was available at the initial sampling of the location during the baseline field study.

Surface water samples were collected in the Las Flores, San Onofre, and San Mateo watersheds utilizing two approaches: grab sampling and deployment of unattended first-flush storm water collection devices. Grab samples were collected using an extension arm with a pre-cleaned polyethylene container attached at the end. Water was collected from the midpoint of the flowing stream and dispensed into appropriate sample containers. Nalgene® storm water sampling devices were installed at designated sampling locations where flow initially was not available for sampling. As the devices become submerged, they collect a first-flush water sample by funneling it through a grated entry port; a floating ball valve rises inside the container to eventually seal off the collection port.

Each surface water grab sample was collected after obtaining water quality field parameters. A calibrated multiparameter water quality meter and turbidimeter were used at each location to gather data such as pH, conductivity, dissolved oxygen, temperature, and turbidity. All samples during the 2011-2012 study were analyzed for total and dissolved lead by USEPA Method 200.8 and explosives constituents by USEPA Method 8330A. Samples collected during the 2012-2013 study were analyzed for total and dissolved lead by USEPA Method 6020A, explosives constituents by USEPA Method 8330B, and perchlorate by USEPA Method 6850. Surface water collected for lead analysis was filtered in the field using .45-micrometer filters.

8.2.2. Groundwater Sampling

Field personnel performed groundwater sampling on 27 September 2011, 24 October 2011, 7–8 August 2012, and 11 December 2012 with oversight by a representative field technician from MCB Camp Pendleton Facilities and Maintenance Department. Groundwater samples from the

September 2011 sampling event were collected from one water supply well in the Las Flores watershed and four water supply wells in the San Onofre watershed. Groundwater samples from the October 2011 sampling event were collected in one water supply well in the Las Flores watershed. Groundwater samples from the August 2012 sampling event were collected from two water supply wells in the San Mateo alluvial basin; four water supply wells in the San Onofre alluvial basin; two water supply wells in the Las Flores alluvial basin; and five water supply wells in the middle and upper Santa Margarita alluvial basins. Groundwater samples from the December 2012 sampling event were collected from three water supply wells in the San Onofre alluvial basin two water supply wells in the Las Flores alluvial basin; and two water supply wells in the middle Santa Margarita alluvial basin. During the sampling conducted in December 2012 (part of the 2012-2013 study), wells were out of service and not available for sampling. All wells except for were used for drinking water production, according to installation personnel.

Each active well system includes the wellhead plumbing connected to pipes feeding on-site reservoirs. Each wellhead is located in a locked fenced area. The wellhead controls, piping, and sampling ports are located within locked concrete structures within the fenced enclosures.

Each groundwater sample was collected after obtaining water quality field parameters. A calibrated multiparameter water quality meter and turbidimeter were used at each location to gather data such as pH, conductivity, dissolved oxygen, temperature, and turbidity. All samples collected in September to October 2011 were analyzed for total and dissolved lead by EPA Method 200.8 and explosives constituents by USEPA Method 8330A. All samples collected in August 2012 were filtered in the field using a 0.2-micrometer filter and analyzed for perchlorate by USEPA Method 6860. All samples collected in December 2012 were analyzed for total and dissolved lead by USEPA Method 6020A, explosives constituents by USEPA Method 8330B, and perchlorate by USEPA Method 6850. Groundwater collected for lead analysis was filtered in the field using .45-micrometer filters.

8.3. Water Quality and Analytical Results

The following sections summarize the water quality parameters and analytical results for surface water and groundwater samples collected during the field sampling activities.

8.3.1. Surface Water Sampling

Surface water samples were analyzed for explosives as well as total and dissolved lead. Samples collected as part of the 2012-2013 study were also analyzed for perchlorate. The water quality parameters measured during surface water sampling activities are summarized in **Table 8-2**. The surface water analytical results were compared to DoD screening values, which were developed to promote consistency across the services' operational range assessment programs.

Table 8-2: Surface Water Field Parameters for MCB Camp Pendleton, REVA Monitoring, 2011–2012 and 2012–2013 Studies

Watershed	Sample Location	Collection Date	Field Parameters					
			pH	*DO (mg/L)*	*Temperature (°C)*	*Specific Conductivity (mS/cm)*	*Turbidity (NTU)*	*Oxidation Reduction Potential (mV)*
Las Flores	LF1	26-Sep-11	7.83	11.66	20.85	1.02	1.54	186
		23-Jan-12	7.29	11.42	15.77	0.874	76.8	165
		19-Nov-12	7.19	8.93	16.06	0.776	NA	201
	LF2	23-Jan-12	7.92	10.61	15.28	1.11	9.00	140
San Onofre	SO2	NS	--	--	--	--	--	--
	SO3	NS	--	--	--	--	--	--
	SO4	26-Sep-11	6.75	10.60	20.70	0.977	1.65	238
		NS	--	--	--	--	--	--
San Mateo	BG1	19-Nov-12	6.78	7.43	14.27	0.94	NA	191

Notes:
°C – Degrees Celsius
mg/L – Milligrams per liter
mS/cm – Millisiemens per centimeter
NTU – Nephelometric turbidity units
mV – millivolts
NA – Not analyzed due to meter malfunction
NS – Not sampled; no surface water flow was available for sampling during the rainy season.
A Horiba U-53 and Lamotte 2020E were used to obtain these measurements. No salinity readings were acquired during field activities.

8.3.1.1. Las Flores Watershed

The analytical results for surface water samples collected in the Las Flores watershed are presented in **Table 8-3** and summarized below.

- Explosives constituents and lead were not detected in any of the Las Flores watershed surface water samples collected in September 2011.

- RDX and 2,4-diamino-6-nitrotoluene (a daughter product of TNT) were detected at one location sampled within the Las Flores watershed in January 2012. There is no DoD screening value nor established surface water standard for 2,4-diamino-6-nitrotoluene, but the RDX detection did not exceed the applicable project screening values (DoD surface water value for ecological receptors of 190 µg/L). Total lead was detected at one sample location within the Las Flores watershed in January 2012, although the concentration was an estimate because it was below the laboratory RL.

Table 8-3: Surface Water Analytical Results for Las Flores Watershed, MCB Camp Pendleton, REVA Monitoring, 2011–2012 and 2012-2013 Studies

Sample ID	Collection Date	Analytical Results (µg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
LF1-SW01	26-Sep-11	ND	ND	ND	ND	NA
LF1-SW02 (Duplicate)	26-Sep-11	ND	ND	ND	ND	NA
LF1-SW04	23-Jan-12	**0.64 J1**	ND	ND	ND	NA
LF1-SW01	19-Nov-12	ND	**0.14 J1**	ND	ND	ND
LF1-SW02 (Duplicate)	19-Nov-12	ND	**0.14 J1**	ND	ND	ND
LF2-SW01	23-Jan-12	ND	ND	**1.1 M J2**	**0.28 M J2**	NA
LF2-SW02 (Duplicate)	23-Jan-12	ND	ND	**0.49 M J2**	ND	NA

Notes:
Bold text indicates an analyte detection.
M – Manual integrated compound
J1 – Estimated; the analyte was positively identified; quantitation is an estimation.
J2 – Estimated; quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control data.
NA – Not analyzed
ND – Not detected above respective method detection limit
Other explosives analyzed via USEPA Method 8330A/B were not detected above listed method detection limits for any samples and are not summarized above.

8.3.1.2. San Onofre Watershed

Samples from only one surface water sample location within the San Onofre watershed (SO4) were collected. Due to the lack of significant precipitation events during the rainy seasons, sufficient stream flow was not available in the San Onofre Creek to collect samples after the initial sampling round.

The analytical results for surface water samples collected in the San Onofre watershed are presented in **Table 8-4** and summarized below.

- Explosives constituents were not detected in any of the San Onofre watershed surface water samples.
- Total lead was detected in one of two samples, although the concentration is an estimate because it was below the RL.

Table 8-4: Surface Water Analytical Results for San Onofre Watershed, MCB Camp Pendleton, REVA Monitoring, 2011–2012 Study

Sample ID	Collection Date	Analytical Results (µg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
SO4-SW01	26-Sep-11	**0.73 J1**	ND	ND	ND	NA
SO3-SW02	NS	NS	NS	NS	NS	NA

Notes:
J1 – Estimated; the analyte was positively identified; quantitation is an estimation.
NA – Not analyzed
ND – Not detected above respective method detection limit
NS – Not sampled; no surface water flow was available for sampling during the 2011–2012 rainy season.
Other explosives analyzed via USEPA Method 8330A were not detected above listed method detection limits for any samples and are not summarized above.

8.3.1.3. San Mateo Watershed

Samples from one surface water sample location within the upper San Mateo watershed (BG1) were collected as background samples, as part of the 2012-2013 study. Due to the lack of significant precipitation events during the 2012-2013 season, samples were collected from standing water near the terminus of flow.

The analytical results for surface water samples collected in the San Mateo watershed are presented in **Table 8-5** and summarized below.

- Neither explosive constituents nor perchlorate were detected in the San Mateo watershed surface water samples.
- Total lead was not detected; however, dissolved lead was detected in both surface water samples.

Table 8-5: Surface Water Analytical Results for San Mateo Watershed, MCB Camp Pendleton, REVA Monitoring, 2012–2013 Study

Sample ID	Collection Date	Analytical Results (µg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
BG01-SW01	19-Nov-12	ND	**0.25**	ND	ND	ND
BG01-SW02 (Duplicate)	19-Nov-12	ND	**0.21**	ND	ND	ND

Notes:
ND – Not detected above respective method detection limit
Other explosives analyzed via USEPA Method 8330B were not detected above listed method detection limits for any samples and are not summarized above.

8.3.2. Data Quality Review

Data validation was performed on the analytical data collected at surface water locations in the Las Flores, San Onofre, and San Mateo watersheds, and the dataset meets the data quality objectives (DQOs) and is considered usable. Minor data quality issues were observed in some analyses related to matrix spike (MS) / matrix spike duplicate (MSD) percent recoveries outside the established limits.

8.3.3. Groundwater Sampling

As noted in **Section 8.2.2**, six groundwater samples from five wells were collected on 27 September 2011, one groundwater sample from one well was collected on 24 October 2011, eighteen groundwater samples from thirteen wells were collected on 7–8 August 2012, and ten samples from seven wells were collected on 11 December 2012. The water quality parameters measured during groundwater sampling activities are summarized in **Table 8-6**. Collected samples from September to October 2011 were analyzed for explosives (excluding perchlorate) as well as total and dissolved lead. Collected samples from August 2012 were analyzed for perchlorate. Collected samples from December 2012 were analyzed for explosives, perchlorate, and total and dissolved lead. The analytical results were compared to DoD screening values.

Table 8-6: Groundwater Field Parameters for MCB Camp Pendleton, REVA Monitoring, 2011–2012 and 2012–2013 Studies

Alluvial Basin	**Sample Location**	**Collection Date**	**Field Parameters**					
			pH	*DO (mg/L)*	*Temperature (°C)*	*Specific Conductance (mS/cm)*	*Turbidity (NTU)*	*Oxidation Reduction Potential (mv)*
Las Flores	LFW1A	27-Sep-11	7.28	11.68	19.35	1.39	0.87	172
		07-Aug-12	6.36	8.56	21.41	1.44	0.0	276
		11-Dec-12	6.75	1.50	19.46	0.933	0.47	82
	LFW3	24-Oct-11	6.58	8.77	21.18	1.26	0.00	194
		07-Aug-12	6.64	4.59	24.58	1.38	0.8	192
		11-Dec-12	6.90	7.21	20.22	0.903	0.29	76
San Onofre	SOW1	27-Sep-11	7.10	11.25	20.10	0.781	1.41	183
		07-Aug-12	7.04	4.34	22.05	0.941	0.8	133
		11-Dec-12	6.55	4.54	17.98	0.580	0.73	563
	SOW2	27-Sep-11	7.18	11.99	20.55	0.797	0.48	196
		07-Aug-12	6.90	12.22	21.56	0.948	1.0	158
	SOW3	27-Sep-11	7.09	10.54	20.93	0.783	0.81	189
		07-Aug-12	6.88	10.01	21.90	0.940	0.7	156
		11-Dec-12	6.85	12.16	19.95	0.580	1.41	105

Alluvial Basin	Sample Location	Collection Date	Field Parameters					
			pH	*DO (mg/L)*	*Temperature (°C)*	*Specific Conductance (mS/cm)*	*Turbidity (NTU)*	*Oxidation Reduction Potential (mv)*
San Onofre	SOW4	27-Sep-11	7.34	11.45	21.93	0.793	0.37	596
		07-Aug-12	6.78	10.74	22.15	0.919	0.8	171
		11-Dec-12	6.64	11.89	18.74	0.553	0.94	238
San Mateo	SMW1	07-Aug-12	7.14	5.74	22.20	0.909	0.8	157
	SMW2	07-Aug-12	7.10	3.69	22.25	0.804	0.7	132
Santa Margarita	SRW1	08-Aug-12	7.23	4.90	19.58	1.40	0.6	3
	SRW2	08-Aug-12	6.92	9.84	24.25	1.35	0.5	--
	SRW3	08-Aug-12	6.95	3.27	22.25	1.52	0.8	--
		11-Dec-12	6.80	4.52	20.45	0.886	0.1	-16
	SRW4	08-Aug-12	6.49	8.40	24.41	1.38	0.7	-117
	SRW5	08-Aug-12	6.99	4.33	23.57	1.54	0.6	--
		11-Dec-12	6.65	0.00	18.41	1.55	0.84	-52

Notes:
A Horiba U-53 and Lamotte 2020E were used to obtain these measurements. No salinity readings were acquired during field activities.
Well LFW1A was sampled in lieu of well LFW1, which was sampled during the REVA baseline monitoring event (2007–2008) but subsequently abandoned.
Well LFW2 could not be sampled because no operable pump was present.

8.3.3.1. Las Flores Alluvial Groundwater Basin

Sample results within the Las Flores alluvial basin indicate that no total or dissolved lead was detected in drinking water supply wells. RDX was detected in raw groundwater at one well during the October 2011 sampling event, but this detection was below the DoD screening value (drinking water value of 0.61 µg/L). No other explosives were detected above listed method detection limits for both samples from this sampling event. Perchlorate was detected in raw groundwater at both wells during the August 2012 and December 2012 sampling events, but these detections were below the applicable screening value (California MCL drinking water value of 6 μg/L). The highest concentrations of perchlorate detected during the August 2012 sampling event (0.44 μg/L) as well as the December 2012 sampling event (0.37 μg/L) were from samples collected in this basin.

Groundwater field parameters are summarized in **Table 8-6**; analytical results are summarized in **Table 8-7**.

Table 8-7: Groundwater Analytical Results for Las Flores Alluvial Groundwater Basin, MCB Camp Pendleton, REVA Monitoring 2011–2012

Sample ID	Collection Date	Analytical Results (μg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
LFW1A-GW01	27-Sep-11	ND	ND	ND	ND	NA
LFW1A-GW09	07-Aug-12	NA	NA	NA	NA	**0.076**
LFW1A-GW11 (Duplicate)	07-Aug-12	NA	NA	NA	NA	**0.072**
LFW1A-GW04	11-Dec-12	ND	ND	ND	ND	**0.072 J**
LFW1A-GW05 (Duplicate)	11-Dec-12	ND	ND	ND	ND	ND
LFW3-GW08	24-Oct-11	ND	ND	ND	**0.090 J**	--
LFW3-GW10	07-Aug-12	--	--	--	--	**0.44**
LFW3-GW06	11-Dec-12	ND	ND	ND	ND	**0.37**

Notes:
Bold text indicates an analyte detection.
J – Estimated; quantitation is an estimation
NA – Not analyzed
ND – Not detected above respective method detection limit
Well LFW1A was sampled in lieu of well LFW1, which was sampled during the REVA baseline monitoring event (2007–2008) but subsequently abandoned.
Well LFW2 could not be sampled because no operable pump was present.
Other explosives analyzed via USEPA Method 8330A were not detected above listed method detection limits for any samples and are not summarized above.

8.3.3.2. San Onofre Alluvial Groundwater Basin

Sample results within the San Onofre alluvial basin indicate that no total or dissolved lead was detected in any of the drinking water supply wells. RDX was detected in raw groundwater at one well during the December 2012 sampling event, but these detections were below the DoD screening value (drinking water value of 0.61 µg/L). Perchlorate was detected in raw groundwater at all four wells during the August 2012 sampling event, as well as the three wells in the December 2012 sampling event, but these detections were below the applicable screening value (California MCL drinking water value of 6 µg/L).

Groundwater field parameters are summarized in **Table 8-6**; analytical results are summarized in **Table 8-8**.

Table 8-8: Groundwater Analytical Results for San Onofre Alluvial Groundwater Basin, MCB Camp Pendleton, REVA Monitoring, 2011–2012 and 2012–2013 Studies

Sample ID	Collection Date	Analytical Results (µg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
SOW1-GW02	27-Sep-11	ND	ND	ND	ND	NA
SOW1-GW12	07-Aug-12	NA	NA	NA	NA	**0.15**
SOW1-GW08	11-Dec-12	ND	ND	ND	**0.091 J**	**0.26**
SOW1-GW09 (Duplicate)	11-Dec-12	ND	ND	ND	**0.084 J**	**0.072 J**
SOW2-GW03	27-Sep-11	ND	ND	ND	ND	NA
SOW2-GW04 (Duplicate)	27-Sep-11	ND	ND	ND	ND	NA
SOW2-GW13	07-Aug-12	NA	NA	NA	NA	**0.20**
SOW3-GW05	27-Sep-11	ND	ND	ND	ND	NA
SOW3-GW17	07-Aug-12	NA	NA	NA	NA	**0.15**
SOW3-GW07	11-Dec-12	ND	ND	ND	ND	**0.25**
SOW4-GW06	27-Sep-11	ND	ND	ND	ND	NA

Sample ID	Collection Date	Analytical Results (µg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
SOW4-GW15	07-Aug-12	NA	NA	NA	NA	**0.16**
SOW4-GW16 (Duplicate)	07-Aug-12	NA	NA	NA	NA	**0.16**
SOW4-GW10	11-Dec-12	ND	ND	ND	ND	**0.24**

Notes:
Bold text indicates an analyte detection.
NA – Not analyzed
ND – Not detected above respective method detection limit
Other explosives analyzed via USEPA Method 8330A were not detected above listed method detection limits for any samples and are not summarized above.

8.3.3.3. San Mateo Alluvial Groundwater Basin

Sample results within the San Mateo alluvial basin indicated that perchlorate was detected in raw groundwater in both wells during the August 2012 sampling event, but these detections were below the applicable screening value (California MCL drinking water value of 6 µg/L).

Groundwater field parameters are summarized in **Table 8-6**; analytical results are summarized in **Table 8-9**.

Table 8-9: Groundwater Analytical Results for San Mateo Alluvial Groundwater Basin, MCB Camp Pendleton, REVA Monitoring, 2011–2012 Study

Sample ID	Collection Date	Analytical Results (µg/L)				
		Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
SMW1-GW18	07-Aug-12	NA	NA	NA	NA	**0.28**
SMW1-GW19 (Duplicate)	07-Aug-12	NA	NA	NA	NA	**0.26**
SMW2-GW20	07-Aug-12	NA	NA	NA	NA	**0.21**

Notes:
Bold text indicates an analyte detection.
NA – Not analyzed

8.3.3.4. Santa Margarita Alluvial Groundwater Basins

Total lead and dissolved lead were detected in raw groundwater at one well (during the December 2012 sampling event, but these detections were below the DoD screening value (drinking water value of 15 µg/L). The detections are estimates because they were below the laboratory RL. Sample results within the Santa Margarita alluvial basins indicated that perchlorate was detected in raw groundwater in three of five wells during the August 2012 sampling event, but these detections were below the applicable screening value (California MCL drinking water value of 6 µg/L). Two of the detections are estimates because both were below the laboratory RL. Only one sample (at one well location) in the middle Santa Margarita alluvial basin indicated the potential presence of perchlorate; majority of detections came from the upper Santa Margarita alluvial basin. Perchlorate was not detected in raw groundwater samples from the two wells in the December 2012 sampling event.

Groundwater field parameters are summarized in **Table 8-6**; analytical results are summarized in **Table 8-10**.

Table 8-10: Groundwater Analytical Results for Santa Margarita Alluvial Groundwater Basin, MCB Camp Pendleton, REVA Monitoring, 2011–2012 and 2012–2013 Studies

Alluvial Basin	Sample ID	Collection Date	Analytical Results (µg/L)				
			Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
Upper Santa Margarita	SRW1-GW27	08-Aug-12	NA	NA	NA	NA	**0.019 J**
	SRW2-GW25	08-Aug-12	NA	NA	NA	NA	**0.10**
	SRW2-GW26 (Duplicate)	08-Aug-12	NA	NA	NA	NA	**0.10**
Middle Santa Margarita	SRW3-GW24	08-Aug-12	NA	NA	NA	NA	ND
	SRW3-GW03	11-Dec-12	ND	ND	NA	NA	ND
	SRW4-GW21	08-Aug-12	NA	NA	NA	NA	ND
	SRW4-GW22 (Duplicate)	08-Aug-12	NA	NA	NA	NA	**0.029 J**
	SRW5-GW23	08-Aug-12	NA	NA	NA	NA	ND
	SRW5-GW01	11-Dec-12	ND	ND	NA	NA	ND

Alluvial Basin	Sample ID	Collection Date	Analytical Results (µg/L)				
			Lead, Total	*Lead, Dissolved*	*2,4-Diamino-6-nitrotoluene*	*RDX*	*Perchlorate*
Middle Santa Margarita	SRW5-GW02 (Duplicate)	11-Dec-12	**0.24 J**	**0.26 J**	NA	NA	ND

Notes:
Bold text indicates an analyte detection.
J – Estimated; quantitation is an estimation
NA – Not analyzed
ND – Not detected above respective method detection limit

8.3.4. Data Quality Review

Data validation was performed on the analytical data collected at well locations in the San Mateo, San Onofre, Las Flores, and Santa Margarita alluvial groundwater basins. Based on the result of this validation, data sets were deemed usable and meet the DQOs. Minor data quality issues were observed in some analyses related to low surrogate and MS/MSD percent recovery; consequently, the affected results are qualified.

8.4. Discussion

Field data collected during this five-year review provides an opportunity to evaluate (1) whether a release of MC to off-range areas has occurred; (2) how MC concentrations may have changed since the baseline REVA assessment; and (3) the need for further project recommendations.

8.4.1. Discussion of Five-Year Review Results

Surface water and groundwater results are compared to the DoD screening values for assessing surface water and drinking water results in the voluntary, proactive operational range assessment programs, including REVA. The draft screening values identified by the DoD applicable to the compounds detected in the surface water and groundwater analytical results are summarized in **Table 8-11**.

Table 8-11: Summary of Applicable Screening Levels, REVA Monitoring, 2011–2012 and 2012-2013 Studies

Criterion	DoD Screening Levels[a]				
	Lead, total (µg/L)	*Lead, dissolved (µg/L)*	*2,4-Diamino-6-nitrotoluene (µg/L)*	*RDX (µg/L)*	*Perchlorate (µg/L)*
RL[b]	1.5	1.5	0.93	0.19	0.050
Surface water (ecological receptors) values	N/A[c]	2.5[d]	N/A	190	9,300
Human drinking water values	15	15	N/A	0.61	15 (DoD) 6 (CA MCL)[e]

Notes:
N/A – Not applicable
[a] Screening levels are based on the DoD document *Operational Range Assessment Screening Values* (DoD, 2012; **Appendix C**), except where noted.
[b] Lead was analyzed by USEPA Method 200.8 or USEPA Method 6020A. Explosives were analyzed by USEPA Method 8330A or USEPA Method 8330B. Perchlorate was analyzed by USEPA Method 6850 or USEPA Method 6860. See **Sections 8.2.1** and **8.2.2** for further details.
[c] Screening-level values apply to dissolved metals.
[d] Value is dependent on the hardness of water; provided value is for a water hardness of 100 mg/L as calcium carbonate (CaCO3).
[e] The California MCL for perchlorate in drinking water (6 µg/L) is included because it is more stringent than the DoD screening level (15 µg/L).

The analytical results for the surface water and groundwater samples collected in the Las Flores watershed are summarized as follows:

- Explosives constituents were not detected in the any of the Las Flores watershed surface water samples collected in September 2011. RDX and 2,4-diamino-6-nitrotoluene (a daughter product of TNT) were detected at one surface water location sampled within the Las Flores watershed in January 2012. The RDX detection did not exceed its respective DoD screening value (DoD surface water value for ecological receptors of 190 µg/L); there are no established DoD screening levels for 2,4-diamino-6-nitrotoluene (maximum detected concentration at 1.1 µg/L). RDX was measured above its respective detection level from one well in the Las Flores groundwater basin (0.090 µg/L); no other explosives were detected. The measured RDX concentration in this well was below the RL (0.19 µg/L) and DoD screening value for drinking water (0.61 µg/L). No explosives were detected in the other sampled groundwater well during the September 2011 sampling round, nor sampled groundwater wells during the December 2012 sampling round.

- Neither total nor dissolved lead was detected in the any of the Las Flores surface water samples collected in September 2011. Total lead was detected at one surface water sample location from the Las Flores watershed in January 2012, although its concentration (0.64 µg/L) was an estimate because it was below both the RL and the DoD surface water screening value for ecological receptors. Dissolved lead was detected at one surface water sample location from the Las Flores watershed in November 2012, although concentrations (0.14 µg/L) were estimated because they were below both the RL and the DoD surface water screening value for ecological receptors. Total and dissolved lead was not detected in any of the groundwater samples collected from the Las Flores alluvial basin.
- Perchlorate was detected in raw groundwater at both Las Flores groundwater wells during the August 2012 and December 2012 sampling events (0.072 to 0.44 µg/L), but these detections were below the applicable screening value (California MCL drinking water value of 6 µg/L).

Following initial groundwater sampling in the Las Flores basin, installation personnel sampled well LFW3 on 12 April 2012 and provided the sample to a different laboratory for explosives analysis by USEPA Method 8330. No MC, including RDX, were detected in the groundwater sample.

The analytical results for the surface water and groundwater samples collected in the San Onofre watershed are summarized as follows:

- Explosives constituents were not detected in any of the San Onofre surface water and raw groundwater samples collected as part of sampling events from September 2011 to August 2012. During the December 2012 sampling event, RDX was measured above its respective detection level from one well in the San Onofre groundwater basin (maximum estimated concentration of 0.091 µg/L); no other explosives were detected. The measured RDX concentrations in this well were below the RL (0.20 µg/L) and DoD screening value for drinking water (0.61 µg/L).
- Total lead was detected at an estimated concentration in a surface water sample collected at SO4 during the September 2011 sampling event (estimated concentration of 0.73 µg/L); it is below the DoD screening values for ecological receptors. Dissolved lead was not detected in samples collected during the September 2011 sampling event. Neither total nor dissolved lead was detected in any of the groundwater samples collected from the San Onofre alluvial basin.
- Perchlorate was detected in raw groundwater at all four San Onofre groundwater wells during the August 2012 and December 2012 sampling events (0.15 to 0.25 µg/L), but these detections were below the applicable screening value (California MCL drinking water value of 6 µg/L).

Raw groundwater samples collected in August 2012 from the San Mateo and Santa Margarita alluvial basins were analyzed only for perchlorate, while raw groundwater samples collected in

December 2012 from the middle Santa Margarita alluvial basin were analyzed for lead and perchlorate. The analytical results are summarized as follows:

- Total lead and dissolved lead were detected in a raw groundwater sample collected in December 2012 from one well in the middle Santa Margarita groundwater basin (estimated concentrations of 0.24 µg/L and 0.26 µg/L, respectively), but these detections were below the RL (1.0 µg/L) and DoD screening value for drinking water (15 µg/L).
- During the August 2012 sampling event, raw groundwater associated with the two sampled San Mateo groundwater wells had detections of perchlorate (0.21 to 0.28 µg/L), as did three of five sampled Santa Margarita groundwater wells (estimated 0.019 to 0.10 µg/L). Detections were found in both the middle and upper Santa Margarita alluvial groundwater basins. However, all detections were below the applicable screening value (California MCL drinking water value of 6 µg/L). No perchlorate was detected in raw groundwater sampled in December 2012 from two wells in the middle Santa Margarita groundwater basin.

Background surface water samples were collected in November 2012 from one location of standing water in the upper San Mateo watershed, and analyzed for explosives, perchlorate and lead. No explosives or perchlorates were detected in the samples. Dissolved lead was detected at a maximum concentration of 0.25 µg/L.

Based on these findings, the limited detections of lead, RDX, and 2,4-diamino-6-nitrotoluene in the surface waters of the Las Flores and San Onofre watersheds do not indicate the existence of a significant issue. The latter constituent is one of the daughter products of TNT, and its presence may indicate that TNT is actively degrading, thereby limiting its migration in the Las Flores watershed. Only a single surface water location in the San Onofre watershed was sampled in September 2011 due to lack of flow. The below-average precipitation of the 2011–2012 and 2012-2013 wet seasons limited potential transportation of MC during this study. In the samples collected from that watershed, only total lead was detected at a very low, estimated concentration.

With the exception of three samples, no explosives were detected in the Las Flores and San Onofre alluvial groundwater basins. RDX was detected in the 2011-2012 study at an estimated concentration of 0.090 µg/L in a sample from one groundwater supply well in the Las Flores alluvial groundwater basin; this was below its respective project screening criterion. The installation re-sampled the same well following this finding and detected no explosives, indicating the presence of the constituent may be intermittent. RDX was also detected in the 2012-2013 study in raw groundwater collected from a single groundwater supply well at a maximum estimated concentration of 0.091 µg/L; this was below its respective project screening criterion. These detections do not indicate the existence of a significant issue. With the exception of one sample, no total or dissolved lead was detected in the Las Flores, San Onofre, and middle Santa Margarita alluvial groundwater basins. Total and dissolved lead were detected (0.24 µg/L and 0.26 µg/L, respectively) in a duplicate sample collected in December 2012 from one groundwater supply well in the middle Santa Margarita alluvial groundwater basin; this was below its respective project screening criterion. No detections of lead were made in the original sample, indicating that these detections do not indicate the existence of a significant issue.

The perchlorate detected in samples collected from groundwater supply wells in the San Mateo, San Onofre, Las Flores, and Santa Margarita alluvial groundwater basins does not indicate the existence of a significant issue. Locations for perchlorate sampling in the Las Flores, San Onofre, and middle Santa Margarita alluvial groundwater basins were selected because of screening-level modeling conducted during the five-year review, while locations in the San Mateo and upper Santa Margarita alluvial groundwater basins were selected on the basis of field data gathered by the installation in 2006. Current information and conservative analysis do not indicate that the perchlorate detected in these latter groundwater basins is attributable to present-day operational training activities. Further, the detected perchlorate concentrations between basins are of similar magnitude and cannot be distinguished from one another. Consequently, it is possible other sources of perchlorate (whether natural or man made) may be present at MCB Camp Pendleton, which may be partially or wholly linked to the perchlorate detections found during this study.

8.4.2. Comparison of Baseline and 5-Year Review Data

An overview of detected MC, along with maximum concentrations, from the baseline and five-year review field data collections is provided in **Table 8-12** (for surface water) and **Table 8-13** (for groundwater). For reference, the applicable screening values for detected MC are provided in both tables. Data for San Mateo watershed is not included since samples were only collected to provide information regarding background concentrations.

Table 8-12: Summary of Detections and Concentrations in Surface Water, REVA Baseline and Five-Year Review

Watershed	MC	DoD Screening Criteria[a] (µg/L)	Maximum Concentration in Surface Water (µg/L)	
			Baseline Assessment	Five-Year Review
Las Flores	Lead, total	Not applicable	23	0.64 J1
	Lead, dissolved	2.5[b]	4.3	0.14 J1
	2,4-Diamino-6-nitrotoluene	Not available	ND	1.1 M J2
	RDX	190	ND	0.28 M J2

Watershed	MC	DoD Screening Criteria[a] (µg/L)	Maximum Concentration in Surface Water (µg/L)	
			Baseline Assessment	Five-Year Review
Las Flores	Perchlorate	15 / 6[c]	NA	ND
San Onofre	Lead, total	Not applicable	74	0.73 J1
	Lead, dissolved	2.5[b]	4.5 J1	ND
	2-Nitrotoluene	Not available	0.70	ND
	3-Nitrotoluene	750	0.11 J1	ND
	RDX	190	2.6	ND

Notes:
J1 – Estimated; the analyte was positively identified; quantitation is an estimation.
J2 – Estimated; quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control data.
M – Manual integrated compound
NA – Not analyzed
ND – Not detected above respective method detection limit
Q – One or more quality control criteria failed (low analyte-specific MSD recovery, high surrogate MSD recovery)
[a] DoD operational range assessment screening values for surface water for ecological receptors.
[b] Provided screening levels for lead assumes a water hardness of 100 µg/L as $CaCO_3$. During the baseline field data collection (Malcolm Pirnie, 2009), the mean hardness value for the Las Flores watershed was 375 mg/L as $CaCO_3$, whereas the mean for San Onofre was 165 mg/L as $CaCO_3$. On the basis of the mean hardness values, adjusted surface water screening values were calculated to be 10.2 µg/L for the Las Flores watershed, and 4.3 µg/L for the San Onofre watershed. During the 2012-2013 study, the mean hardness value for the Las Flores watershed was 313 mg/L as $CaCO_3$. On the basis of this mean hardness value, the adjusted surface water screening value for the Las Flores watershed is 8.5 µg/L.
[c] The California MCL for perchlorate in drinking water (6 µg/L) is included because it is more stringent than the DoD screening level (15 µg/L).
This table only shows MC detections from the baseline assessment and/or five-year review. Other MC not listed in this table were not detected in either event, and results are not presented here.

Table 8-13: Summary of Detections and Concentrations in Groundwater, REVA Baseline and Five-Year Review

Alluvial Basin	MC	DoD Screening Criteria[a] (µg/L)	Maximum Concentration in Groundwater (µg/L)	
			Baseline Assessment	Five-Year Review
Las Flores	Lead, total	15	0.50 J	ND
	Lead, dissolved	15	0.29 J	ND
	RDX	0.61	ND	0.090 J
	Perchlorate	15 / 6[b]	NA	0.44
San Onofre	Lead, total	15	0.27 J	ND
	2-nitrotoluene	0.27	0.12 J	ND
	RDX	0.61	ND	0.091 J
	Perchlorate	15 / 6[b]	NA	0.26
San Mateo	Perchlorate	15 / 6[b]	NA	0.28
Middle Santa Margarita	Lead, total	15	NA	0.024 J
	Lead, dissolved	15	NA	0.026 J
	Perchlorate	15 / 6[b]	NA	0.029 J
Upper Santa Margarita	Perchlorate	15 / 6[b]	NA	0.10

Notes:
J – Estimated; the analyte was positively identified; quantitation is an estimation
NA – Not analyzed
ND – Not detected above respective method detection limit
[a] DoD operational range assessment screening values for drinking water for human receptors.
[b] The California MCL for perchlorate in drinking water (6 µg/L) is included because it is more stringent than the DoD screening level (15 µg/L).
This table only shows MC detections from the baseline assessment and/or five-year review. Other MC not listed in this table were not detected in either event, and results are not presented here.

When comparing the different data sets, it is evident that trace and intermittent levels of MC and lead may be present in some surface water and groundwater:

- In the Las Flores watershed, only total and dissolved lead was detected in surface water during the baseline assessment. During the five-year review, total and dissolved lead was detected in surface water, though not consistently between the January 2012 sampling event and the November 2012 sampling event. Trace amounts of RDX and 2,4-diamino-6-nitrotoluene were found in surface water during the five-year review, whereas they were not detected during the prior study.
- Total and dissolved lead were detected in the Las Flores alluvial groundwater basin during the baseline assessment, while lead was not detected in samples collected during the five-year review. Trace RDX also was detected in one groundwater sample during the five-year review. Additional sampling conducted by the installation following this sampling did not detect the presence of RDX.
- In the San Onofre watershed, total and dissolved lead, RDX, 3-nitrotoluene, and 2-nitrotoluene were detected in surface water during the baseline assessment, while only total lead was detected in surface water during the five-year review. Dissolved lead and explosives were not detected in any samples collected from the San Onofre watershed during the five-year review.
- Total lead and 2-nitrotoluene were detected in the San Onofre alluvial groundwater basin during the baseline assessment, while only RDX was detected in raw groundwater samples from one water supply well; no lead was detected during the five-year review. Regardless, all detected concentrations were at very low concentrations.
- Perchlorate was only evaluated during the five-year review field sampling effort. Only surface water samples collected at one location in the Las Flores watershed were analyzed for perchlorate, but there were no detections. Detections were found across all the sampled alluvial groundwater basins during the 2011–2012 and 2012–2013 studies. However, all detections were at very low concentrations.

Examining potential differences between the baseline and five-year data collection efforts is limited by variability in hydrologic conditions, fire conditions, and sampling timing. During the 2007–2008 winter season, numerous storms occurred in quick succession. The winter season was preceded by severe wildfires burning the Las Flores and San Onofre watersheds, which removed vegetation and increased potential for erosion and sediment transport. MC transport would be expected to be high under such conditions. Precipitation during the 2011–2012 and 2012–2013 winter seasons was below average and significantly less than that encountered during the baseline data collection effort. The 2011–2012 season followed a couple years of heavy, above-average precipitation, allowing for the possibility of relatively more established vegetation in the watersheds. Consequently, unlike the baseline effort, there were limited opportunities during the 2011–2012 and 2012–2013 seasons to collect surface water samples. Notably, there was no opportunity to collect surface water samples at the San Onofre watershed following a storm since there was insufficient stream flow. Additionally, given the sampling protocol utilized for data collections efforts, these data represent snapshots of potential off-range MC migration and do not account for the full variability that may occur over an entire season or longer period of time.

Regardless, detections of explosives and lead in surface water and groundwater were at very low concentrations during both events and fell under prescribed project screening criteria with one exception. During the baseline assessment, dissolved lead was detected in a single surface water sample from the San Onofre watershed at a concentration slightly higher than its hardness-adjusted screening value; however, it was not detected again during sampling conducted later in the baseline wet season. Perchlorate was assessed only during the latest sampling efforts; while it was detected multiple times across the sampled alluvial groundwater basins, concentrations were very low and did not represent a significant issue with respect to applicable screening criteria.

8.4.3. Further Actions

As noted in **Section 8.4.1**, the MC and lead found at MCB Camp Pendleton during the five-year field data collection effort indicate no significant concern with respect to screening criteria. The data indicate these constituents may be intermittently present. Notably, the estimated concentration of RDX found during October 2011 at a water supply well in the Las Flores basin falls just under its applicable DoD screening level, though additional sampling by the installation did not detect the presence of this constituent. Estimated concentrations of RDX were also found during December 2012 at a water supply well in the San Onofre basin; these fall under the applicable DoD screening level. Annual field sampling should continue as a proactive measure. Additional data will allow continued assessment of fluctuations in MC migration, as well as further examine seasonal variations that could impact MC fate and transport processes. Since quantitative screening-level assessment of lead migration from large MC loading areas is not possible without site-specific information, further consideration of lead deposition associated with the San Mateo and San Onofre watersheds may be warranted.

As previously noted, perchlorate was not sampled in previous REVA efforts. The initial design of the field data collection efforts is based upon modeling conducted during the REVA baseline assessment, which did not predict perchlorate transport. This five-year review updates the information that the modeling utilizes, including incorporation of current training patterns and up-to-date environmental data. Analysis during the five-year review (**Section 6**) indicated perchlorate potentially may be migrating in surface water to alluvial groundwater basins, reaching drinking water wells in the Las Flores and San Onofre watersheds. Modeling also indicated perchlorate loading associated with the Range 104B MC loading area potentially may transport through the vadose zone and reach groundwater in the middle Santa Margarita alluvial basin, which in turn may reach drinking water wells. Though results from the additional groundwater sampling performed during this five-year review to address these modeling results showed perchlorate to be below applicable project screening criteria, further evaluation of perchlorate in the San Onofre, Las Flores, and middle Santa Margarita alluvial basins should be conducted as a proactive measure.

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