6. Screening-Level Assessment Results

Primary 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 primary MC loading areas are presented within this section based on the hydrologic watershed basins within which they are located, since multiple primary MC loading areas fall within each watershed.

- Bristol Dry Lake Watershed (**Section 6.1**)
- Dry Lake Watershed of (**Section 6.2**)
- Dale Lake Watershed (**Section 6.3**)
- Deadman Lake Watershed (**Section 6.4**)
- Lavic Lake Watershed (**Section 6.5**)
- Quackenbush Lake Watershed (**Section 6.6**)

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

Table 6-1: Primary MC Loading Areas

Primary MC Loading Area	Size of MC Loading Area	
	Acres	1,000 m^2
Bristol Dry Lake		
Lead Mountain I	4,484	18,144
Lead Mountain II/Bullion	2,483	10,047
Delta	6,243	25,263
Lava	853	3,453
Prospect	4,329	17,518
Dry Lake		
Lead Mountain I	4,484	18,144
Lava	853	3,453
Black Top I	3,626	14,675
Black Top II	2,424	9,810

Primary MC Loading Area	Size of MC Loading Area	
	Acres	1,000 m^2
Dale Lake		
Cleghorn Pass I	1,267	5,127
Cleghorn Pass II	1,913	7,742
Prospect	4,329	17,518
Delta	6,243	25,263
Deadman Lake		
Range I	2,488	10,070
Range II	1,703	6,891
Range III	735	2,976
Range IV	4,745	19,203
Quackenbush	7,744	31,341
Lavic Lake		
Gays Pass I	2,364	9,568
Gays Pass II	2,167	8,771
Lavic Lake I	2,789	11,287
Lavic Lake II	4,072	16,479
Quackenbush Lake		
Gays Pass I	2,364	9,568
Quackenbush	7,744	31,341

All identified primary MC loading areas underwent screening-level modeling during the five-year review.

The section for each hydrologic watershed basin 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 18 MC loading areas located within six watershed areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages 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. Also estimated were MC concentrations in surface water runoff entering identified downstream receptor exposure locations (playa

lakes) and MC concentrations in the sediment of playa lake beds resulting from potential MC accumulation as a result of water evaporating from the playa lakes.

MC concentrations in surface water runoff at the edge of all MC loading areas were estimated to be above REVA trigger values, while MC concentrations in sediment at the edge of all MC loading areas were estimated to be below REVA trigger values. Annual average MC concentrations in surface water runoff entering five playa lakes were predicted to be above REVA trigger values, and the cumulative MC concentrations in the sediment of all identified playa lake beds were predicted to be above REVA trigger values. The results of the surface water and sediment screening-level analyses for the 18 MC loading areas are discussed in detail in **Section 6.1.2**, **Section 6.2.2**, **Section 6.3.2**, **Section 6.4.2**, **Section 6.5.2**, and **Section 6.6.2**.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for five MC loading areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and their proximity to potential future groundwater receptors. The initial groundwater screening-level analysis predicted MC concentrations at MC loading areas leaching into the vadose zone above REVA trigger values. Therefore, vadose zone modeling was conducted at the MC loading areas. Subsequent screening-level analysis of the saturated zone at the MC loading areas was not conducted because results of the vadose zone modeling indicated no current concern of MC migration to groundwater, and there are no current water supply wells within the study area or pathway to ecological receptors is unlikely. The results of the groundwater screening-level analysis for the five MC loading areas are discussed in detail in **Section 6.1.3, Section 6.2.3, Section 6.3.3, Section 6.4.3, Section 6.5.3, and Section 6.6.3**.

6.1. Bristol Dry Lake Watershed

The Bristol Dry Lake Watershed is located in the eastern part of MCAGCC Twentynine Palms; it is approximately 471,700 acres, with a large part of the area (approximately 80%) located outside of MCAGCC Twentynine Palms (**Figure 6-1**). The watershed area encompasses an ephemeral stream network and Bristol Dry Lake playa. Bristol Dry Lake, which is a potential receptor exposure location, is located outside of the installation boundary. Part or all of eight RTAs are located within the watershed:

- America Mine (20,809 acres)
- Bullion (28,129 acres)
- Lead Mountain (53,314 acres)
- Cleghorn Pass (36,358 acres)

- Lava (22,925 acres)
- Delta (29,791 acres)
- Prospect (13,189 acres)
- Noble Pass (24,315 acres)

Five primary MC loading areas partially or fully located within the eight RTAs where the majority of MC deposition is anticipated to occur are listed in **Table 6-2**.

Table 6-2: Primary MC Loading Areas in the Bristol Dry Lake Watershed

Primary MC Loading Area	Size (acres)
Lead Mountain I	4,484
Lead Mountain II / Bullion	2,483
Lava	853
Delta	6,243
Prospect	4,329

Military Munitions

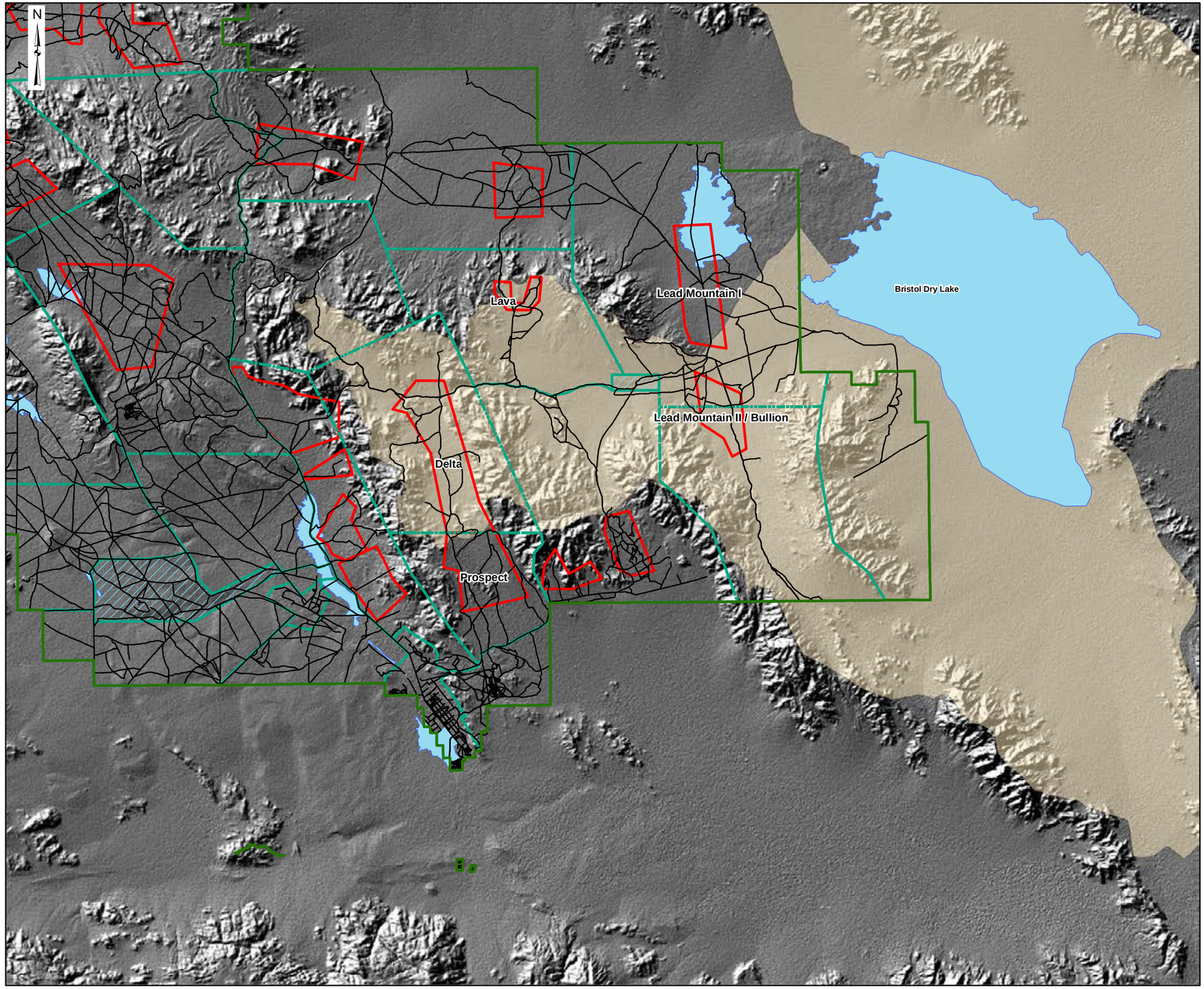
The general classes of military munitions expected in this RTA include small arms ammuntions high explosive munitions.

6.1.1. Conceptual Site Model

6.1.1.1. Estimated Munitions Constituents Loading

The primary MC loading areas within the Bristol Dry Lake Watershed are shown in **Figure 6-1**. The boundaries of each primary 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 within this MC loading area over time (**Table 6-3**); the assumptions used to guide the estimates are detailed in **Section 3**. Compared to estimated baseline MC loading rates derived from munitions data available during the prior assessment, the estimated MC loading rates for this review suggest loading has increased since the baseline assessment (**Table 6-3**).



REVA
FIGURE 6-1
MCAGCC TWENTYNINE PALMS
PRIMARY MC LOADING AREAS WITHIN THE BRISTOL DRY LAKE WATERSHED

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- MC Loading Areas
- Range Training Areas (RTAs)
- Restricted Areas
- Bristol Dry Lake Watershed
- Playa
- Main Supply Routes

0 1.25 2.5 5 7.5
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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Notably, estimated HMX loading increased from two to six orders of magnitude across the primary MC loading areas in this watershed. Estimated RDX and TNT loading in Bullion and Lead Mountain RTAs has increased one to two orders of magnitude; estimated TNT loading in the Lava RTA increased by one order of magnitude. Lastly, estimated perchlorate loading has increased one to three orders of magnitude in the Bullion, Lava, and Lead Mountain RTAs.

Table 6-3: Estimated MC Loading Rates for the Bristol Dry Lake Watershed

Primary MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)				
		Time Period F (2006–2010)				
		Assessment	HMX (kg/m^2)	RDX (kg/m^2)	TNT (kg/m^2)	Perchlorate (kg/m^2)
Delta	32,124,000	Baseline	1.39E-11	2.04E-07	3.82E-07	1.02E-10
	25,263,439	Five-year Review	2.28E-09	1.99E-07	2.94E-07	3.45E-10
Lava	9,220,000	Baseline	1.65E-12	1.17E-07	1.86E-07	1.41E-12
	3,452,938	Five-year Review	1.56E-08	7.79E-07	1.06E-06	3.52E-09
Bullion	11,684,000	Baseline	2.76E-13	5.98E-08	5.49E-08	2.66E-10
Lead Mountain	44,585,000	Baseline	1.42E-12	1.36E-07	1.84E-07	5.88E-11
Lead Mountain I	18,144,380	Five-year Review	3.02E-07	1.81E-06	1.91E-06	1.67E-10
Lead Mountain II / Bullion	10,046,505	Five-year Review	2.85E-07	2.14E-06	2.65E-06	2.98E-08
Prospect	17,518,000	Baseline	8.22E-12	1.28E-07	1.21E-07	3.87E-10
	17,517,863	Five-year Review	8.63E-10	1.41E-07	1.44E-07	5.16E-10

Note:

Estimated "Baseline" MC loading rates are based on "Period E" values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping, which would suggest a lower loading rate than actually occurring during that assessment. "Five-year Review" values cover 2006 to 2010.

Annual lead deposition for the MC loading areas in the Bristol Dry Lake 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 lead loading estimates. Calculations indicate the most concentrated lead deposition in the watershed may be at the Lava MC loading area with an estimated 1.35E-04 kg/m^2, while the largest deposition by mass may be found at Lead Mountain II / Bullion MC loading area with 2,758 lb of lead annually.

Table 6-4: Estimated Annual Lead Deposition for the Bristol Dry Lake Watershed

MC Loading Area	Size (m^2)	Lead		
		kg/m^2	lb/yd^2	Total lb
Delta	2.53E+07	4.36E-05	8.04E-05	2,428
Lava	3.45E+06	1.35E-04	2.49E-04	1,030
Lead Mountain I	1.81E+07	9.01E-05	1.66E-04	3,603
Lead Mountain II / Bullion	1.00E+07	1.25E-04	2.30E-04	2,758
Prospect	1.75E+07	5.10E-05	9.41E-05	1,971

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

6.1.1.2. Geography and Topography

The Bristol Dry Lake watershed is characterized by rugged terrain consisting of desert, mountains, and playa. The watershed area consists of the Bullion Mountains in the western part of the watershed and the Bristol Dry Lake playa in the east bordering the installation boundary. Most of the terrain lies on the intramountain basin and generally slopes toward the center of the watershed area and then east, with broad alluvial plains and fans and ephemeral washes. Available elevation contour data indicate the elevation of the watershed area within the installation boundary ranges from approximately 328 ft amsl in Bristol Dry Lake playa to approximately 4,133 ft amsl at the Bullion Mountains (MCAGCC Twentynine Palms FMD, 2010). Based on available GIS data, the slope within the installation boundary of the watershed area can range from nearly level to approximately 60% in the mountain hills, but the majority of area has a slope ranging from approximately 2% to 8% (MCAGCC Twentynine Palms FMD, 2006).

6.1.1.3. Surface Water Features

The Bristol Dry Lake watershed contains an ephemeral stream network with a combination of dendritic and parallel drainage patterns. Streams flow in northeast, southeast, and east directions and ultimately discharge into Bristol Dry Lake, which borders the eastern boundary of MCAGCC Twentynine Palms. All of Lead Mountain II / Bullion and most of Delta and Lava MC loading areas drain within the Bristol Dry Lake watershed. In addition, small proportions of Lead Mountain I and Prospect MC loading areas drain within the Bristol Dry Lake watershed.

Table 6-5 describes the drainage characteristics of the five primary MC loading areas within the Bristol Dry Lake watershed.

Table 6-5: Drainage Description for the MC Loading Areas within the Bristol Dry Lake Watershed

Primary MC Loading Area	Drainage Description
Lead Mountain II / Bullion	The ephemeral stream networks drain northeast within the MC loading area and discharge into the Bristol Dry Lake approximately 4.9 miles downstream of the MC loading area.
Delta	A tributary stream network drains north within the MC loading area and converges with the major ephemeral stream network that drains east and discharges into the Bristol Dry Lake approximately 14.6 miles east and downstream of the MC loading area.
Lava	Tributary ephemeral streams drain south from within the MC loading area and converges with the major stream network that drains east into the Bristol Dry Lake.
Lead Mountain I	The major ephemeral stream network drains northeast within the southeastern end of the MC loading area (within approximately 2% of the loading area) and discharges into the Bristol Dry Lake approximately 3.8 miles downstream of the MC loading area. A large proportion of the MC loading area (approximately 98%) drains within the Dry Lake watershed.
Prospect	A small proportion of the MC loading area (approximately 2%) drains north into a tributary stream network that drains north and converge with the major ephemeral stream network that drains east into Bristol Dry Lake. The remaining proportion of the MC loading area drains within the Dale Lake watershed.

6.1.1.4. Soil Characteristics and Land Cover

The predominant soil types of the Bristol Dry Lake watershed within the installation boundary include Goldroad-Dalvord-Rock outcrop (416) and Carrizo complex (313). These soils are excessively well drained and are slightly to moderately alkaline. The organic contents of the soils range from 0% to 0.5%, with the Carrizo complex having a lower organic content of 0% to 0.2% and the Goldroad-Dalvord-Rock outcrop having an organic content of 0% to 0.5% (USDA NRCS, 1999). The soil types have low inherent soil erodibility, with soil erodibility factors ranging from 0.02 to 0.05 tons per acre (tons/acre). The watershed area is largely covered with sparse vegetation mostly consisting of Creosote Bush Shrubland and some Creosote Bush and Brittlebush Mosaic. A small portion of the watershed area includes lava beds and cider cones.

6.1.1.5. Erosion Potential

The estimated soil erosion potential of the five identified primary MC loading areas within the Bristol Dry Lake watershed ranges from low to moderate. The Lead Mountain I MC loading area, which has a small proportion of the loading area draining within the

Bristol Dry Lake watershed, was estimated to have a moderate soil erosion potential, and all the other remaining four primary MC loading areas draining within the Bristol Dry Lake watershed were estimated to have low soil erosion potential. The moderate soil erosion potential estimated at Lead Mountain I MC loading area is a result of the higher inherent soil erodibility factor within the loading area, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the area. The MC loading areas with low estimated soil erosion potentials generally have low inherent soil erodibility factor and lower topographic slopes.

6.1.1.6. Groundwater Characteristics

The Bristol Dry Lake Watershed area lies in the Bristol Valley and the Dale Valley intramountain groundwater basins (**Figure 4-2**). A larger proportion of the watershed area lies within the Bristol Valley groundwater basin. Groundwater within these basins occurs in unconsolidated alluvial deposits. There are limited data available for these groundwater basins, but the water-bearing units in the basins are generally similar to the aquifer units known to exist within the Twentynine Palms basin described in **Section 4.5**. Northwest-trending faults within the basins create groundwater subbasins. In the Bristol Valley basin, this is evidenced by different water chemistries observed in wells that lie on opposite sides of the Ludlow fault, which trends down the basin axis (Koehler, 1983).

In the Bristol Valley basin, perched groundwater zones exist near Bristol Dry Lake and Dry Lake, with water levels recorded at 14 to 89 ft bgs (Koehler, 1983). The perched groundwater tables are assumed to be limited in extent based on the available groundwater data and the relatively small aerial extent of the playas. It is uncertain if the perched groundwater recharges the deeper aquifer system. Depth to groundwater in the deeper aquifer system within this basin ranges from 124 to 300 ft bgs.

Subsurface data are not available for the Dale Valley intramountain basins found within the Bullion Mountains. The subsurface conditions in these areas are expected to be similar to the Bristol Valley and the Twentynine Palms groundwater basins, with a few exceptions: 1) the water-bearing sedimentary deposits are expected to be thinner with proximity to the exposed bedrock outcrops and 2) the average grain size that composes the subbasins is expected to be coarser due to the proximal position of the basin with respect to the bedrock source, potentially affecting the average hydraulic conductivity (Malcolm Pirnie, 2007). The limited data available from the Lava RTA indicate a depth to groundwater of 127 ft bgs within the Dale Valley intramountain basin (Almgren and Koptionak, 1993).

6.1.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Bristol Dry Lake watershed. Runoff coefficients at primary MC loading areas were assumed to range from 0.41 to 0.55. These relatively high runoff potentials are attributable to the infrequent torrential storms that occur (often resulting in flash floods), the sparse vegetation covers, and the moderate topographic slopes at the identified primary MC loading areas. As indicated in **Section 6.1.1.5**, many of the MC loading areas within the watershed have low soil erosion potential, making land surface erosion a less important mechanism for MC mobilization into surface water runoff. However, erosion due to the occurrence of flash flood events can be an important MC pathway to the potential downstream receptor exposure location in Bristol Dry Lake. MC in streams would drain northeast, southeast, and east, and ultimately discharge into Bristol Dry Lake.

Groundwater Pathways

MC deposited on the primary MC loading areas within the Bristol Dry Lake watershed have the potential to migrate toward the water table by dissolution into precipitation and subsequent infiltration into the subsurface. However, such vertical migration of MC to groundwater is limited due to 1) the infrequent nature of rainfall in the area (less than 5 in/yr), 2) the high evaporation rate, and 3) the depth to groundwater. MC from the primary MC loading areas can also likely be transported to groundwater through preferential recharge from the infrequent stream flow along the ephemeral streambeds and dry washes. The potential groundwater flow pathway is 1) southward off the installation boundary in the western part of the watershed area where the Delta MC loading area is located, 2) eastward in the central part of the watershed area, and 3) northward toward Dry Lake playa in the eastern part of the watershed area where Lead Mountain II / Bullion and portions of the Lead Mountain I MC loading area are located (**Figure 4-2**).

6.1.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

The Bristol Dry Lake playa supports salt mining operations where there could be potential human exposure pathways through dermal contact during the salt mining process. Additionally, if consumed, water and sediment accumulated in the Bristol Dry Lake playa may present potential exposure pathways for ecological species, including the federally and state threatened desert tortoise and the California special concern species MFTL.

Groundwater Receptors

There are no known drinking water wells within the Bristol Dry Lake watershed, and a complete groundwater pathway to ecological receptors is unlikely. Groundwater (shallow or perched groundwater under Bristol Dry Lake and from deeper groundwater bearing zones) is used as brine source for salt production at the salt mine operations in Bristol Dry Lake; however, groundwater from the primary MC loading areas within the Bristol Dry Lake watershed does not flow toward Bristol Dry Lake (**Figure 4-2**). The low permeable soils underlying the Bristol Dry Lake playa would prevent infiltration of accumulated surface water potentially containing MC in the lake down to the underlying perched groundwater.

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 five primary MC loading areas that drain to the Bristol Dry Lake playa. The MC loading areas included Lead Mountain I, Lead Mountain II / Bullion, Delta, Lava, and Prospect. These MC loading areas were selected for screening-level analysis based on their current use of munitions containing HE and surface drainages that lead to potential receptor exposure location in the Bristol Dry Lake playa (sediment human exposure through dermal contact and threatened and California special concern species). 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 conducted for time period matching the estimated MC loading period (2006–2010 [Period F]). The proportions of the MC loading areas draining to the Bristol Dry Lake are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Bristol Dry Lake watershed.

Table 6-6 presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to the Bristol Dry Lake, respectively. The Lead Mountain II / Bullion MC loading area was predicted to contribute the highest proportion of all four MC mass (over 65%) to the Bristol Dry Lake playa. The Delta MC loading area was predicted to contribute higher percentages of RDX and TNT mass than the Lava, Prospect, and Lead Mountain I MC loading areas (**Table 6-6**).

Table 6-6: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the Bristol Dry Lake

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Lead Mountain II / Bullion	93	69	72	93
Lava	2	10	8	4
Prospect	<1	<1	<1	<1
Delta	2	19	18	3
Lead Mountain I	4	2	1	<1

Table 6-7 and **Table 6-8** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the Bristol Dry Lake watershed. Based on the screening-level calculations, the average annual concentrations of RDX and TNT in runoff at the edge of all MC loading areas were predicted to be above REVA trigger values (**Table 6-7**). The average annual concentrations of HMX and perchlorate in runoff were predicted to be above REVA trigger values at the edge of three (Lead Mountain II / Bullion, Lava and Lead Mountain I) and two (Lead Mountain II/Bullion and Lava) MC loading areas, respectively (**Table 6-7**). The average annual MC concentrations in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values (**Table 6-8**).

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

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Water (µg/L)	0.114	0.110	0.113	0.021
MC Concentration (µg/L)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Lead Mountain II / Bullion	**4.37**	**4.22**	**13.74**	**0.564**
Lava	**0.204**	**1.47**	**3.78**	**0.055**
Prospect	0.012	**0.273**	**0.508**	0.009
Delta	0.027	**0.352**	**1.040**	0.005
Lead Mountain I	**4.44**	**3.54**	**6.77**	0.003

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

Table 6-8: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Bristol Dry Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Sediment (µg/kg)	51	32.5	25	0.18
MC Concentration (µg/kg)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Lead Mountain II / Bullion	0.009	0.019	4.18	~0
Lava	~0	0.012	2.00	~0
Prospect	4.25E-05	0.002	0.268	~0
Delta	9.02E-05	0.003	0.520	~0
Lead Mountain I	0.017	0.031	~0	~0

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff entering the Bristol Dry Lake, the identified downstream receptor exposure location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of MC in surface water runoff entering the Bristol Dry Lake were predicted to be below REVA trigger values (**Table 6-9**).

Table 6-9: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff Entering the Bristol Dry Lake

MC	REVA Trigger Value (µg/L)	Concentration (µg/L)
HMX	0.114	0.025
RDX	0.110	0.030
TNT	0.113	0.094
Perchlorate	0.021	0.003

Average annual MC concentrations in sediment entering the downstream receptor exposure location in Bristol Dry Lake were not estimated because the edge-of-loading-area MC concentrations in sediment were predicted to be below REVA trigger values (**Table 6-10**), and the concentrations are expected to be even lower in the downstream location in Bristol Dry Lake. However, MC concentrations in the playa lakebed were estimated (as described in **Section 5.1.2**), and the results are presented in **Table 6-10**. The cumulative perchlorate concentration in the sediment of the Bristol Dry Lake bed was predicted to be above the REVA trigger value (**Table 6-10**).

Table 6-10: Screening-Level Estimates of Cumulative MC Concentrations in the Sediment of Bristol Dry Lake Bed

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
HMX	51	4.7–470	2.45
RDX	32.5	13 –1300	3.20
TNT	25	92–9200	9.91
Perchlorate	0.18	NA	**0.314**

Note:
NA – not available (screening level was not developed due to the lack of data on the constituent)
Shading and bold indicate concentration exceeds the REVA trigger value.

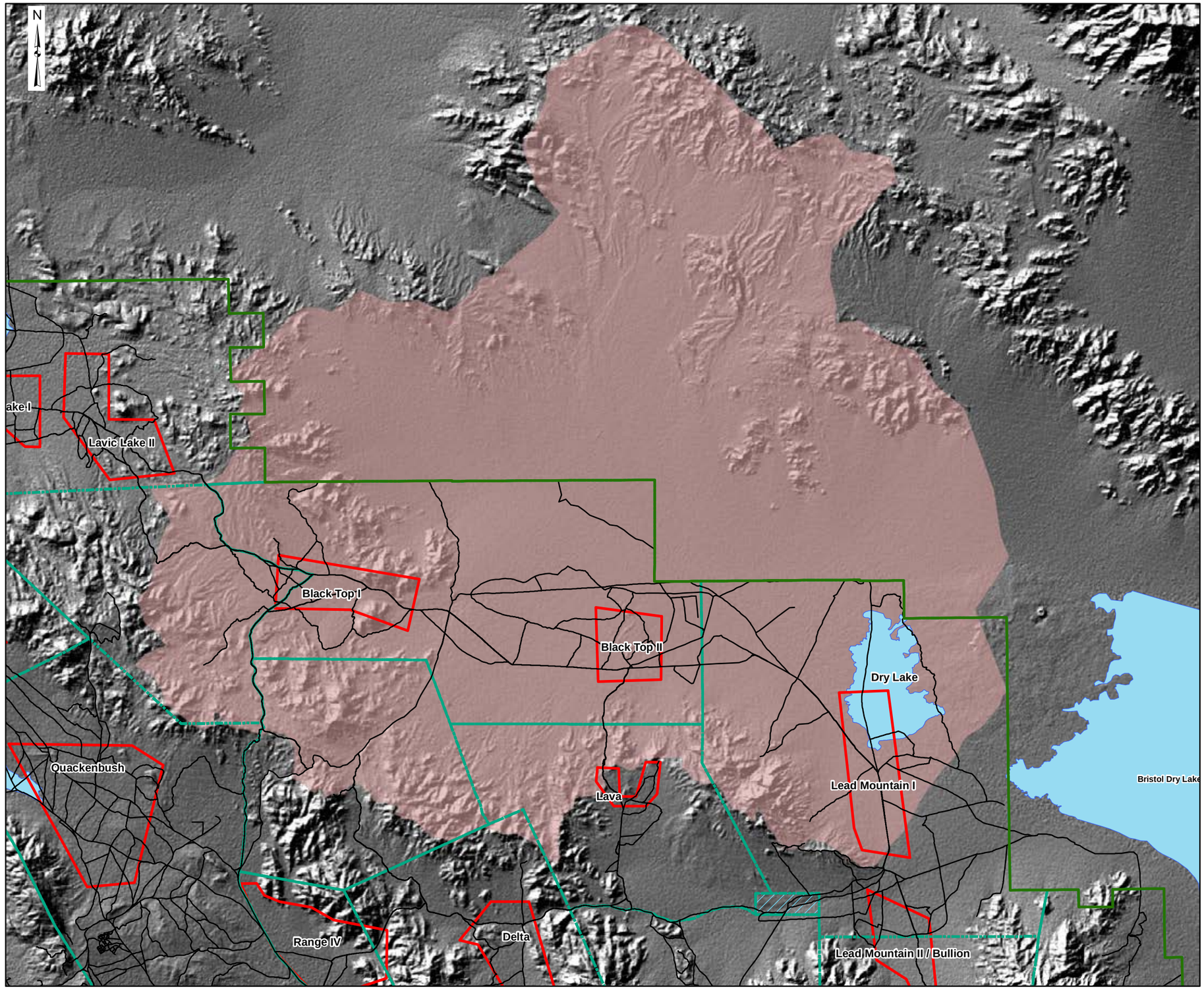
The actual perchlorate concentration in the sediment of the playa lakebed is expected to be lower because of the conservative approach used in the screening-level analysis, where loss terms (such as degradation and volatilization) were not used and only land surface erosion was considered. In the absence of a perchlorate dry sediment or soil RMUS screening value, the perchlorate soil screening value for human receptors, developed by the State of California's Office of Environmental Health Hazard Assessment (OEHHA), was reviewed and compared to the estimated cumulative sediment concentration of perchlorate in the Bristol Dry Lake bed. The soil screening number for perchlorate in soil at commercial/industrial sites is 3,500 mg/kg, which is significantly greater (approximately seven orders of magnitude) than the concentration estimated to have accumulated in the Bristol Dry Lake playa.

6.1.3. Groundwater Analysis Results

A qualitative groundwater analysis was performed by analyzing the source media, migration mechanisms, and exposure pathways (as described in the earlier subsections and in **Section 4**). Based on the results of the qualitative analysis of the groundwater information, limited potential exists for MC migration to groundwater and no known groundwater receptor exposure locations are present down gradient of the MC loading areas located within the Bristol Dry Lake watershed. Therefore, the MC loading areas within the Bristol Dry Lake watershed are not considered areas of concern for MC migration in groundwater; no further analysis is required at this time.

6.2. Dry Lake Watershed

The Dry Lake watershed is located on the northeastern part of MCAGCC Twentynine Palms; it is approximately 251,100 acres, with nearly one-half the watershed area located within MCAGCC Twentynine Palms (**Figure 6-2**). The watershed area encompasses an ephemeral stream network and the Dry Lake playa. Dry Lake playa, which is a potential



REVA
FIGURE 6-2
MCAGCC TWENTYNINE PALMS
PRIMARY MC LOADING AREAS WITHIN THE DRY LAKE WATERSHED

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- Dry Lake Watershed
- MC Loading Areas
- Restricted Areas
- Playa
- Main Supply Routes

0 1 2 4 6
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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receptor exposure location, is located within the installation boundary. Part or all of six RTAs are located within the watershed:

- Lavic Lake (56,985 acres)
- Rainbow Canyon (25,348 acres)
- Lead Mountain (53,314 acres)
- Lava (22,925 acres)
- Blacktop (50,894 acres)
- Noble Pass (24,315 acres)

These areas are operational live-fire RTAs and are used for various training activities; allowable munitions for these areas include all conventional munitions (air/ground) where the safety footprint can remain within 1000 m from the RTA or installation boundary.

A brief summary of four primary MC loading areas partially or fully located within the six RTAs where the majority of MC deposition is anticipated to occur is listed in **Table 6-11**.

Table 6-11: Primary MC Loading Areas in the Dry Lake Watershed

MC Loading Area	Size (acres)
Black Top I	3626
Black Top II	2424
Lava	853
Lead Mountain I	4484

Military Munitions

The general class of military munitions expected in this RTA are high explosive munitions.

6.2.1. Conceptual Site Model

6.2.1.1. Estimated Munitions Constituents Loading

The primary MC loading areas within the Dry Lake watershed are shown in **Figure 6-2**. The boundaries of each primary 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 within this MC loading area over time (**Table 6-12**); the assumptions used to guide the estimates are detailed in **Section 3**. Compared to estimated baseline MC loading rates derived from munitions data available during the prior assessment, the estimated MC loading rates for this review suggest loading generally has increased since the baseline assessment (**Table 6-12**). Notably, estimated HMX loading increased from two to five orders of magnitude across the MC loading areas in this watershed; TNT loading increased by an order of magnitude across the watershed. Estimated RDX loading in Lead Mountain has increased one order of magnitude, while estimated perchlorate loading in the Black Top and Lava RTAs increased by two to three orders of magnitude.

Table 6-12: Estimated Annual MC Loading for the Dry Lake Watershed

Primary MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)				
		Time Period F (2006–2010)				
		Assessment	HMX (kg/m^2)	RDX (kg/m^2)	TNT (kg/m^2)	Perchlorate (kg/m^2)
Black Top	47,099,000[a]	Baseline	3.30E-11	2.22E-07	3.05E-07	1.86E-10
Black Top I	14,674,765	Five-year Review	2.45E-09	5.14E-07	1.33E-06	4.04E-08
Black Top II	9,810,335	Five-year Review	1.72E-09	5.21E-07	1.34E-06	4.03E-08
Lava	727,100	Baseline	1.65E-12	1.17E-07	1.86E-07	1.41E-12
	3,452,938	Five-year Review	1.56E-08	7.79E-07	1.06E-06	3.52E-09
Lead Mountain	44,585,000	Baseline	8.22E-12	1.28E-07	1.21E-07	3.87E-10
Lead Mountain I	18,144,380	Five-year Review	3.02E-07	1.81E-06	1.91E-06	1.67E-10

Note:
Estimated "Baseline" MC loading rates are based on "Period E" values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping, which would suggest a lower loading rate than actually occurring during that assessment. "Five-year Review" values cover 2006 to 2010.

[a] Represents the total combined area of the Black Top 1 and Black Top 2 primary MC loading areas from the baseline report

Annual lead deposition for the RTAs in the Dry Lake watershed was estimated during this five-year review (**Table 6-13**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimation of the total amount of lead deposited in a given MC loading area. The baseline assessment did not include lead loading estimates. Calculations indicate the most concentrated lead deposition in the watershed may be at the Lava MC loading area with an estimated 1.35E-04 kg/m^2

annually, while the largest deposition by weight may be found at Lead Mountain I MC loading area with 3,603 lb of lead annually.

Table 6-13: Estimated Annual Lead Deposition for the Dry Lake Watershed

Primary MC Loading Area	Size (m^2)	Lead		
		kg/m^2	lb/yd^2	Total lb
Black Top I	1.47E+07	2.00E-05	3.68E-05	647
Black Top II	9.81E+06	2.00E-05	3.69E-05	432
Lava	3.45E+06	1.35E-04	2.49E-04	1,030
Lead Mountain I	1.81E+07	9.01E-05	1.66E-04	3,603

6.2.1.2. Geography and Topography

The Dry Lake Watershed is characterized by rugged terrain consisting of mountains, playa, and level flat land. The watershed boundary on the south borders the Bullion Mountains, and the Dry Lake playa is located on the southeastern part of the watershed area. Basaltic lava fields are located on the southeastern part of the watershed, east of Dry Lake playa. The terrain generally slopes from northwest to southeast and from southwest to northeast toward the Dry Lake playa. Available elevation contour data indicate the elevation of the watershed area within the installation boundary ranges from approximately 689 ft amsl close to the Dry Lake playa to approximately 4,231 ft amsl at the Bullion Mountains (MCAGCC Twentynine Palms FMD, 2010). Based on available GIS data, the slope within the installation boundary of the watershed area can range from less than 2% to approximately 60% in the mountain hills, but the majority of the area has an average slope of approximately 7% (MCAGCC Twentynine Palms FMD, 2006).

6.2.1.3. Surface Water Features

The Dry Lake Watershed contains an ephemeral stream network. The stream network originates outside the installation boundary and drains southward into Dry Lake playa. The main stream channel of the ephemeral stream network within the installation drains in a northeast direction into Dry Lake. All of the Black Top I and the Black Top II, a significant proportion of the Lead Mountain I, and a small proportion of the Lava primary MC loading areas drain within the Dry Lake watershed.

Table 6-14 describes the drainage characteristics of the four primary MC loading areas within the Dry Lake Watershed.

Table 6-14: Drainage Description for the MC Loading Areas within the Dry Lake Watershed

Primary MC Loading Area	Drainage Description
Black Top I	A tributary stream network drains east within the MC loading area, then northeast from the loading area and converges with the main ephemeral stream channel, which drains southeastward into the Dry Lake playa.
Lava	The small proportion of the MC loading area (approximately 2%) that drains within the Dry Lake watershed drains north into tributary ephemeral streams, which drain northeast into the main stream channel. The main stream channel drains southeast into the Dry Lake playa. The remaining larger proportion of the MC loading area drains within the Bristol Dry Lake watershed.
Black Top II	Tributary ephemeral streams drain east within the MC loading area and converge with the mains stream channel, which drains southeast into Dry Lake playa.
Lead Mountain I	Ephemeral streams drain north and northeast within a large proportion of the MC loading area (approximately 98%) into Dry Lake playa. The remaining proportion of the MC loading area drains within the Bristol Dry Lake watershed.

6.2.1.4. Soil Characteristics and Land Cover

The predominant soil types of the Dry Lake watershed within the installation boundary include Carrizo complex (313), Bristolake-Carrizo association (252), Noble Pass-Pacific Mesa-Sunrock complex (407), Haleburu-Noble Pass complex (406), and Sunrock-Haleburu-Lava flows association (141). These soils are well to excessively well drained and are slightly to strongly alkaline. The organic content of the soils ranges from 0% to 0.5%, with the Carrizo complex having a lower organic content of 0% to 0.2%, while the other soil types having an organic content of 0% to 0.5% (USDA NRCS, 1999). The soil types have low inherent soil erodibility, with their soil erodibility factors ranging from 0.02 to 0.1 tons/acre. The Bristolake-Carrizo association and the Sunrock-Haleburu-Lava flows association can have the upper range soil erodibility factor of 0.1 tons/acre, while the soil erodibility factors for the other soil types range from 0.02 to 0.05 tons/acre (USDA NRCS, 1999). The watershed area is largely covered with sparse vegetation mostly consisting of Creosote Bush Shrubland. A small portion of the watershed area includes lava beds and cinder cones.

6.2.1.5. Erosion Potential

The estimated soil erosion potential of the four identified primary MC loading areas within the Dry Lake watershed ranges from low to moderate. The Black Top I and The Lead Mountain I MC loading areas were estimated to have moderate soil erosion potential, and the remaining two MC loading areas within the watershed (Black Top II

and Lava) were estimated to have low soil erosion potential. The moderate soil erosion potential estimated at Black Top I and Lead Mountain I MC loading areas is a result of higher topographic slope or higher soil erodibility factor, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas. The MC loading areas with low estimated soil erosion potentials generally have low inherent soil erodibility factor and lower topographic slopes.

6.2.1.6. Groundwater Characteristics

The Dry Lake watershed area lies in the Bristol Valley groundwater basin (**Figure 4-2**), for which limited hydrogeologic information exists. Groundwater within this basin occurs in unconsolidated alluvial deposits. The groundwater characteristics for the Bristol Valley basin are presented in **Section 6.1.1.6**.

6.2.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Dry Lake watershed. Runoff coefficients at primary MC loading areas were assumed to range from 0.41 to 0.57. These relatively high runoff potentials are largely attributable to the infrequent torrential storms that occur (often resulting in flash floods), the sparse vegetation covers, and the moderate to high topographic slopes at the identified primary MC loading areas within the watershed. The loading area with the highest runoff coefficient (Black Top I) has a soil type with a high runoff potential and a relatively high topographic slope. As indicated in **Section 6.2.1.5**, the primary MC loading areas within the watershed have low or moderate soil erosion potential. The moderate soil erosion potential that could occur at two of the loading areas (Black Top I and Lead Mountain I) makes soil erosion an important mechanism for MC mobilization into surface water runoff. MC in streams would drain northeast then east into Dry Lake playa or north into Dry Lake playa.

Groundwater Pathways

MC deposited on the primary MC loading areas within the Dry Lake watershed have the potential to migrate toward the water table by dissolution into precipitation and subsequent infiltration into the subsurface. However, such vertical migration of MC to groundwater is limited due to 1) the infrequent nature of rainfall in the area (less than 5 in/yr), 2) the high evaporation rate, and 3) the depth to groundwater. MC can also migrate down to groundwater through preferential recharge from the infrequent stream flow at the ephemeral streambeds and dry washes. The potential groundwater flow pathway is east and southeast toward the Dry Lake playa and away from the Bullion Mountains in the western and central parts of the watershed and north toward Dry Lake playa in the southeastern part of the watershed area (**Figure 4-2**).

6.2.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

Water and sediment accumulated in the Dry Lake playa downstream of the primary MC loading areas within the Dry Lake watershed may present potential exposure pathways for ecological species, including federally and state threatened desert tortoise and the California special concern species MFTL. A human exposure pathway has not been identified in the sediment and water within the Dry Lake watershed.

Groundwater Receptors

There are no known drinking water wells within the Dry Lake watershed, and a complete groundwater pathway to ecological receptors is unlikely.

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 four primary MC loading areas that drain to the Dry Lake playa. The MC loading areas included Black Top I, Black Top II, Lava, and Lead Mountain I. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages that lead to potential receptor exposure location in the Dry Lake playa (threatened and California special concern species). 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 (2006–2010 [period F]). The proportions of the MC loading areas draining to the Dry Lake playa are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Dry Lake watershed.

Table 6-15 presents the estimated percentage of total MC mass contributed by the individual primary MC loading areas draining to the Dry Lake playa, respectively. The Lead Mountain I MC loading area was predicted to contribute significant proportions of HMX and RDX (over 68%) and nearly half the TNT mass to the Dry Lake playa, whereas the Black Top I MC loading area was predicted to contribute over half of the proportion of the perchlorate mass (60%) into the Dry Lake playa (**Table 6-15**). The Black Top II MC loading area was predicted to contribute nearly half of the perchlorate mass (40%) into the Dry Lake playa (**Table 6-15**).

Table 6-15: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the Dry Lake Playa

Primary MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Black Top I	1	19	28	60
Lava	<1	<1	<1	<1
Black Top II	<1	11	22	40
Lead Mountain I	99	70	49	<1

Table 6-16 and **Table 6-17** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the watershed of the Dry Lake playa. The estimated edge-of-loading-area MC concentrations for Lava and Lead Mountain I are presented in **Table 6-7** and **Table 6-8** in **Section 6.1.2** (under the Bristol Dry Lake watershed) because these areas are also upstream contributors of the Bristol Dry Lake playa. Based on the screening-level calculations, the average annual concentrations of RDX and TNT in runoff at the edge of all four MC loading areas draining within the Dry Lake watershed were predicted to be above REVA trigger values (**Table 6-7** and **Table 6-16**). The average annual concentration of HMX in runoff was predicted to be above the REVA trigger value at the edge of the Lava and the Lead Mountain I MC loading areas, whereas the average annual concentration of perchlorate was predicted to be above the REVA trigger value at the edge of the Black Top I, Lava, and Black Top II MC loading areas (**Table 6-7** and **Table 6-16**). The average annual MC concentrations in sediment at the edge of all the primary MC loading areas draining within the Dry Lake watershed were predicted to be below REVA trigger values (**Table 6-8** and **Table 6-17**).

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

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Water (µg/L)	0.114	0.110	0.113	0.021
MC Concentration (µg/L)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Black Top I	0.028	**0.859**	**3.52**	**0.556**
Black Top II	0.026	**1.02**	**5.81**	**0.763**

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

Table 6-17: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Dry Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Sediment (µg/kg)	51	32.5	25	0.18
MC Concentration (µg/kg)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Black Top I	~0	0.010	2.70	~0
Black Top II	~0	0.006	2.42	~0

Note:

Shading and bold indicate concentration exceeds the REVA trigger value.

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff entering the Dry Lake playa, the identified downstream receptor exposure location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentration of TNT in surface water runoff entering the Dry Lake playa was predicted to be above the REVA trigger value (**Table 6-18**). However, the average annual concentrations of all other MC in surface water runoff entering the Dry Lake playa were predicted to be below REVA trigger values (**Table 6-18**). All predicted MC concentrations, including TNT, were at least two orders of magnitude lower than the RMUS freshwater values and at least three orders of magnitude lower than the RMUS marine water values (**Table 6-18**). As a result, the ecological receptors identified to potentially use the water in Dry Lake playa are unlikely to be impacted by MC release to the playa lake.

Table 6-18: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Entering the Dry Lake Playa

MC	REVA Trigger Value (µg/L)	RMUS Freshwater Value (µg/L)	RMUS Marine Water Value (µg/L)	Concentrations (µg/L)
HMX	0.114	150	330	0.078
RDX	0.110	190	5000	0.084
TNT	0.113	90	180	**0.226**
Perchlorate	0.021	9300	9300	0.015

Note:

Shading and bold indicate concentration exceeds the REVA trigger value.

Average annual MC concentrations in sediment entering the Dry Lake playa were not estimated because the edge-of-loading-area MC concentrations in sediment were predicted to be below REVA trigger values (**Table 6-8** and **Table 6-17**); thus, the

concentrations are expected to be even lower in the downstream location in Dry Lake playa. However, MC concentrations that would result from MC accumulation in the playa lakebed as a result of water evaporating from the playa lake were estimated (as described in **Section 5.1.2**), and the results are presented in **Table 6-19**. The cumulative perchlorate concentration in the sediment of the Dry Lake playa bed was predicted to be above the REVA trigger value (**Table 6-19**).

Table 6-19: Screening-Level Estimates of Cumulative MC Concentrations in the Sediment of Dry Lake Playa Bed

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
HMX	51	4.7–470	3.20
RDX	32.5	13 –1300	3.58
TNT	25	92–9200	9.75
Perchlorate	0.18	NA	**0.721**

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

The actual perchlorate concentration in the sediment of the playa lakebed is expected to be lower because of the conservative approach used in the screening-level analysis. The predicted cumulative perchlorate concentration in the sediment of the Dry Lake playa bed, which is a highly conservative estimate, is seven orders of magnitude lower than the State of California OEHHA soil screening number for perchlorate in soil at commercial/industrial sites of 3,500 mg/kg. This indicates no impact to potential receptors by way of the sediment in the playa lake.

6.2.3. Groundwater Analysis Results

A qualitative groundwater analysis was performed by analyzing the source media, migration mechanisms, and exposure pathways (as described in the earlier subsections and in **Section 4**). Based on the results of the qualitative analysis of the groundwater information, limited potential exists for MC migration to groundwater and no known groundwater receptor exposure locations are present down gradient of the MC loading areas located within the Dry Lake watershed. Therefore, the MC loading areas within the Dry Lake watershed are not considered areas of concern for MC migration in groundwater. No further analysis is required at this time.

6.3. Dale Lake Watershed

The Dale Lake watershed is located in the southeast corner of MCAGCC Twentynine Palms; it is approximately 212,000 acres, with less than 20% of the watershed area

located within MCAGCC Twentynine Palms (**Figure 6-3**). The watershed area encompasses an ephemeral stream network and the Dale Lake playa, which is located approximately 18 miles southeast of the installation boundary. Dale Lake playa is a potential receptor exposure location. A total of five RTAs are located within the watershed:

- Delta (29,791 acres)
- Prospect (13,189 acres)
- Cleghorn Pass (36,358 acres)
- East (6,502 acres)
- Bullion (28,129 acres)

The Delta, Prospect, Cleghorn Pass, and Bullion RTAs are operational live-fire RTAs and are used for various training activities; allowable munitions for these areas include all conventional munitions (air/ground) where the safety footprint can remain within 1000 m from the RTA or installation boundary, with the exception of East RTA. East RTA is a non-live-fire RTA; allowable munitions include blanks, simmunitions, pyrotechnics, and other less-than-lethal ammunition for direct weapons. No fires or effects of fires are allowed in East RTA for indirect weapons.

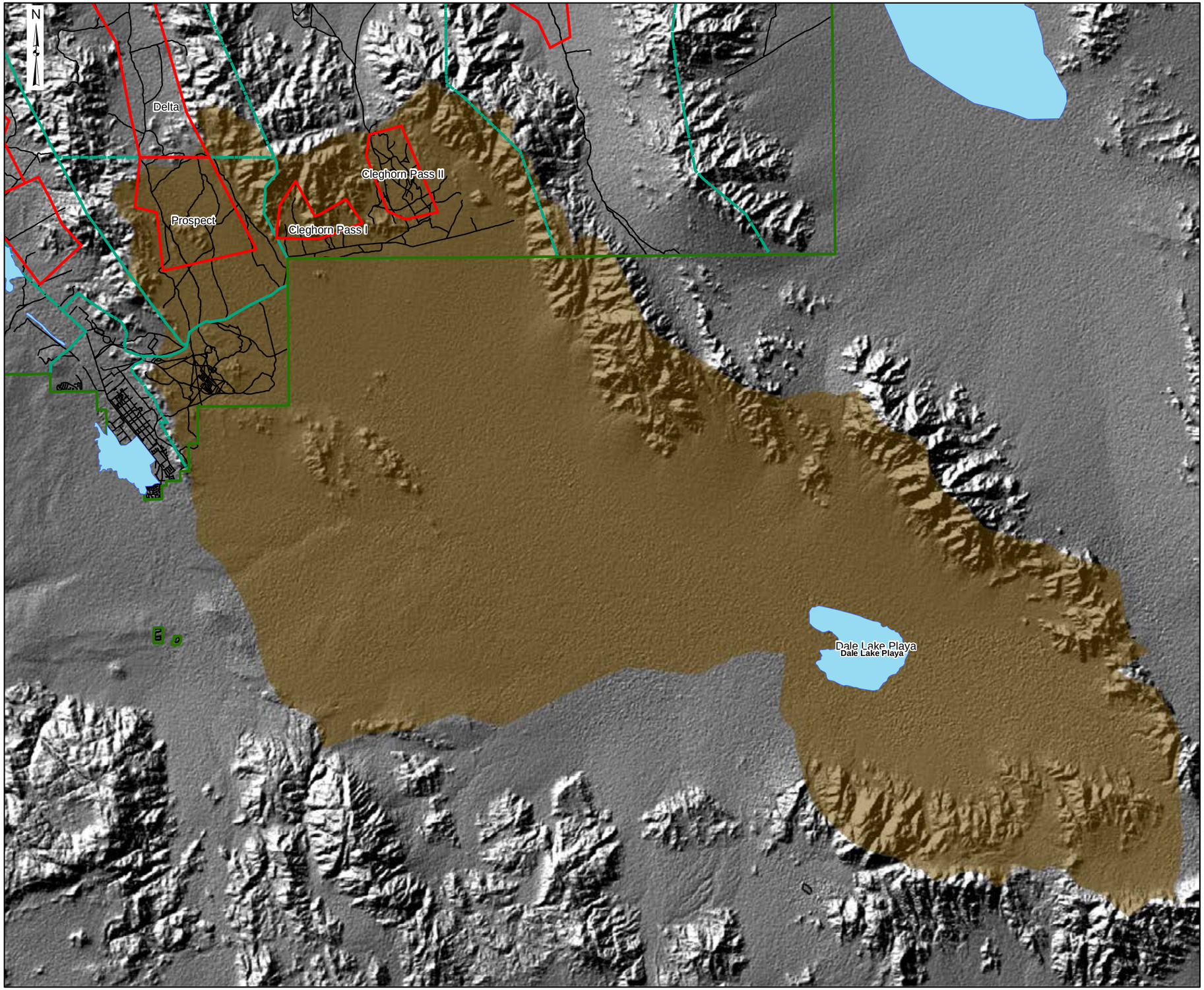
Four primary MC loading areas partially or fully located within the five RTAs within where the majority of MC deposition is anticipated to occur are listed in **Table 6-20**.

Table 6-20: Primary MC Loading Areas in the Dale Lake Watershed

MC Loading Area	Size (acres)
Cleghorn Pass I	1,267
Cleghorn Pass II	1,913
Prospect	4,329
Delta	6,243

Military Munitions

The general classes of military munitions expected at this RTA include small arms ammunitions, practice ammuntions, and high explosive munitions.



REVA
FIGURE 6-3
MCAGCC TWENTYNINE PALMS
PRIMARY MC LOADING AREAS
WITHIN THE DALE LAKE
WATERSHED

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- MC Loading Areas
- Restricted Areas
- Dale Lake Watershed
- Playa
- Main Supply Routes

0 0.45 0.9 1.8 2.7
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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6.3.1. Conceptual Site Model

6.3.1.1. Estimated Munitions Constituents Loading

The primary MC loading areas within the Dale Lake Watershed are shown in **Figure 6-3**. The boundaries of each primary 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 within this MC loading area over time (**Table 6-21**); the assumptions used to guide the estimates are detailed in **Section 3**. Compared to estimated baseline MC loading rates derived from munitions data available during the prior assessment, the estimated MC loading rates for this review suggest loading generally has remained constant since the baseline assessment (**Table 6-21**). There are two notable exceptions to this. First, estimated HMX loading increased from one to four orders of magnitude across the MC loading areas in this watershed. Second, TNT loading for Cleghorn Pass appears to have increased by an order of magnitude.

Table 6-21: Estimated Annual MC Loading for the Dale Lake Watershed

Primary MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)				
		Time Period F (2006–2010)				
		Assessment	HMX (kg/m^2)	RDX (kg/m^2)	TNT (kg/m^2)	Perchlorate (kg/m^2)
Cleghorn Pass	14,697,000	Baseline	7.65E-11	1.54E-07	9.99E-08	3.28E-09
Cleghorn Pass I	5,127,189	Five-year Review	4.29E-10	2.16E-06	1.14E-06	7.53E-08
Cleghorn Pass II	7,742,468	Five-year Review	8.77E-07	1.54E-07	2.47E-07	4.49E-10
Delta	32,124,000	Baseline	1.39E-11	2.04E-07	3.82E-07	1.02E-10
	25,263,439	Five-year Review	2.28E-09	1.99E-07	2.94E-07	3.45E-10
Prospect	17,518,000	Baseline	8.22E-12	1.28E-07	1.21E-07	3.87E-10
	17,517,863	Five-year Review	8.63E-10	1.41E-07	1.44E-07	5.16E-10

Note:
Estimated "Baseline" MC loading rates are based on "Period E" values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping, which would suggest a lower loading rate than actually occurring during that assessment. "Five-year Review" values cover 2006 to 2010.

Annual lead deposition for the RTAs in the Dale Lake watershed was estimated during this five-year review (**Table 6-22**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimation of the total amount of lead deposited in a given MC loading area. The baseline assessment did not include lead

loading estimates. Calculations indicate the greatest lead deposition in the watershed may be at the Cleghorn Pass I MC loading area, with an estimated 1.76E-03 kg/m^2 annually, for a total annual deposition of 19,840 lb of lead.

Table 6-22: Estimated Annual Lead Deposition for the Dale Lake Watershed

MC Loading Area	Size (m^2)	Lead		
		kg/m^2	lb/yd^2	Total lb
Cleghorn Pass I	5.13E+06	1.76E-03	3.24E-03	19,840
Cleghorn Pass II	7.74E+06	2.63E-04	4.85E-04	4,490
Delta	2.53E+07	4.36E-05	8.04E-05	2,428
Prospect	1.75E+07	5.10E-05	9.41E-05	1,971

6.3.1.2. Geography and Topography

The small portion of the Dale Lake Watershed located within the installation boundary consists of mountainous terrain with large bedrock outcrops. The Bullion Mountains border the northern, northwestern, and northeastern boundary of the watershed area. The terrain generally slopes from northwest to southeast toward the Dale Lake playa. Available elevation contour data indicate the elevation of the watershed area ranges from approximately 1,181 ft amsl in Dale Lake playa to approximately 4,428 ft amsl at the mountains southeast of the installation boundary (MCAGCC Twentynine Palms FMD, 2010). Based on available GIS data, the slope within the installation boundary of the watershed area ranges from less than 2% to approximately 70% in the mountain hills, but the majority of area has an average slope of approximately 11% (MCAGCC Twentynine Palms FMD, 2006).

6.3.1.3. Surface Water Features

The Dale Lake watershed contains an ephemeral stream system with a parallel drainage pattern. The streams originate from within the installation boundary and drain southeast off the installation boundary to ultimately discharge into the Dale Lake playa, which is located approximately 18 miles from the installation boundary. All of the Cleghorn Pass I and the Cleghorn Pass II, a large proportion of the Prospect (approximately 98%), and a small proportion of the Delta (approximately 1%) primary MC loading areas drain within the Dale Lake watershed.

Table 6-23 describes the drainage characteristics of the four primary MC loading areas within the Dale Lake watershed.

Table 6-23: Drainage Description for the Primary MC Loading Areas within the Dale Lake Watershed

Primary MC Loading Area	Drainage Description
Cleghorn Pass I	The main ephemeral stream channel drains southeast within the MC loading area and off the installation boundary, ultimately discharging into Dale Lake playa.
Cleghorn Pass II	Tributaries of the main ephemeral stream channel drain southwest within the MC loading area and off the installation boundary where they converge with the main ephemeral stream channel. The main ephemeral stream channel drains southeast into the Dale Lake playa.
Prospect	Tributaries of the main ephemeral stream channel drain southeast within the large proportion of the MC loading area (approximately 98%) and off the installation boundary where it converges with the main ephemeral stream channel. The remaining proportion of the MC loading area drains within the Bristol Dry Lake watershed.
Delta	A tributary stream drains southwest within the very small proportion of the MC loading area that drains within the Dale Lake watershed. The stream continues to drain southeast through the Prospect MC loading area and off the installation boundary, where it converges with the main stream channel.

6.3.1.4. Soil Characteristics and Land Cover

The predominant soil types of the Dale Lake watershed within the installation boundary include Goldroad-Dalvord-Rock outcrop (416), Arizo, dry Twobitter association (276), Arizo sand (279), and Arizo extremely gravely loamy sand. These soils are well to excessively well drained and are slightly to moderately alkaline. The organic content of the soils ranges from 0% to 0.5% with the Arizo extremely gravelly loamy sand (274) having a lower organic content of 0% to 0.3%, while the other soil types having an organic content of 0% to 0.5% (USDA NRCS, 1999). The soil types have low inherent soil erodibility, with their soil erodibility factors ranging from 0.02 to 0.17 tons/acre. The Arizo, dry-Twobitter association and the Arizo sand can have the higher range soil erodibility factors of 0.1 and 0.17 tons/acre, while the soil erodibility factor for the other soil types range from 0.02 to 0.05 tons/acre (USDA NRCS, 1999). The watershed area is largely covered with sparse vegetation predominantly consisting of Creosote Bush Shrubland and some Creosote Bush/Brittle Mosaic.

6.3.1.5. Erosion Potential

The estimated soil erosion potential of the four identified primary MC loading areas within the Dale Lake watershed ranges from low to moderate. The Cleghorn Pass I MC loading area was estimated to have moderate soil erosion potential, and the other three MC loading areas within the watershed (Cleghorn Pass II, Prospect and Delta) were estimated to have low soil erosion potential. The moderate soil erosion potential

estimated at the Cleghorn Pass I MC loading area is a result of a high topographic slope, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the area. The MC loading areas with low estimated soil erosion potentials have low inherent soil erodibility factors and low to moderate topographic slopes.

6.3.1.6. Groundwater Characteristics

The Dale Lake watershed lies within the Dale Valley intramountain basin found within the Bullion Mountains (**Figure 4-2**), for which subsurface data are not available. However, due to the expected similarity of the groundwater characteristics between the intramountain basin and the Twentynine Palms basin, groundwater within the Dale Valley intramountain basin is expected to occur in unconsolidated alluvial deposits. The expected differences between the intramountain basin and the Twentynine Palms basin are 1) the water-bearing sedimentary deposits are expected to be thinner in the intramountain basin with proximity to the exposed bedrock outcrops and 2) the average grain size that composes the intramountain subbasins is expected to be coarser due to the proximal position of the basin with respect to the bedrock source, potentially affecting the average hydraulic conductivity (Malcolm Pirnie, 2007). The limited data available from the Lava RTA indicate a depth to groundwater of 127 ft bgs within the Dale Valley intramountain basin (Almgren and Koptionak, 1993).

6.3.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Dale Lake watershed. Runoff coefficients at primary MC loading areas were assumed to range from 0.41 to 0.61. These relatively high runoff potentials are largely attributable to the infrequent torrential storms that occur (often resulting in flash floods), the sparse vegetation cover, and the moderate to high topographic slopes at the identified primary MC loading areas within the watershed. The Cleghorn Pass I and the Delta MC loading areas have the highest runoff coefficients (0.55 and 0.61) and soil types with high runoff potential (hydrologic group D) and moderate to relatively high topographic slopes.

As indicated in **Section 6.3.1.5**, three of the four primary MC loading areas within the watershed have low soil erosion potential, while one primary MC loading area (Cleghorn Pass I) has a moderate soil erosion potential. The low soil erosion potential that could occur at a majority of the primary MC loading areas makes land surface erosion a less important mechanism for MC mobilization into surface water runoff. However, streambed erosion resulting from flash flood events can be an important MC pathway to the potential downstream receptor exposure location in Dale Lake. Furthermore, the moderate soil erosion potential estimated at the Cleghorn Pass I primary MC loading area

indicates the importance of soil erosion for MC mobilization into surface water runoff at this MC loading area. MC in streams would drain southeast off the installation boundary and into Dale Lake, which is a known receptor exposure location.

Groundwater Pathways

MC deposited on the primary MC loading areas within the Dale Lake watershed have the potential to migrate toward the water table by direct infiltration of rain water or through preferential recharge from the infrequent stream flow at the ephemeral stream beds and dry washes. However, the vertical migration of MC is limited due to the infrequent rain fall, the high evaporation rate, and the depth to water table. The infrequent rainfall leads to infrequent stream flow at the ephemeral stream beds and dry washes where preferential recharge takes place. The potential groundwater flow pathway is southeast toward the Dale Lake playa and away from the Bullion Mountains (**Figure 4-2**).

6.3.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

The Dale Lake playa supports salt mining operations, where there could be potential human exposure pathways in the sediment of the playa lakebed through dermal contact during the salt mining process. Additionally, water and sediment accumulated in the Dale Lake playa may present potential exposure pathways for ecological species, including federally and state threatened desert tortoise and the California special concern species MFTL.

Groundwater Receptors

There are no known drinking water wells within the Dale Lake watershed, and a complete groundwater pathway to ecological receptors is unlikely. Groundwater (shallow or perched groundwater under Dale Lake playa and from deeper groundwater bearing zones) is used as brine source for salt production at the salt mine operations in Dale Lake; however, the salt mine operations at Dale Lake are significant distances away (more than 18 miles) from the MC loading areas within the watershed that it is highly unlikely for MC to reach these receptors at concentrations of concern.

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 four primary MC loading areas that drain to the Dale Lake playa. The MC loading areas include Cleghorn Pass I, Cleghorn Pass II, Prospect, and Delta. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages that lead to potential receptor exposure location in the Dale Lake playa (sediment human exposure through dermal contact and threatened and California special

concern species). 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 (2006–2010 [Period F]). The proportions of the primary MC loading areas draining to the Dale Lake playa are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Dale Lake watershed.

Table 6-24 presents the estimated percentage of total MC mass contributed by the individual primary MC loading areas draining to the Dale Lake playa. The Cleghorn Pass I primary MC loading area was predicted to contribute significant proportions of RDX, TNT, and perchlorate mass (over 55%) to the Dale Lake playa, whereas the Cleghorn Pass II MC loading area was predicted to contribute almost all of the HMX mass to the Dale Lake playa.

Table 6-24: Screening-Level Estimates of Percentage MC Mass Contributed by Individual Primary MC Loading Areas into the Dale Lake Playa

Primary MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Cleghorn Pass I	<1	77	59	97
Cleghorn Pass II	100	7	18	1
Prospect	<1	16	23	2
Delta	<1	<1	1	<1

Table 6-25 and **Table 6-26** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual primary MC loading areas draining within the watershed of Dale Lake playa. The estimated edge-of-loading-area MC concentrations for the Prospect and the Delta primary MC loading areas are presented in **Table 6-7** and **Table 6-8** in **Section 6.1.2** (under the Bristol Dry Lake watershed) as these areas are also upstream contributors of the Bristol Dry Lake playa. Based on the screening-level calculations, the average annual concentrations of RDX and TNT in runoff at the edge of all four MC loading areas were predicted to be above REVA trigger values (**Table 6-7** and **Table 6-25**). Furthermore, the average annual concentrations of HMX and perchlorate in runoff at the edge of the Cleghorn Pass II and the Cleghorn Pass I MC loading areas were predicted to be above REVA trigger values (**Table 6-7** and **Table 6-25**).The average annual MC concentrations in sediment at the edge of all the primary MC loading areas draining within the Dale Lake watershed were predicted to be below REVA trigger values (**Table 6-8** and **Table 6-26**).

Table 6-25: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Dale Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Water (µg/L)	0.114	0.110	0.113	0.021
MC Concentration (µg/L)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Cleghorn Pass I	0.005	**3.35**	**3.32**	**0.968**
Cleghorn Pass II	**13.41**	**0.299**	**0.990**	0.009

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

Table 6-26: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Dale Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Sediment (µg/kg)	51	32.5	25	0.18
MC Concentration (µg/kg)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Cleghorn Pass I	~0	0.032	2.13	~0
Cleghorn Pass II	0.040	0.002	0.452	~0

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff entering the Dale Lake playa, the identified downstream receptor exposure location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentration of HMX in surface water runoff entering the Dale Lake playa was predicted to be above the REVA trigger value (**Table 6-27**). However, the average annual concentrations of all other MC entering the Dale Lake playa were predicted to be below REVA trigger values (**Table 6-27**). All predicted MC concentrations, including HMX, were at least three orders of magnitude lower than the RMUS freshwater and marine water values. As a result, the ecological receptors identified to potentially use the water in Dale Lake playa are unlikely to be impacted by MC release to the playa lake.

Table 6-27: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff Entering the Dale Lake Playa

MC	REVA Trigger Value (µg/L)	RMUS Fresh water Value (µg/L)	RMUS Marine Water Value (µg/L)	Concentrations (µg/L)
HMX	0.114	150	330	**0.121**
RDX	0.110	190	5000	0.028
TNT	0.113	90	180	0.039
Perchlorate	0.021	9300	9300	0.006

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

Average annual MC concentrations in sediment entering the Dale Lake playa were not estimated because the edge-of-loading-area MC concentrations in sediment were predicted to be below REVA trigger values (**Table 6-8** and **Table 6-16**); thus, the concentrations are expected to be even lower in the downstream location in Dale Lake playa. However, MC concentrations that would result from MC accumulation in the playa lakebed as a result of water evaporating from the playa lake were estimated (as described in **Section 5.1.2**), and the results are presented in **Table 6-28**. The cumulative perchlorate concentration in the sediment of the Dale Lake playa bed was predicted to be above the REVA trigger value.

Table 6-28: Screening-Level Estimates of Cumulative MC Concentrations in the Sediment of Dale Lake Playa Bed

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
HMX	51	4.7–470	6.45
RDX	32.5	13 –1300	2.06
TNT	25	92–9200	2.67
Perchlorate	0.18	NA	**0.472**

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

The actual perchlorate concentration in the sediment of the playa lakebed is expected to be lower because of the conservative approach used in the screening-level analysis. The predicted cumulative perchlorate concentration in the sediment of the Dale Lake playa bed is approximately seven orders of magnitude lower than the State of California OEHHA soil screening number for perchlorate in soil at commercial/industrial sites of 3,500 mg/kg. This indicates no current impact to potential human (through dermal contact) and ecological receptors of the sediment in the playa lake.

6.3.3. Groundwater Analysis Results

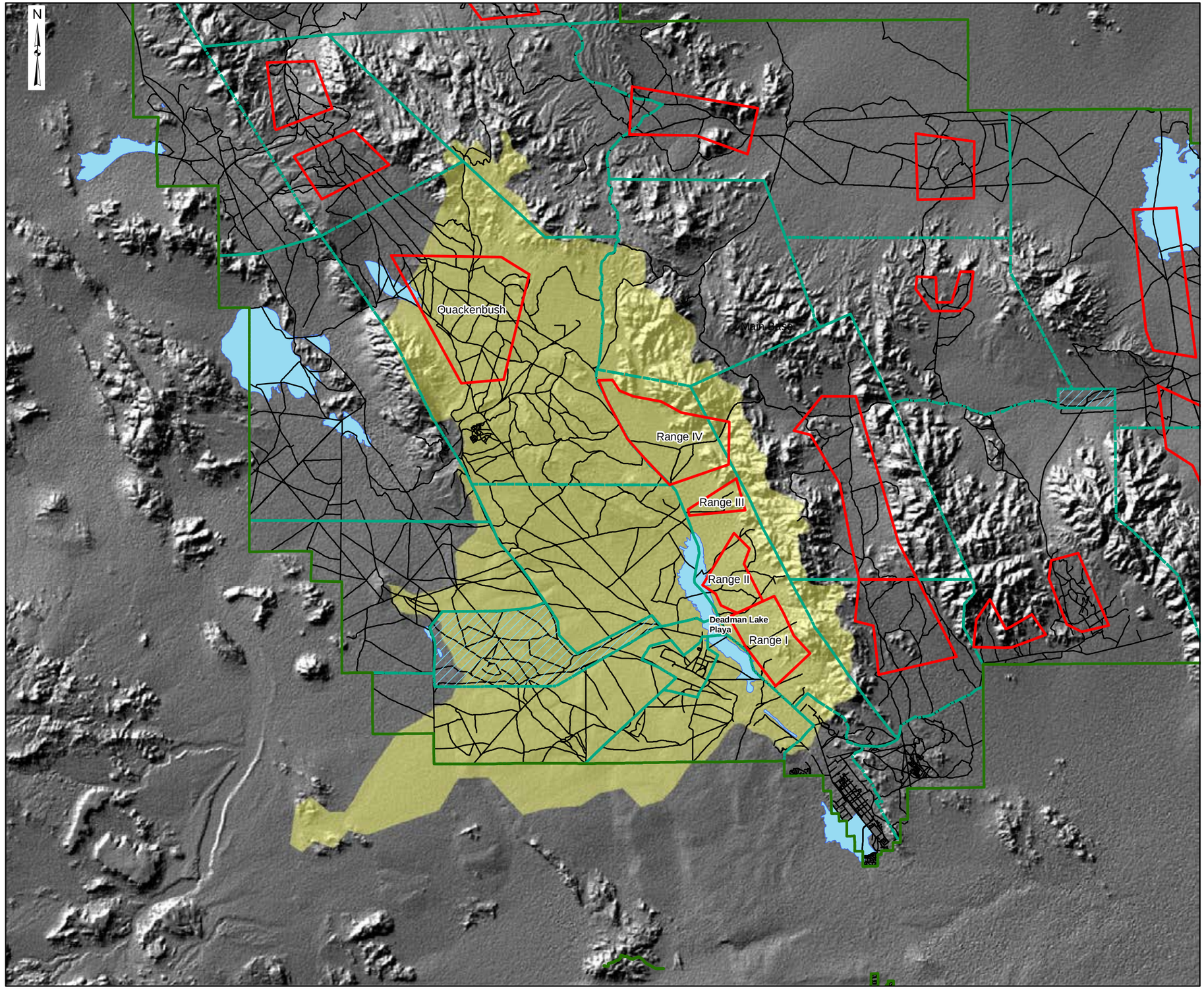
A qualitative groundwater analysis was performed by analyzing the source media, migration mechanisms, and exposure pathways (as described in the earlier subsections and in **Section 4**). Based on the results of the qualitative analysis of the groundwater information, limited potential exists for MC migration to groundwater and there are no known potable wells present within the Dale Lake watershed. There are nonpotable wells located near the salt mine operations at Dale Lake playa, a significant distance from the loading areas within the watershed. It is highly unlikely MC can reach the wells. Therefore, the MC loading areas within the Dale Lake watershed are not considered areas of concern for MC migration in groundwater. No further analysis is required at this time.

6.4. Deadman Lake Watershed

The Deadman Lake watershed is located on the western part of MCAGCC Twentynine Palms; it is approximately 136,200 acres, with a large portion of the area located within the MCAGCC Twentynine Palms (**Figure 6-4**). The watershed area encompasses the Deadman Lake playa and ephemeral streams consisting of the Rainbow Canyon, the Wood Canyon, and the Bullion Wash. The Deadman Lake playa, which is a potential receptor exposure location, is located within the installation boundary. A total of 13 RTAs are located within the watershed:

- Quackenbush (42,037 acres)
- Noble Pass (24,315 acres)
- Delta (56,985 acres)
- Gypsum Ridge (18,265 acres)
- Acorn (17,369 acres)
- Sandhill (15,810 acres)
- Range (20,158 acres)
- West (9,966 acres)
- Prospect (13,189 acres)
- Rainbow Canyon (25,348 acres)
- Gays Pass (18,316 acres)
- Emerson Lake (32,287 acres)
- Mainside (5,263 acres)

Quackenbush, Noble Pass, Delta, Range, Prospect, Rainbow Canyon, Gays Pass, and Emerson Lake are live-fire RTAs used for various training; allowable munitions for these



REVA
FIGURE 6-4
MCAGCC TWENTYNINE PALMS PRIMARY MC LOADING AREAS WITHIN THE DEADMAN LAKE WATERSHED

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- MC Loading Areas
- Restricted Areas
- Deadman Lake Watershed
- Playa
- Main Supply Routes

0 0.5 1 2 3
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

ARCADIS MALCOLM PIRNIE
Infrastructure Water Environment Buildings

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areas include all conventional munitions (air/ground) where the safety footprint can remain within 1000 m from the RTA / installation boundary. The Rainbow Canyon, Noble Pass, Delta, and Prospect RTAs intersect the Deadman Lake watershed only in the mountainous western boundaries of these RTAs, where little training occurs. Gypsum Ridge, Acorn, Sandhill, West, and Mainside are non-live-fire RTAs, and the allowable munitions include blanks, simmunitions, pyrotechnics, less-than-lethal direct weapons, and no fires or effects of fires for indirect weapons.

Five primary MC loading areas partially or fully located within the 13 RTAs where the majority of MC deposition is anticipated to occur are listed in **Table 6-29**.

Table 6-29: Primary MC loading areas in the Deadman Lake Watershed

MC Loading Area	Size (acres)
Range I	2,488
Range II	1,703
Range III	735
Range IV	4,745
Quackenbush	7,744

Military Munitions

The general classes of military munitions expected at this RTA include small arms ammunitions, practice munitions, and high explosive munitions.

6.4.1. Conceptual Site Model

6.4.1.1. Estimated Munitions Constituents Loading

The primary MC loading areas within the Deadman Lake watershed are shown in **Figure 6-4**. The boundaries of each primary 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 within this MC loading area over time (**Table 6-30**); the assumptions used to guide the estimates are detailed in **Section 3**. Additional range-specific assumptions had to be

developed with regard to UXO disposal at MCAGCC Twentynine Palms. Most EOD activities are conducted within the live-fire RTAs, with some UXO collected and

Table 6-30: Estimated Annual MC Loading for the Deadman Lake Watershed

Primary MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)				
		Time Period F (2006–2010)				
		Assessment	HMX (kg/m^2)	RDX (kg/m^2)	TNT (kg/m^2)	Perchlorate (kg/m^2)
Range	51,785,000	Baseline	3.69E-10	1.21E-07	5.49E-08	2.75E-09
Range I	10,069,913	Five-year Review	1.73E-09	2.00E-06	1.23E-06	3.23E-09
Range II	6,891,398	Five-year Review	1.29E-09	2.55E-09	1.16E-10	2.41E-09
Range III	2,975,704	Five-year Review	5.15E-11	2.47E-06	2.08E-08	7.50E-09
Range IV	19,202,818	Five-year Review	4.33E-11	8.87E-07	1.68E-07	1.81E-09
Quackenbush	73,836,000	Baseline	6.55E-12	3.10E-07	5.64E-07	1.14E-10
	31,340,708	Five-year Review	5.82E-08	1.95E-06	3.36E-06	4.77E-08

Note:
Estimated "Baseline" MC loading rates are based on "Period E" values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping, which would suggest a lower loading rate than actually occurring during that assessment. "Five-year Review" values cover 2006 to 2010.

destroyed at Range 112 and Range 114 in Range RTA and at Range 051. MC deposition attributable to demolition activities at these locations were factored into the R-051 and Range IV primary MC loading areas, respectively.

R-051 is the primary EOD range at the installation used for the destruction of unexploded or malfunctioning munitions. The range is permitted for destruction of up to 150 lb net explosive weight (NEW); however, given the proximity of the range to range support offices, EOD rarely uses more than 1.0 lb NEW per demolition shot. Range 112 also is established as a demolition range with a NEW limit up to 150 lb; however, EOD typically restricts activities at this range to use of only demolition materials (no UXO included). Range 114 is a combat engineer demolition range with a NEW limit up to 100 lb. While the RFMSS expenditure data captured use of donor charges and associated materials, it did not document what items were destroyed at these ranges.

EOD personnel provided two types of data that were used to account for EOD-related expenditures that may not be captured in the primary records. The first was a summary table listing counts of general types of munitions destroyed at ranges between January 2010 and October 2010. The second was a series of call sheets from 18 June 2010 to 26

October 2010, which contained more detailed information than available in the former summary table. These data were used to develop a single year of averages, which supplemented information extracted from the primary expenditure data, using the following assumptions:

- Data for dates in the summary table that were not covered by the call sheets were compared to the expenditure data to identify appropriate DoDICs. An HE-containing version of the munition typically was selected to allow for conservative calculations.
- DoDICs where MC content data were not available in MIDAS or other inventories were managed using similar assumptions described previously in this section.
- EOD documented final disposition of munitions items, and only events involving destruction of munitions (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 destruction was not provided, it was assumed to have occurred at R-051.

The EOD data covered a 10-month period of operations. Expenditure counts were increased by 20% to create representative numbers over a 12-month period. Since these data were assumed to represent a typical year of operation, the totals were added to corresponding annual averages developed from the expenditure data.

Compared to estimated baseline MC loading rates derived from munitions data available during the prior assessment, the estimated MC loading rates for this review suggest loading has increased since the baseline assessment (**Table 6-30**). There does not appear to be significant differences in loading for the Range MC loading area, although the division of the corresponding RTA in this five-year review demonstrates variability across the former single MC loading area. However, the Quackenbush MC loading area shows increases in all estimated MC loading rates, with each MC loading rate one to four orders of magnitude greater than estimated during the baseline study.

Annual lead deposition for the RTAs in the Deadman Lake watershed was estimated during this five-year review (**Table 6-31**). As noted in **Section 3.1**, the lead deposition rate is not comparable to an MC loading rate, rather it is an estimation of the total amount of lead deposited in a given MC loading area; the baseline assessment did not include such estimates. Calculations indicate the greatest lead deposition in the watershed may be at the Range IV MC loading area, with an estimated 4.58E-04 kg/m^2 deposited annually, for a total annual deposition of 19,384 lb of lead.

Table 6-31: Estimated Annual Lead Deposition for the Deadman Lake Watershed

MC Loading Area	Size (m^2)	Lead		
		kg/m^2	lb/yd^2	Total lb
Range I	1.01E+07	4.36E-04	8.04E-04	9,687
Range II	6.89E+06	1.93E-04	3.55E-04	2,925
Range III	2.98E+06	1.07E-04	1.97E-04	699
Range IV	1.92E+07	4.58E-04	8.44E-04	19,384
Quackenbush	3.13E+07	5.88E-05	1.08E-04	4,066

6.4.1.2. Geography and Topography

The Deadman Lake Watershed is bordered by the Hidalgo Mountains on the west and the Bullion Mountains on the east. The area generally is characterized by rugged terrain and low-level rolling hills. The terrain generally slopes from northwest to southeast, northeast to southwest, and southwest to northeast toward the Deadman Lake playa. Available elevation contour data indicate the elevation of the watershed area within the installation boundary ranges from approximately 1,870 ft amsl in Deadman Lake playa to approximately 4,625 ft amsl at the Bullion Mountains (MCAGCC Twentynine Palms FMD, 2010). Based on available GIS data, the slope within the installation boundary of the watershed area ranges from less than 2% to approximately 50% in the mountain hills, but the majority of area has an average slope of approximately 9% (MCAGCC Twentynine Palms FMD, 2006).

6.4.1.3. Surface Water Features

The Deadman Lake watershed consists of ephemeral stream networks and the Deadman Lake playa. Streams flow in southeast, southwest, and northeast directions into the Deadman Lake playa. The major streams within the watershed include the Rainbow Canyon on the east, Wood Canyon on the west, and the Bullion Wash. All of the Range I, Range II, Range III, Range IV, and a significant proportion of the Quackenbush (approximately 90%) primary MC loading areas drain within the Deadman Lake watershed.

Table 6-32 describes the drainage characteristics of the five primary MC loading areas within the Deadman Lake watershed.

Table 6-32: Drainage Description for the Primary MC Loading Areas within the Deadman Lake Watershed

Primary MC Loading Area	Drainage Description
Range I	Ephemeral streams from the Bullion Mountains drain northwest within the MC loading area into the Deadman Lake playa. The MC loading area is right next to the Deadman Lake playa.
Range II	Ephemeral streams from the Bullion Mountains drain west within the MC loading area into the Deadman Lake playa. The MC loading area is right next to the Deadman Lake playa.
Range III	Streams from the Bullion Mountains drain west within the MC loading area into the Bullion Wash, which also drains south within the MC loading area into the Deadman Lake playa.
Range IV	Streams from the Bullion Mountains drain southwest within the MC loading area into the Bullion Wash, which also drains south within the MC loading area into the Deadman Lake playa.
Quackenbush	Tributaries of the Wood Canyon from the Bullion and the Hidalgo Mountains drain southwest and northeast within the MC loading area into the Wood Canyon, which also drains southeast within the MC loading area. Wood Canyon converges with the Bullion Wash southeast of the loading area and ultimately discharges into the Deadman Lake playa. A small portion of the MC loading area drains within the Quackenbush Lake watershed.

6.4.1.4. Soil Characteristics and Land Cover

The predominant soil types of the Deadman Lake watershed within the installation boundary include Goldrock-Dalvord-Rock outcrop (416), Eastrange gravelly sandy loam (120), Edalph loamy sand (230), Arizo hypoint association (295), Blue Point sand (110), Calcio-Edalph-Calcio (231), Narea-Macagce-Edalph complex (200), and Narea-Desfirex-Edalph complex (203). These soils are well to excessively well drained and are neutral to strongly alkaline. The organic content of the soils ranges from 0% to 0.5%, with the Edalph loamy sand having a lower organic content of 0% to 0.2% (USDA NRCS, 1999). The soil types have low inherent soil erodibility, with their soil erodibility factors ranging from 0.02 to 0.2 tons/acre. The Edalph loamy sand and the Calcio-Edalph-Calcio soils have higher soil erodibility factors of 0.1 to 0.15 tons/acre and 0.1 to 0.2 tons/acre, respectively. Additionally, the Eastrange gravelly sandy loam, the Arizo hypoint association, the Narea-Macagce-Edalph complex, and the Narea-Desfirex-Edalph complex can have higher soil erodibility factors of 0.1 tons/acre, 0.15 tons/acre, 0.2 tons/acre and 0.17 tons/acre, respectively. The soil erodibility factors for the other soil

types (Goldrock-Dalvord-Rock outcrop and Blue Point sand) range from 0.02 to 0.05 tons/acre (USDA NRCS, 1999). The watershed area is largely covered with sparse vegetation mostly consisting of Creosote Bush Shrubland and some Creosote Bush/Brittle Bush Mosaic. A small portion of the watershed area includes Dunes.

6.4.1.5. Erosion Potential

The estimated soil erosion potential of the five identified primary MC loading areas within the Deadman Lake watershed is low. This low soil erosion potential at the MC loading areas is primarily a result of low inherent soil erodibility factors and low to moderate topographic slopes within the areas.

6.4.1.6. Groundwater Characteristics

The Deadman Lake watershed lies within the Deadman Lake groundwater subbasin of the Twentynine Palms basin (**Figure 4-2**), which is the best-understood water bearing unit at MCAGCC Twentynine Palms. The subbasins within the Twentynine Palms basin are divided hydrogeologically by bedrock outcrops, faults, and folds (Riley et al., 2001; Londquist and Martin, 1991; MCAGCC Twentynine Palms, 2006).

The groundwater bearing units within the subbasins comprise the Quaternary-Tertiary alluvial fan deposits and the Tertiary older sedimentary deposits. On the basis of lithologic and downhole geophysical logs, Li and Martin (2008) have divided the Quaternary-Tertiary alluvial fan deposits into two aquifers referred to as the “upper” and the “middle” aquifers. The older Tertiary sedimentary deposits have been designated as a single aquifer referred to as the “lower” aquifer (Li and Martin, 2008). The pre-Tertiary basement complex that consists of bedrock units forms the base of the aquifer system. This unit is essentially non-water-bearing and forms an effective groundwater barrier. The characteristics of the aquifer systems are described in detail in **Section 4.5**. The groundwater subbasin also contains thick clay deposits and perched groundwater tables beneath playas (Panacea, 2001a; Panacea, 2001b; ENSR, 1990). These perched aquifers are assumed to be limited in extent based on the available groundwater data and relatively small areal extent of the playas. It is unknown if these perched aquifers recharge the deeper aquifer system. However, the playa deposits, which mostly consist of clay, can have a thickness of approximately 50 ft (as estimated at the Deadman and Mesquite playa lakes by Li and Martin (2008)), indicating that recharge through the perched aquifer likely would be minimal.

Depth to groundwater within the Twentynine Palms groundwater basin at the installation ranges from 5 to 400 ft bgs. However, the depth to groundwater within this groundwater basin near the installation water supply source (within the restricted area) and near Mainside is generally 185 to 260 ft bgs (Malcolm Pirnie, 2007). The depth to

groundwater at perched zones that exist beneath playas ranges from 5 to 75 ft (Malcolm Pirnie, 2007).

6.4.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Deadman Lake watershed. Runoff coefficients at primary MC loading areas were assumed to range from 0.42 to 0.50. These relatively high runoff potentials are largely attributable to the infrequent torrential storms that occur (often resulting in flash floods), the sparse vegetation cover, and the moderate topographic slopes at the identified primary MC loading areas within the watershed. As indicated in **Section 6.4.1.5**, the primary MC loading areas within the watershed have low soil erosion potential, making land surface erosion a less important mechanism for MC mobilization into surface water runoff. However, erosion due to the occurrence of flash flood events can be an important MC pathway to the potential downstream receptor exposure location in the Deadman Lake playa. MC in streams would drain southwest and west and then southeast into the Deadman Lake playa or northwest into the Deadman Lake playa.

Groundwater Pathways

MC deposited on the primary MC loading areas within the Deadman Lake watershed have the potential to migrate toward the water table by direct infiltration of rain water or through preferential recharge from the infrequent stream flow at the ephemeral stream beds and dry washes. However, the vertical migration of MC is limited due to the infrequent rainfall, the high evaporation rate, and the depth to water table over a large portion of the watershed area. The shallow groundwater depth of approximately 5 to 75 ft occurs at perched groundwater zones that exist beneath the playa, where recharge is minimal due to the presence of thick (approximately 50 ft) low permeable soils underlying the playa. Thus, the likelihood for accumulated surface water potentially containing MC in the Deadman Lake playa to infiltrate down to the underlying perched groundwater is very limited. The infrequent rainfall leads to infrequent stream flow at the ephemeral stream beds and dry washes where preferential recharge takes place. The potential groundwater flow pathway is southeast and west toward the Deadman Lake playa from the primary MC loading areas within the watershed (**Figure 4-2**).

6.4.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

Water and sediment accumulated in the Deadman Lake playa downstream of the primary MC loading areas within the Deadman Lake watershed may present potential exposure pathways for ecological species, including federally and state threatened desert tortoise

and the California special concern species MFTL. Human exposure pathways have not been identified in the sediment and water within the Deadman Lake watershed.

Groundwater Receptors

There are no known potable wells within the Deadman Lake watershed, and a complete groundwater pathway to ecological receptors is unlikely. There are two nonpotable wells located within the Deadman Lake watershed (**Figure 4-2**), and water drawn from these wells is used for washing vehicles and field equipments by Marines in the field. Furthermore, the installation has future plans to draw water from the Deadman Lake groundwater subbasin for drinking water use by mixing with groundwater from the Surprise Spring subbasin where the installation currently draws water for drinking water use. The installation has not yet identified where in the Deadman Lake subbasin the water would be drawn as they are currently conducting studies.

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 five primary MC loading areas that drain to the Deadman Lake playa. The MC loading areas include Range I, Range II, Range III, Range IV, and Quackenbush. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages that lead to potential receptor exposure location in the Deadman Lake playa (threatened and California special concern species). 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 period matching the estimated MC loading periods (2006–2010 [Period F]). The proportions of the MC loading areas draining to the Deadman Lake playa are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Deadman Lake watershed.

Table 6-33 presents the estimated percentage of total MC mass contributed by the individual primary MC loading areas draining to the Deadman Lake playa. The Quackenbush MC loading area was predicted to contribute just over one-half of the RDX mass and above 80% of the HMX, TNT, and perchlorate mass to the Deadman Lake playa .

Table 6-33: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the Deadman Lake Playa

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Range I	1	20	13	2
Range II	1	<1	<1	1
Range III	<1	8	<1	2
Range IV	<1	19	3	2
Quackenbush	98	53	83	93

Table 6-34 and **Table 6-35** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the Deadman Lake watershed. Based on the screening-level calculations, the average annual concentrations of perchlorate in runoff at the edge of all five MC loading areas was predicted to be above the REVA trigger values (**Table 6-34**). The average annual concentrations of RDX and TNT in runoff were predicted to be above REVA trigger values at the edge of four (Range I, Range III, Range IV, and Quackenbush) and three (Range I, Range IV and Quackenbush) MC loading areas, respectively (**Table 6-34**). Additionally, the average annual concentration of HMX in runoff at the edge of the Quackenbush MC loading area was predicted to be above the REVA trigger value. The average annual MC concentrations in sediment at the edge of all the primary MC loading areas draining within the Dry Lake watershed were predicted to be below REVA trigger values (**Table 6-35**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and sediment entering the Deadman Lake playa, the identified downstream receptor exposure location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX, TNT, and perchlorate in surface water runoff entering the Deadman Lake playa were predicted to be above REVA trigger values (**Table 6-36**). However, the average annual concentration of HMX in surface water runoff entering the Deadman Lake playa was predicted to be below the REVA trigger values (**Table 6-36**). All predicted MC concentrations, including those exceeding REVA trigger values, were at least two orders of magnitude lower than the RMUS freshwater and marine water values. As a result, the ecological receptors identified to potentially use the water in Deadman Lake playa are unlikely to be impacted by MC release to the playa lake

Table 6-34: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Deadman Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Water (µg/L)	0.114	0.110	0.113	0.021
MC Concentration (µg/L)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Range I	0.025	**3.85**	**4.37**	**0.056**
Range II	0.019	0.005	~0	**0.044**
Range III	0.001	**4.62**	0.066	**0.120**
Range IV	0.001	**1.70**	**0.537**	**0.029**
Quackenbush	**0.789**	**3.81**	**10.4**	**0.883**

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

Table 6-35: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Deadman Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Sediment (µg/L)	0.114	0.110	0.113	0.18
MC Concentration (µg/kg)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Range I	~0	0.030	2.31	~0
Range II	~0	~0	~0	~0
Range III	~0	0.042	0.040	~0
Range IV	~0	0.015	0.323	~0
Quackenbush	0.004	0.043	7.86	~0

.

Table 6-36: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff Entering Deadman Lake Playa

MC	REVA Trigger Value (µg/L)	RMUS Freshwater Value (µg/L)	RMUS Marine Water Value (µg/L)	Concentrations (µg/L)
HMX	0.114	150	330	0.041
RDX	0.110	190	5000	**0.349**
TNT	0.113	90	180	**0.631**
Perchlorate	0.021	9300	9300	**0.048**

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

Average annual MC concentrations in sediment entering the Deadman Lake playa were not estimated because the edge-of-loading-area MC concentrations in sediment were predicted to be below REVA trigger values (**Table 6-35**), and the concentrations are expected to be even lower in the downstream location in Deadman Lake playa. However, MC concentrations that would result from MC accumulation in the playa lakebed as a result of water evaporating from the playa lake were estimated (as described in **Section 5.1.2**), and the results are presented in **Table 6-37**. The cumulative TNT and perchlorate concentrations in the sediment of the Deadman Lake playa bed were predicted to be above REVA trigger values.

Table 6-37: Screening-Level Estimates of Cumulative MC Concentrations in the Sediment of the Deadman Lake Playa Bed

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Industrial Soil Screening Values (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
HMX	51	4.7–470	49,000,000[a]	2.84
RDX	32.5	13 –1300	24,000[a]	25.5
TNT	25	92–9200	79,000[a]	**44.3**
Perchlorate	0.18	NA	3,500,000[b]	**3.37**

Note:
Shading and bold indicate concentration exceeds the REVA trigger value
[a]EPA Region 9 soil screening values (June, 2011)
[b]California OEHHA industrial soil screening values

The actual TNT and perchlorate concentrations in the sediment of the playa lakebed is expected to be lower because of the conservative approach used in the screening-level analysis. The predicted cumulative TNT concentration is approximately 1.5 times lower than the lower range RMUS freshwater and marine water sediment value of 92 µg/kg. These RMUS screening values are based on sediment being in constant contact with

water, which is not the case in the playa lakes. The sediments within the playa lakes are characterized as dry sediment (following evaporation of the collected surface water within the playa), which is more akin to a soil exposure media rather than the saturated freshwater and marine sediments for which existing RMUS values for ecological receptors have not been established. Note that there is no established RMUS sediment screening value for perchlorate. The predicted cumulative MC concentrations in the sediment of the Deadman Lake playa bed also were compared to the EPA Region 9 and the State of California OEHHA industrial soil screening values. The predicted cumulative TNT concentration in sediment is three orders of magnitude lower than the EPA Region 9 soil screening value of 79,000 µg/kg. The predicted cumulative perchlorate concentration in sediment is six orders of magnitude lower than the the State of California OEHHA Industrial soil screening value of 3,500,000 µg/kg (**Table 6-37**).

These findings indicate that there is no current concern of impact to receptors, but additional evaluations may be warranted if future changes are anticipated within the Deadman Lake watershed area (such as land use changes or significant increases in the use of munitions containing HE).

6.4.3. Groundwater Analysis Results

Groundwater fate and transport modeling through screening-level analysis was conducted for the five primary MC loading areas that drain within the Deadman Lake watershed (Range I, Range II, Range III, Range IV, and Quackenbush). These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE, their moderately shallow depth to groundwater (relative to other portions of the installation), and their proximity to potential future groundwater receptors. All five MC loading areas analyzed are located within the Deadman Lake groundwater subbasin, where the installation has future plans to draw water for drinking water use by mixing with groundwater from the Surprise Spring subbasin.

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 MC loading areas assessed within the Deadman Lake watershed. In doing this, the estimated MC loading rates were divided by the estimated low and high recharge rates. The low and high recharge rates were estimated based on the assumptions that 1) recharge is evenly distributed across the MC loading areas (the low recharge rate of 0.096 in/yr (Londquist & Martin, 1991)) and 2) preferential recharge occurs at the ephemeral stream beds and dry washes (the high recharge rates of 2.39 to 2.77 in/yr at the individual primary MC loading areas analyzed).

Table 6-38 shows the resulting maximum infiltration MC concentrations at the primary MC loading areas within the Deadman Lake watershed. These MC concentrations

represent the maximum of the two estimated infiltration concentrations (from the low and high recharge rates). MC loading areas were sorted into Group A (Range I and Range II) and Group B (Range III, Range IV and Quackenbush) based on similar hydrogeologic properties for the vadose zone. The results for a given MC and MC loading area scenario presented in bold exceed the trigger value for the respective MC, while scenario results highlighted in yellow indicate the worst-case scenario for each group of MC loading areas. All MC concentrations were estimated to exceed REVA trigger values at the Range I and Quackenbush MC loading areas. Additionally, RDX and perchlorate were estimated to exceed REVA trigger values at the Range II, Range III, and Range IV MC loading areas, and TNT was estimated to exceed the REVA trigger value at the Range III and Range IV MC loading areas. MC loading areas from each group with the worst-case scenario of all four MC were carried forward to the next step of the Part I screening-level analysis, vadose zone modeling.

Table 6-38: Maximum MC Concentrations in Infiltrating Water at MC the Primary Loading Areas within the Deadman Lake Watershed

				HMX	RDX	TNT	Perchlorate
			REVA Trigger Value (µg/L)	0.114	0.110	0.113	0.021
MC Loading Area		Time Period		Predicted Maximum Infiltration Concentration (µg/L)			
Group A	Range I	2006–2010	F	**0.14**	**165**	**101**	**0.27**
	Range II	2006–2010	F	0.106	**0.21**	0.01	**0.20**
Group B	Range III	2006–2010	F	0.004	**203**	**1.7**	**0.62**
	Range IV	2006–2010	F	0.004	**73**	**13.8**	**0.15**
	Quackenbush	2006–2010	F	**4.3**	**160**	**299**	**3.9**

Note:
Bold scenario indicates predicted concentration exceeds the REVA trigger value.
Highlighted scenario indicates predicted concentration is worst-case scenario.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. 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 worst-case scenario for each MC in each MC loading area group from the initial step of the screening analysis was evaluated using VLEACH. Results are presented in **Table 6-39**. 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 decay rate was applied to the VLEACH output

concentrations based on the elapsed time. Modeling results including decay are presented in **Table 6-39** for comparison.

Based on the recharge rate estimates, the minimum travel time for MC to reach the water table at concentrations greater than or equal to the respective MC trigger value for the modeled scenarios is at least 1,370 years. When decay is included, all MC except perchlorate are predicted to degrade below their respective trigger value before reaching the water table.

Table 6-39: Estimated Maximum MC Concentrations Reaching the Water Table

(Low Recharge Rate, High Concentration)

MC Loading Area	MC	Trigger Value (µg/L)	Step 1	VLEACH (No Decay)		VLEACH (Decay)	
			Ground Surface Infiltration Concentration (µg/L)	Steady State Concentration at Water Table (µg/L)	Time to Exceed Trigger Value (years)	Steady State Concentration at Water Table (µg/L)	Time to Exceed Trigger Value (years)
Group A	HMX	0.114	**0.14**	**0.14**	3,400	0	--
	RDX	0.110	**165**	**165**	1,370	0	--
	TNT	0.113	**101**	**101**	2,440	0	--
	Perchlorate	0.021	**0.27**	**0.27**	2,110	**0.24**	2,100
Group B	HMX	0.114	**4.3**	**4.3**	3,830	0	--
	RDX	0.110	**203**	**203**	2,720	0	--
	TNT	0.113	**299**	**299**	4,160	0	--
	Perchlorate	0.021	**3.9**	**3.9**	3,250	**3.1**	3,250

Note:
-- denotes that the MC degrade before reaching the water table.
Bold scenario indicates predicted concentration exceeds the REVA trigger value.

Perchlorate concentrations are estimated to exceed the trigger value after a minimum travel time of 2,100 years. Perchlorate concentrations were estimated to reach steady-state concentration of 0.24 µg/L at Group A ranges after 6,000 years and 3.1 µg/L at Group B ranges after 12,000 years. These concentrations exceed the trigger value for perchlorate of 0.021 µg/L. While the maximum perchlorate concentration predicted to reach the water table of 3.1 µg/L exceeds the REVA trigger value, it is an significantly lower than the EPA Region 9 Risk Screening Level (RSL) for perchlorate in tap water of 26 µg/L and the RMUS drinking water value of 15 µg/L, and the estimated time to exceed the REVA trigger value is over 2000 years.

A complementary scenario using the high recharge rate discussed earlier was run using VLEACH in order to simulate MC transport to the water table when preferential recharge occurs at the ephemeral stream beds and dry washes. The rate of recharge in these areas,

which constitute a small portion of the total MC loading areas, was assumed to be the annual precipitation rate less site runoff (approximately 50% of precipitation). Results for this scenario are presented in **Table 6-40**.

Table 6-40: Estimated Maximum MC Concentrations Reaching the Water Table
(High Recharge Rate, Low Concentration)

MC Loading Area	MC	Trigger Value (µg/L)	Step 1	VLEACH (No Decay)		VLEACH (Decay)	
			Ground Surface Infiltration Concentration (µg/L)	Concentration at Water Table (µg/L)	Travel Time (years)	Concentration at Water Table (µg/L)	Travel Time (years)
Group A	HMX	0.114	0.0052	not modeled		not modeled	
	RDX	0.110	**6.0**	**6.0**	20	0	--
	TNT	0.113	**3.7**	**3.7**	47	0	--
	Perchlorate	0.021	0.010	not modeled		not modeled	
Group B	HMX	0.114	**0.15**	**0.15**	72	0	--
	RDX	0.110	**8.0**	**8.0**	44	0	--
	TNT	0.113	**10**	**10**	74	0	--
	Perchlorate	0.021	**0.14**	**0.14**	54	**0.14**	54

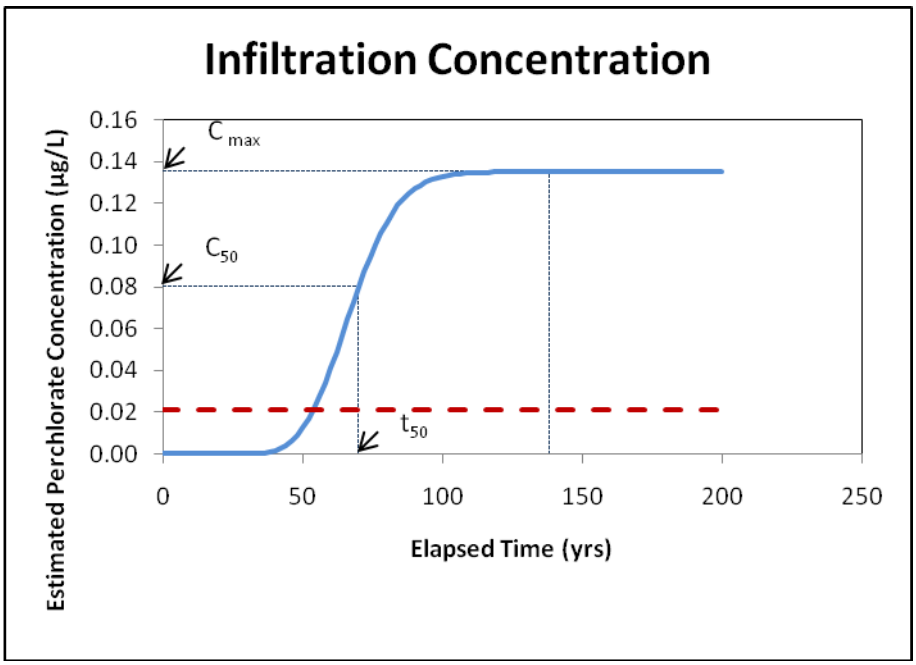
Note:
-- denotes that the MC degrade before reaching the water table.
***Bold** scenario indicates predicted concentration exceeds the REVA trigger value.*

Results of this complimentary scenario, which simulates preferential recharge at ephemeral stream beds and dry washes, indicate perchlorate may reach the water table at concentrations exceeding the trigger value within 54 years at the Group B MC loading areas (**Figure 6-5**). A maximum perchlorate concentration of 0.14 µg/L was predicted; while this concentration exceeds the REVA trigger value, it is two orders of magnitude lower than the Region 9 RSL of 26 µg/L and the RMUS drinking water value of 15 µg/L. Therefore, where there is preferential recharge (such as near the ephemeral streams), it is possible for perchlorate to reach the groundwater at concentrations above the REVA trigger value within a limited recharge area. However, when groundwater moves from these limited recharge areas, perchlorate levels will be reduced. Perchlorate concentration in the groundwater originating from the MC loading areas is not expected to approach the RSL or the RMUS drinking water value.

Based on the vadose zone modeling results of the two modeled scenarios (low and high recharge), there are no current concerns of MC migration to groundwater. The low recharge rate scenario predicts higher concentrations reaching the water table, but the travel time for the MC to arrive at the water table is extremely slow (over 2000 years). The predicted travel time for the higher recharge rate scenario is much faster than the

predicted travel time for the low recharge rate scenario (54 years versus 2000 years), but the travel times are still long enough and the predicted concentration low enough for the MC migration to be of no concern through the next REVA five-year review.

Figure 6-5: Estimated Infiltration Concentration
(Worst-Case Scenario for Group B MC Loading Areas, Perchlorate)

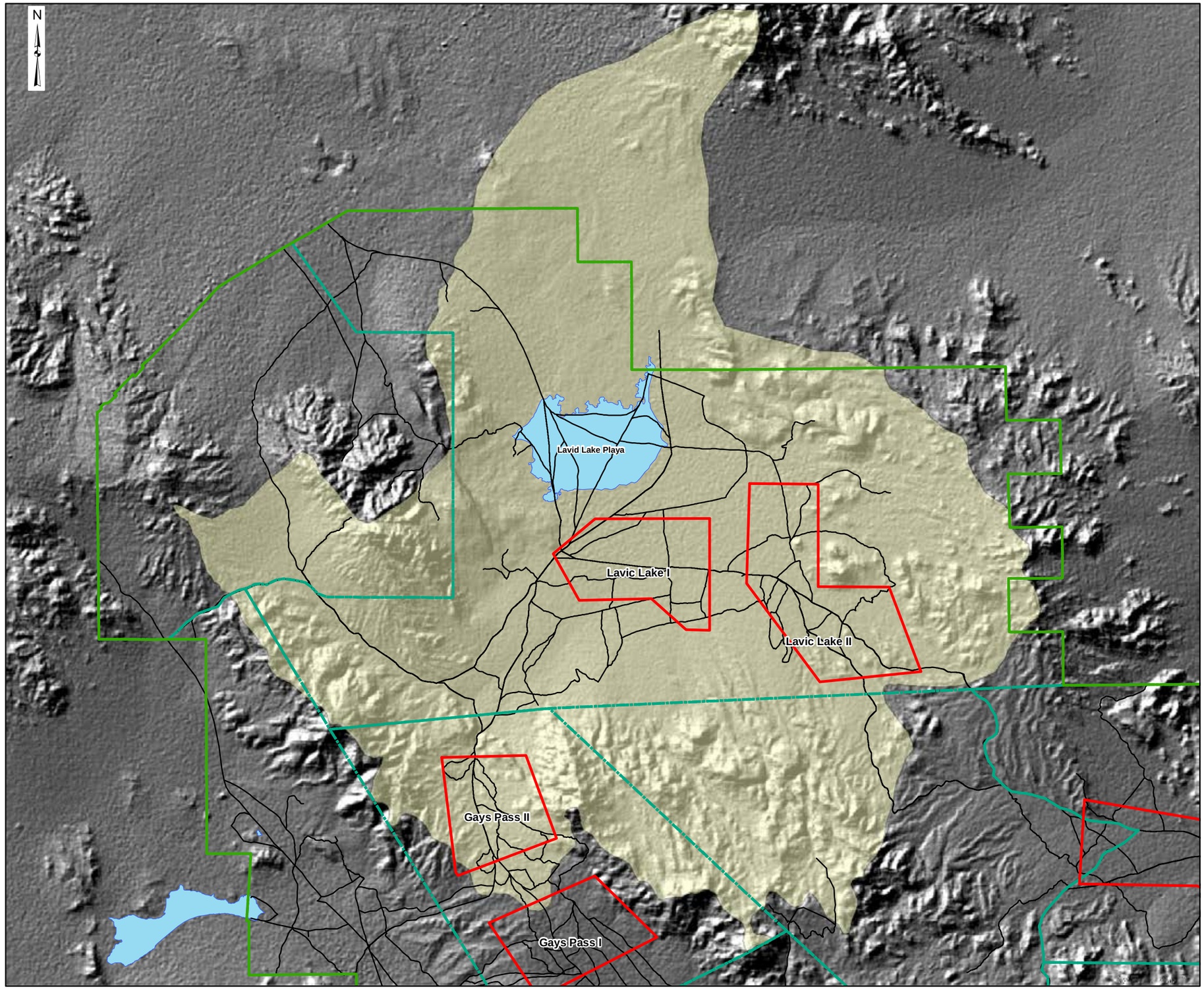


Note:
C_{max} = maximum concentration
C_{50} = 50% of the maximum concentration
t_{50} = time at 50% of the maximum concentration

Additional analysis (such as saturated zone modeling) is not required at this time. However, migration through the saturated zone might be reevaluated as part of the following five-year review period.

6.5. The Lavic Lake Watershed

The Lavic Lake Watershed is located in the northwest corner of MCAAGCC Twentynine Palms; it is approximately 88,400 acres, with a large proportion of the area located within the MCAGCC Twentynine Palms installation boundary (**Figure 6-6**). The watershed area encompasses ephemeral stream networks and the Lavic Lake playa. The Lavic Lake playa, which is a potential receptor exposure location, is located within the installation boundary. A total of five RTAs are located within the watershed:



REVA
FIGURE 6-6
MCAGCC TWENTYNINE PALMS
PRIMARY MC LOADING AREAS
WITHIN THE LAVIC LAKE WATERSHED

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- MC Loading Areas
- Restricted Areas
- Lavic Lake Watershed
- Playa
- Main Supply Routes

0 0.5 1 2 3
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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- Lavic Lake (56,985 acres)
- Sunshine Peak (22,859 acres)
- Rainbow Canyon (25,348 acres)
- Gays Pass (18,316 acres)
- Maumee Mine (16,141 acres)

Each of these five RTAs are used for various live-fire training; allowable munitions for these areas include all conventional munitions (air/ground) where the safety footprint can remain within 1000 m of the RTA or installation boundary.

Four primary MC loading areas partially or fully located within the five RTAs where the majority of MC deposition is anticipated to occur are listed in **Table 6-41**.

Table 6-41. MC Loading Areas in the Lavic Lake Watershed

MC Loading Area	Size (acres)
Lavic Lake I	2,789
Lavic Lake II	4,072
Gays Pass I	2,364
Gays Pass II	2,167

Military Munitions

The general class of military munitions expected at this RTA is high explosive munitions.

6.5.1. Conceptual Site Model

6.5.1.1. Estimated Munitions Constituents Loading

The primary MC loading areas within the Lavic Lake Watershed are shown in **Figure 6-6**. The boundaries of each primary 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 within this MC loading area over time (**Table 6-42**); the assumptions used to guide the estimates are detailed in **Section 3**. Compared to estimated baseline MC loading rates derived from munitions data available during the prior assessment, the estimated MC loading rates for this review suggest loading has increased slightly since the baseline assessment (**Table 6-42**). Notably, estimated HMX loading increased three orders of magnitude at the Gays Pass MC loading area; HMX is now being used in the Lavic Lake RTA. Perchlorate loading increased by one to three orders of magnitude across the watershed.

Table 6-42: Estimated Annual MC Loading for the Lavic Lake Watershed

Primary MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)				
		Time Period F (2006–2010)				
		Assessment	HMX (kg/m^2)	RDX (kg/m^2)	TNT (kg/m^2)	Perchlorate (kg/m^2)
Gays Pass	41,047,000	Baseline	5.48E-13	1.55E-07	2.29E-07	3.64E-11
Gays Pass I	9,567,943	Five-year Review	5.12E-10	3.03E-07	4.40E-07	1.47E-10
Gays Pass II	8,770,744	Five-year Review	5.59E-10	3.30E-07	4.80E-07	1.60E-10
Lavic Lake	40,939,000	Baseline	0.00E-00	1.95E-07	3.24E-07	1.97E-11
Lavic Lake I	11,286,872	Five-year Review	0.00E-00	2.18E-07	6.41E-07	8.73E-08
Lavic Lake II	16,478,630	Five-year Review	2.81E-09	2.15E-07	6.54E-07	8.97E-08

Note:

Estimated "Baseline" MC loading rates are based on "Period E" values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping, which would suggest a lower loading rate than actually occurring during that assessment. "Five-year Review" values cover 2006 to 2010.

Annual lead deposition for the RTAs in the Lavic Lake watershed was estimated during this five-year review (**Table 6-43**). 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. Calculations indicate the greatest lead deposition in the watershed may be within the two Lavic Lake MC loading areas (estimated annual deposition of between 1.47E-05 and 1.51E-05 kg/m^2, for a total annual deposition in the areas of between 366 and 549 lb of lead).

Table 6-43: Estimated Annual Lead Deposition for the Lavic Lake Watershed

MC Loading Area	Size (m^2)	Lead		
		kg/m^2	lb/yd^2	Total lb
Gays Pass I	9.57E+06	1.17E-05	2.16E-05	248
Gays Pass II	8.77E+06	1.28E-05	2.36E-05	248
Lavic Lake I	1.13E+07	1.47E-05	2.71E-05	366
Lavic Lake II	1.65E+07	1.51E-05	2.79E-05	549

6.5.1.2. Geography and Topography

The Lavic Lake Watershed is an area primarily consisting of level lava formations. Volcanic lava flows are evidenced around the Lavic Lake playa, to the southwest and north of the playa lake. The watershed area is bordered on the south and east by the Bullion Mountains, and the Lava Bed Mountains on the west. The terrain generally slopes from the western, southern, and eastern mountains toward the center of the watershed toward the Lavic Lake playa. Available elevation contour data indicate the elevation of the watershed area within the installation boundary ranges from approximately 1,870 ft amsl near Lavic Lake playa to approximately 4,625 ft amsl at the Bullion Mountains (MCAGCC Twentynine Palms FMD, 2010). Based on available GIS data, the slope within the installation boundary of the watershed area ranges from less than 2% to approximately 70% in the mountain hills, but the majority of area has an average slope of approximately 5% (MCAGCC Twentynine Palms FMD, 2006).

6.5.1.3. Surface Water Features

The Lavic Lake watershed contains an ephemeral stream network with a parallel drainage pattern. Streams generally originate from within the installation boundary and flow radially toward the Lavic Lake playa. All of the Lavic Lake I, Lavic Lake II, and Gays Pass II and a very small proportion of the Gays Pass I primary MC loading areas (approximately 1%) drain within the Lavic Lake watershed.

Table 6-44 describes the drainage characteristics of the three MC loading areas within the Lavic Lake watershed.

Table 6-44: Drainage Description for the Primary MC Loading Areas within the Lavic Lake Watershed

Primary MC Loading Area	Drainage Description
Lavic Lake I	Ephemeral streams originating from the Bullion Mountains on the southern border of the watershed area drain north within the MC loading area and discharge into the Lavic Lake playa approximately 3,100 ft north of the loading area.
Lavic Lake II	Ephemeral streams originating from the Bullion Mountains on the southeastern border of the watershed area drain northwest within the MC loading area and discharge into Lavic Lake playa approximately 1.8 miles northwest of the loading area.
Gays Pass I	The small proportion of the loading area within the Lavic Lake watershed drains north to ephemeral streams that flow north from between the Bullion and the Lava Bed Mountains toward the Lavic Lake playa. The remaining proportion of the loading area drains within the Quackenbush watershed.
Gays Pass II	Ephemeral streams originating between the Bullion and the Lava Bed Mountains on the southwestern border of the watershed drain north within the MC loading area then northeast and discharge into the Lavic Lake playa.

6.5.1.4. Soil Characteristics and Land Cover

The predominant soil types of the Lavic Lake watershed within the installation boundary include Haleburu-Noble Pass complex (406), Noble Pass-Pacific Mesa-Sunrock complex (407), Arizo extremely gravelly loamy sand (274), Sunrock-Lava flows complex (144), and Haleburu-Upspring complex (403). These soils are well to excessively well drained and are slightly to moderately alkaline. The organic content of the soils ranges from 0% to 0.5%, with the Arizo extremely gravelly loamy sand soil having a lower organic content of 0% to 0.3% (USDA NRCS, 1999). The soil types have low inherent soil erodibility, with the soil erodibility factors of the majority of the soils ranging from 0.02 to 0.05 tons/acre. The soil erodibility factor for the Sunrock-Lava flows complex is a little higher and ranges from 0.05 to 0.2 tons/acre (USDA NRCS, 1999). The watershed area is largely covered with sparse vegetation mostly consisting of Creosote Bush Shrubland and some Mojave Yucca Shrubland. A small portion of the watershed area includes lava beds and cinder cones.

6.5.1.5. Erosion Potential

The estimated soil erosion potential of the four identified primary MC loading areas within the Lavic Lake watershed ranges from low to moderate. The Lavic Lake I, Lavic Lake II and Gays Pass I primary MC loading areas were estimated to have low soil

erosion potential, while the Gays Pass II MC loading area was estimated to have moderate soil erosion potential. The moderate soil erosion potential estimated at the Gays Pass II primary MC loading area is a result of higher topographic slope, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the area. The MC loading areas with low estimated soil erosion potential have lower topographic slopes.

6.5.1.6. Groundwater Characteristics

A significant proportion of the Lavic Lake watershed area lies in the Lavic Valley intramountain groundwater basins found within the Bullion and the Lava Bed Mountains (**Figure 4-2**). As mentioned in **Section 6.3.1.6**, limited subsurface data are available for the intramountain basins. The subsurface conditions encountered in these areas are generally expected to be similar to the Bristol Valley and the Twentynine Palms groundwater basins encountered in the northeast and the southwest portions of the installation. A very small portion of the southwestern tip of the watershed also lies in the Deadman Lake groundwater subbasin of the Twentynine Palms basin. The groundwater characteristics for the Twentynine Palms basin, which encompasses the Deadman Lake groundwater subbasin, are described in **Section 6.4.1.6**.

6.5.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Lavic Lake watershed. Runoff coefficients at primary MC loading areas were assumed to range from 0.41 to 0.59. These relatively high runoff potentials are largely attributable to the infrequent torrential storms that occur (often resulting in flash floods), the sparse vegetation cover, and the moderate to high topographic slopes at the identified primary MC loading areas within the watershed. The loading area with the highest runoff coefficient (Gays Pass II) has a soil type with a high runoff potential and a relatively high topographic slope. As indicated in **Section 6.5.1.5**, the primary MC loading areas within the watershed have low or moderate soil erosion potential. The moderate soil erosion potential that could occur at the Gays Pass II MC loading area makes soil erosion an important mechanism for MC mobilization into surface water runoff. MC in streams would drain northeast, east, north, northwest, and west into the Lavic Lake playa.

Groundwater Pathways

MC deposited on the primary MC loading areas within the Lavic Lake watershed have the potential to migrate toward the water table by direct infiltration of rain water or through preferential recharge from the infrequent stream flow at the ephemeral stream beds and dry washes. However, the vertical migration of MC is limited due to the infrequent rain fall, the high evaporation rate, and the depth to water table. The

infrequent rainfall leads to infrequent stream flow at the ephemeral stream beds and dry washes where preferential recharge takes place. The potential groundwater flow pathway within the Lavic Lake groundwater subbasin is north toward the Lavic Lake playa, and the groundwater may continue to flow north off the installation boundary (**Figure 4-2**). The potential groundwater pathway within the small portion of the watershed area that lies in the Deadman Lake groundwater subbasin is southeast toward Deadman Lake (**Figure 4-2**).

6.5.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Water and sediment accumulated in the Lavic Lake playa downstream of the primary MC loading areas within the Lavic Lake watershed may present potential exposure pathways for ecological species, including federally and state threatened desert tortoise and the California special concern species MFTL. A human exposure pathway has not been identified in the sediment or water within the Lavic Lake watershed.

Groundwater Receptors

There are no known potable wells within the boundaries of the Lavic Lake watershed, and a complete groundwater pathway to ecological receptors is unlikely.

6.5.2. 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 the four primary MC loading areas that drain to the Lavic Lake playa. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages that lead to potential receptor exposure locations in the Lavic Lake playa (threatened and California special concern species). 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 (2006–2010 [Period F]). The proportions of the MC loading areas draining to the Lavic Lake playa are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Lavic Lake watershed.

Table 6-45 presents the estimated percentage of total MC mass contributed by the individual primary MC loading areas draining to the Lavic Lake playa, respectively. The Lavic Lake II primary MC loading area was predicted to contribute the highest

Table 6-45: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the Lavic Lake Playa

Primary MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Lavic Lake I	0	27	31	40
Lavic Lake II	90	41	49	60
Gays Pass I	<1	<1	<1	<1
Gays Pass II	9	32	20	<1

proportions of MC mass (nearly all of HMX, more than 55% of perchlorate, and nearly one-half of RDX and TNT) to the Lavic Lake playa

Table 6-46 and **Table 6-47** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the watershed of the Lavic Lake playa. The average annual concentrations of RDX and TNT in runoff were predicted to be above REVA trigger values at the edge of all four MC loading areas draining within the Lavic Lake watershed (**Table 6-46**). The average annual concentration of perchlorate was predicted to be above the REVA trigger value at the edge of the Lavic Lake I and Lavic Lake II MC loading areas, and the average annual concentrations of HMX was predicted to be below the REVA trigger value at the edge of all four primary MC loading areas draining within the Lavic Lake watershed (**Table 6-46**). The average annual MC concentrations in sediment at the edge of all the primary MC loading areas draining within the Lavic Lake watershed were predicted to be below REVA trigger values (**Table 6-47**).

Table 6-46: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Lavic Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Water (µg/L)	0.114	0.110	0.113	0.021
MC Concentration (µg/L)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Lavic Lake I	N/A	**0.423**	**2.25**	**1.65**
Lavic Lake II	0.041	**0.418**	**2.34**	**1.61**
Gays Pass I	0.008	**0.644**	**1.76**	0.003
Gays Pass II	0.006	**0.446**	**1.34**	0.002

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

Shading and bold indicate concentration exceeds the REVA trigger value.

Table 6-47: Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Lavic Lake Watershed

	HMX	RDX	TNT	Perchlorate
REVA Trigger Value for Sediment (µg/kg)	51	32.5	25	0.18
MC Concentration (µg/kg)				
MC Loading Area	HMX	RDX	TNT	Perchlorate
Lavic Lake I	N/A	0.003	1.25	~0
Lavic Lake II	~0	0.003	1.24	~0
Gays Pass I	~0	0.008	1.54	~0
Gays Pass II	~0	~0	0.079	~0

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

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and sediment entering the Lavic Lake playa, the identified downstream receptor exposure location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of TNT and perchlorate in surface water runoff entering the Lavic Lake playa were predicted to be above REVA trigger values (**Table 6-48**). However, the average annual concentrations of HMX and RDX in surface water runoff entering the Lavic Lake playa were predicted to be below REVA trigger values. All predicted MC concentrations, including TNT and perchlorate, were at least two orders of magnitude lower than the RMUS freshwater values and at least three orders of magnitude lower than the RMUS marine water values. The predicted perchlorate concentrations were four orders of magnitude lower than the RMUS freshwater and marine water values. As a result, the ecological receptors identified to potentially use the water in Lavic Lake playa are unlikely to be impacted by MC release to the playa lake.

Table 6-48: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff Entering the Lavic Lake Playa

MC	REVA Trigger Value (µg/L)	RMUS Freshwater Value (µg/L)	RMUS Marine Water Value (µg/L)	Concentrations (µg/L)
HMX	0.114	150	330	0.002
RDX	0.110	190	5000	0.044
TNT	0.113	90	180	**0.212**
Perchlorate	0.021	9300	9300	**0.127**

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

Average annual MC concentrations in sediment entering the Lavic Lake playa were not estimated because the edge-of-loading-area MC concentrations in sediment were predicted to be below REVA trigger values (**Table 6-47**); thus, the concentrations are expected to be even lower in the downstream location in Lavic Lake playa. However, MC concentrations in the playa lake bed were estimated (as described in **Section 5.1.2**), and the results are presented in **Table 6-49**. The cumulative perchlorate concentration in the sediment of the Lavic Lake playa bed was predicted to be above the REVA trigger value.

Table 6-49: Screening-Level Estimates of Cumulative MC Concentrations in the Sediment of Lavic Lake Playa Bed

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
HMX	51	4.7–470	0.127
RDX	32.5	13 –1300	2.85
TNT	25	92–9200	13.36
Perchlorate	0.18	NA	**7.51**

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

The actual perchlorate concentration in the sediment of the playa lakebed is expected to be lower because of the conservative approach used in the screening-level analysis. The predicted cumulative perchlorate concentration in the sediment of the Lavic Lake playa bed is five orders of magnitude lower than the State of California OEHHA soil screening number for perchlorate in soil at commercial/industrial sites of 3,500 mg/kg. This indicates no current impact to potential receptors of the sediment in the playa lake.

6.5.3. Groundwater Analysis Results

A qualitative groundwater analysis was performed by analyzing the source media, migration mechanisms, and exposure pathways (as described in the earlier subsections and in **Section 4**). Based on the results of the qualitative analysis of the groundwater information, limited potential exists for MC migration to groundwater and no known existing groundwater receptor exposure locations are present down gradient of the MC loading areas located within the Lavic Lake watershed. The Gays Pass I and a portion of the Gays Pass II MC loading areas lie within the Deadman Lake groundwater subbasin where the installation has future plans to utilize the groundwater for drinking; however, due to the estimated significant depth to groundwater at these MC loading areas, MC migration to groundwater is expected to be minimal. Therefore, the MC loading areas

within the Lavic Lake watershed are not considered areas of concern for MC migration in groundwater. No further analysis is required at this time.

6.6. Quackenbush Lake Watershed

The Quackenbush Lake Watershed is located on the western part of MCAGCC Twentynine Palms; it is approximately 12,800 acres, with the entire area located inside the MCAGCC installation boundary (**Figure 6-7**). The watershed area encompasses an ephemeral stream network and the Quackenbush Lake. The Quackenbush Lake, which is a potential receptor exposure location, is located within the installation boundary. A total of three RTAs are located within the watershed:

- Gays Pass (18,316 acres)
- Quackenbush (42,037 acres)
- Emerson Lake (32,287 acres)

Each of these are live-fire RTAs used for various training; allowable munitions for these areas include all conventional munitions (air/ground) where the safety footprint can remain within 1000 m of the RTA or installation boundary.

Two primary MC loading areas partially or fully located within the three RTAs where the majority of MC deposition is anticipated to occur are listed in **Table 6-50**.

Table 6-50: Primary MC Loading Areas in the Quackenbush Lake Watershed

MC Loading Area	Size (acres)
Gays Pass I	2,364
Quackenbush	7,744

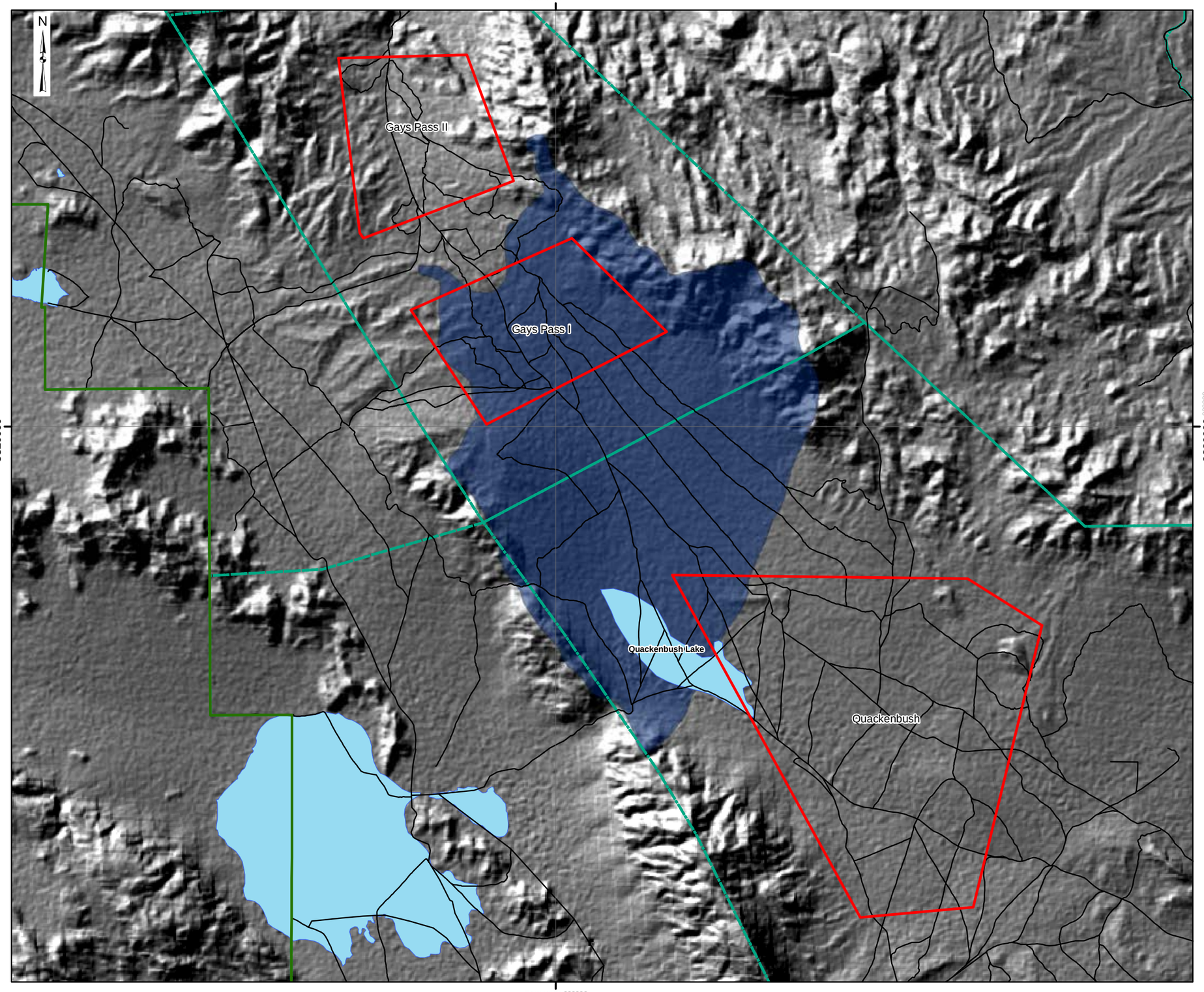
Military Munitions

The general classes of military munitions expected at this RTA include small arms ammunitions and high explosive ammunitions.

6.6.1. Conceptual Site Model

6.6.1.1. Estimated Munitions Constituents Loading

The primary MC loading areas within the Quackenbush Lake watershed are shown in **Figure 6-7**. The boundaries of each primary MC loading area were selected based on training-specific information (e.g., operational range boundaries, target locations, other



REVA
FIGURE 6-7
MCAGCC TWENTYNINE PALMS
PRIMARY MC LOADING AREAS WITHIN THE QUACKENBUSH WATERSHED

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- MC Loading Areas
- Restricted Areas
- Quackenbush Watershed
- Playa
- Main Supply Routes

0 0.2 0.4 0.8 1.2
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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GIS data), which does not necessarily capture the complete potential spatial distribution of MC loading.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within this MC loading area over time (**Table 6-51**); the assumptions used to guide the estimates are detailed in **Section 3**. Compared to estimated baseline MC loading rates derived from munitions data available during the prior assessment, the estimated MC loading rates for this review suggest loading generally has increased since the baseline assessment (**Table 6-51**). HMX loading increased by three to four orders of magnitude, while perchlorate loading increased one to two orders of magnitude, across the watershed. RDX and TNT loading increased less than one order of magnitude in the Quackenbush MC loading area.

Table 6-51: Estimated Annual MC Loading for the Quackenbush Lake Watershed

Primary MC Loading Area	Assumed Loading Area (m^2)	Estimated Annual Loading Rate (kg/m^2)				
		Time Period F (2006–2010)				
		Assessment	HMX (kg/m^2)	RDX (kg/m^2)	TNT (kg/m^2)	Perchlorate (kg/m^2)
Gays Pass	41,047,000	Baseline	5.48E-13	1.55E-07	2.29E-07	3.64E-11
Gays Pass I	9,567,943	Five-year Review	5.12E-10	3.03E-07	4.40E-07	1.47E-10
Quackenbush	73,836,000	Baseline	6.55E-12	3.10E-07	5.64E-07	1.14E-10
	31,340,708	Five-year Review	5.82E-08	1.95E-06	3.36E-06	4.77E-08

Note:
Estimated "Baseline" MC loading rates are based on "Period E" values of the baseline report (covering 1989–2005), which incorporate a +50% training factor to account for potential/actual inconsistent expenditure recordkeeping, which would suggest a lower loading rate than actually occurring during that assessment. "Five-year Review" values cover 2006 to 2010.

Annual lead deposition for the RTAs in the Quackenbush watershed was estimated during this five-year review (**Table 6-52**). 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. Calculations indicate the greatest lead deposition in the watershed may be at the Quackenbush MC loading area, with an estimated deposition of 5.88E-05 kg/m^2 annually, for a total annual deposition of 4,066 lb of lead.

Table 6-52: Estimated Annual Lead Deposition for the Quackenbush Watershed

MC Loading Area	Size (m^2)	Lead		
		kg/m^2	lb/yd^2	Total lb
Gays Pass I	9.57E+06	1.17E-05	2.16E-05	248
Quackenbush	3.13E+07	5.88E-05	1.08E-04	4,066

6.6.1.2. Geography and Topography

The Quackenbush Lake Watershed is bordered by the Hidalgo Mountains on the west and the Bullion Mountains on the northeast. The area is characteristic of a pass of level land. The terrain generally slopes from northwest to southeast and from northeast to southwest toward the Quackenbush Lake playa. Available elevation contour data indicate the elevation of the watershed area within the installation boundary ranges from approximately 2,755 ft amsl in Quackenbush Lake playa to approximately 4,625 ft amsl at the Bullion Mountains (MCAGCC Twentynine Palms FMD, 2010). Based on available GIS data, the slope within the installation boundary of the watershed area ranges from less than 2% to approximately 60% in the mountain hills, but the majority of area has an average slope of approximately 6% (MCAGCC Twentynine Palms FMD, 2006).

6.6.1.3. Surface Water Features

The Quackenbush Lake Watershed contains an ephemeral stream network. Streams originate from the Bullion Mountains on the northeast and the Hidalgo Mountains on the west and drain south toward the Quackenbush Lake. A large proportion of the Gays Pass I (approximately 99%) and a small proportion of the Quackenbush primary MC loading areas drain within the Quackenbush Lake watershed.

Table 6-53 describes the drainage characteristics of the two primary MC loading areas within the Dry Lake watershed.

Table 6-53: Drainage Description for the MC Loading Areas within the Quackenbush Lake Watershed

Primary MC Loading Area	Drainage Description
Gays Pass I	Streams drain southeast and southwest within the loading area and ultimately discharge into the Quackenbush Lake.
Quackenbush	Streams originating from the Bullion Mountains on the northeast drain south within the small proportion of the MC loading area that drains within the watershed, into the Quackenbush Lake. The loading area is adjacent to the Quackenbush Lake.

6.6.1.4. Soil Characteristics and Land Cover

The predominant soil types of the Quackenbush Lake Watershed within the installation boundary include Arizo extremely gravelly loamy sand (274), Haleburu-Upspring complex (403), and Arizo-Hypoint association (295). These soils are well to excessively well drained and are slightly to moderately alkaline. The organic content of the soils ranges from 0% to 0.5%, with the Arizo extremely gravelly loamy sand having a lower organic content of 0% to 0.3%, while the other soil types having an organic content of 0% to 0.5% (USDA NRCS, 1999). The soil types have low inherent soil erodibility, with their soil erodibility factors ranging from 0.02 to 0.05 tons/acre (USDA NRCS, 1999). The watershed area is largely covered with sparse vegetation mostly consisting of Creosote Bush Shrubland.

6.6.1.5. Erosion Potential

The estimated soil erosion potential of the two identified primary MC loading areas within the Quackenbush Lake Watershed are low. This low soil erosion potential at the MC loading areas is primarily a result of low inherent soil erodibility factors and low to moderate topographic slopes within the areas.

6.6.1.6. Groundwater Characteristics

The Quackenbush Lake Watershed lies within the Deadman Lake groundwater subbasin of the Twentynine Palms basin (**Figure 4-2**), which is the best-understood water bearing unit at MCAGCC Twentynine Palms. The groundwater characteristics of this subbasin are described in **Section 6.4.1.6**.

6.6.1.7. Potential Surface Water and Groundwater Pathways

Surface Water and Sediment Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the Dry Lake watershed. Runoff coefficients at primary MC loading areas were assumed to range from 0.42 to 0.45. These relatively high runoff potentials are largely attributable to the infrequent torrential storms that occur (often resulting in flash floods), the sparse vegetation cover, and the low to moderate topographic slopes at the identified primary MC loading areas within the watershed. As indicated in **Section 6.2.1.5**, the primary MC loading areas within the watershed have low soil erosion potential, making land surface erosion a less important mechanism for MC mobilization into surface water runoff. However, streambed erosion due to the occurrence of flush flood events can be an important MC pathway to the potential downstream receptor exposure location in Quackenbush Lake. MC in streams would drain southeast and southwest into Quackenbush Lake.

Groundwater Pathways

MC deposited on the primary MC loading areas within the Quackenbush Lake watershed have the potential to migrate toward the water table by direct infiltration of rain water or through preferential recharge from the infrequent stream flow at the ephemeral stream beds and dry washes. However, the vertical migration of MC is limited due to the infrequent rain fall, the high evaporation rate, and the depth to water table. The infrequent rainfall leads to infrequent stream flow at the ephemeral streambeds and dry washes where preferential recharge takes place. Furthermore, the likelihood for accumulated surface water potentially containing MC in the Quackenbush Lake playa to infiltrate down to the underlying perched groundwater is very limited due to the presence of thick (approximately 50 ft thick) low permeable soils beneath the playa. The potential groundwater pathway is southeast toward the Deadman Lake playa (**Figure 4-2**).

6.6.1.8. Potential Surface Water and Groundwater Receptors

Surface Water and Sediment Receptors

Water and sediment accumulated in the Quackenbush Lake playa downstream of the primary MC loading areas within the Quackenbush Lake watershed may present potential exposure pathways for ecological species, including federally and state threatened desert tortoise and the California special concern species MFTL. A human exposure pathway has not been identified in the sediment and water within the Quackenbush Lake watershed.

Groundwater Receptors

There are no known potable wells within the Quackenbush Lake watershed, and a complete groundwater pathway to ecological receptors is unlikely. However, the installation has future plans to draw water from the Deadman Lake groundwater subbasin for drinking water use by mixing with groundwater from the Surprise Spring subbasin where the installation currently draws water for drinking water use. The installation has not yet identified from where in the Deadman Lake subbasin the water would be drawn as they are currently conducting studies.

6.6.2. 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 two primary MC loading areas that drain to the Quackenbush Lake playa. The MC loading areas included Gays Pass I and Quackenbush. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and surface drainages that lead to potential receptor exposure location in the Quackenbush Lake playa (threatened and

California special concern species). 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 (2006–2010 [Period F]). The proportions of the MC loading areas draining to the Quackenbush Lake playa are presented in **Table 5-2**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the Quackenbush Lake watershed.

Table 6-54 presents the estimated percentage of total MC mass contributed by the individual primary MC loading areas draining to the Dry Lake playa, respectively. The Quackenbush MC loading area was predicted to contribute significant proportions of MC (over 60%) into the Quackenbush Lake playa.

Table 6-54: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the Quackenbush Lake Playa

MC Loading Area	MC Contributed (% Total Mass)			
	HMX	RDX	TNT	Perchlorate
Gays Pass I	3	35	35	1
Quackenbush	97	65	65	99

The estimated edge-of-loading-area MC concentrations in surface water runoff and in sediment for the Quackenbush and Gays Pass I primary MC loading areas are presented in **Table 6-34** and **Table 6-35** (for Quackenbush) and in **Table 6-46** and **Table 6-47** (for Gays Pass I) in **Section 6.4.2** and **Section 6.5.2** (within the Deadman Lake and the Lavic Lake watershed sections), as these areas are also upstream contributors of the Deadman Lake and the Lavic Lake playas.

Based on the screening-level calculations, the average annual concentrations of RDX and TNT in runoff at the edge of both MC loading areas were predicted to be above REVA trigger values (**Table 6-34** and **Table 6-46**). The average annual concentrations of HMX and perchlorate in runoff also were predicted to be above REVA trigger values at the edge of the Quackenbush MC loading area (**Table 6-34**). The average annual MC concentrations in sediment at the edge of both primary MC loading areas draining within the Quackenbush Lake watershed were predicted to be below REVA trigger values (**Table 6-35** and **Table 6-47**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and sediment entering the Quackenbush Lake playa, the identified downstream receptor exposure location (as described in **Section 5.1.1.2** and **Section**

5.1.2). The average annual concentrations of RDX, TNT, and perchlorate in surface water runoff entering the Quackenbush Lake playa were predicted to be above REVA trigger values (**Table 6-55**). All predicted MC concentrations, including the MC predicted to exceed REVA trigger values, were at least one order of magnitude lower than the RMUS freshwater values and at least two orders of magnitude lower than the RMUS marine water values. As a result, the ecological receptors identified to potentially use the water in Quackenbush Lake playa are unlikely to be impacted by MC release to the playa lake.

Table 6-55: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff Entering the Quackenbush Lake Playa

MC	REVA Trigger Value (µg/L)	RMUS Freshwater Value (µg/L)	RMUS Marine Water Value (µg/L)	Concentrations (µg/L)
HMX	0.114	150	330	0.049
RDX	0.110	190	5000	**0.348**
TNT	0.113	90	180	**0.950**
Perchlorate	0.021	9300	9300	**0.054**

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

Average annual MC concentrations in sediment entering the Quackenbush Lake playa were not estimated because the edge-of-loading-area MC concentrations in sediment were predicted to be below REVA trigger values (**Table 6-35** and **Table 6-47**); thus, the concentrations are expected to be even lower in the downstream location in Quackenbush Lake playa. However, MC concentrations that would result from MC accumulation in the playa lakebed as a result of water evaporating from the playa lake were estimated (as described in **Section 5.1.2**); the results are presented in **Table 6-56**. The cumulative TNT and perchlorate concentrations in the sediment of the Quackenbush Lake playa bed were predicted to be above REVA trigger values.

Table 6-56: Screening-Level Estimates of Cumulative MC Concentrations in the Sediment of the Quackenbush Lake Playa Bed

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Industrial Soil Screening Values (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
HMX	51	4.7–470	49,000,000[a]	3.03
RDX	32.5	13 –1300	24,000[a]	21.8
TNT	25	92–9200	79,000[a]	**59.7**

MC	REVA Trigger Value (µg/kg)	RMUS Freshwater and Marine Sediment (µg/kg)	Industrial Soil Screening Values (µg/kg)	Cumulative Sediment Concentrations (µg/kg)
Perchlorate	0.18	NA	3,500,000[b]	**3.32**

Note:
Shading and bold indicate concentration exceeds the REVA trigger value
[a]EPA Region 9 soil screening values (June, 2011)
[b]California OEHHA industrial soil screening values

The actual TNT and perchlorate concentrations in the sediment of the playa lakebed are expected to be lower because of the conservative approach used in the screening-level analysis. The predicted cumulative TNT concentration is approximately 1.5 times lower than the lower range RMUS freshwater and marine water sediment value of 92 µg/kg. The sediments within the playa lakes are characterized as dry sediment (following evaporation of the collected surface water within the playa), which is more akin to a soil exposure medium rather than the saturated freshwater and marine sediments, for which existing RMUS values for ecological receptors have not been established. Note that there is no established RMUS sediment screening value for perchlorate. The predicted cumulative MC concentrations in the sediment of the Quackenbush Lake playa bed were also compared to the EPA Region 9 and the State of California OEHHA industrial soil screening values. The predicted cumulative TNT and perchlorate concentrations in sediment are three and six orders of magnitude lower than the EPA Region 9 and the State of California OEHHA Industrial soil screening values of 79,000 µg/kg and 3,500,000 µg/kg, respectively (**Table 6-56**).

These findings indicate that there is no current concern of impact to receptors, but additional evaluations may be warranted if future changes are anticipated within the Deadman Lake watershed area (such as land use changes or significant increases in the use of munitions containing HE).

6.6.3. Groundwater Analysis Results

Groundwater fate and transport modeling through screening-level analysis was conducted for the Quackenbush primary MC loading area within the Quackenbush Lake watershed. This MC loading area was selected for quantitative transport analysis based on its current use of munitions containing HE, its moderately shallow depth to groundwater, and its proximity to potential future groundwater receptors. The Quackenbush primary MC loading area analyzed is located within the Deadman Lake groundwater subbasin where the installation has future plans to draw water for drinking water use by mixing with groundwater from the Surprise Spring subbasin. Results for the groundwater screening-level analysis for the Quackenbush primary MC loading area are presented in **Section 6.4.3**.

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. Therefore, ranges that solely use small arms ammunition for training purposes are qualitatively assessed under the REVA program. Ranges that perform joint small arms and live-fire training with HE munitions are not assessed through this process; rather, they are assessed through the MC loading estimation and modeling processes previously described. Only operational SARs are addressed in this protocol; historical use SARs that are no longer used are not assessed due to lack of information to adequately perform an assessment.

MOUT facilities are assessed using the SARAP during the REVA five-year review process. MOUT facilities generally consist of modular buildings or other temporary structures established in a range or training area to support a variety of urban training operations, including building-entry and room-clearing techniques under live- and blank-fire conditions. MOUT facilities may be tailored to various mission training needs and can include assault course, indoor shoot houses, breaching facilities, and convoy course operations. Large-scale MOUT facilities, such as the 274-acre Combined Arms MOUT located in Quackenbush RTA, support major EMV training exercises. Blank, simmunitions, and other training aids generally are used within MOUT structures; however, some live-fire MOUT facilities allow the use of small arms in special buildings (e.g., those containing shock-absorbing concrete walls) or in outdoor MOUT locations. As such, the SARAP was selected to provide the initial evaluation of lead loading at live-fire MOUT facilities.

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 environmental concern evaluation rankings for surface water and groundwater conditions. The scoring system assigns minimal, moderate, and high values for each environmental concern category:

- Minimal (0 to 29 points) – The SAR has minimal or no potential for lead migration, indicating minimal threat of environmental concern, but actions may be considered to maintain a minimal ranking.
- Moderate (30 to 49 points) – The SAR may have the potential for lead migration, most likely indicating that there is no immediate environmental concern, 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, creating the greatest level of environmental concern and requiring the recommendation of additional action(s).

Additional documentation describing the purpose, requirements, and supporting drivers for the performance of the SAR assessment is provided with the range-specific assessments in **Appendix C**, which contains the assessments of the operational SARs at MCAGCC Twentynine Palms. Where warranted, key range-specific considerations not captured by the SARAP were taken into account during the assessments, and rankings were modified accordingly.

The locations of the ranges are shown on **Figure 7-1 and Figure 7-2**. **Table 7-1** provides a summary of the assessment of each range. These results are discussed in the following sections.

Table 7-1: Summary of SAR Prioritizations

Range Name	Range Type	Surface Water Environmental Concern	Groundwater Environmental Concern
SARs			
Range 1	Known distance rifle range	Minimal	Minimal*
Range 1A	Unknown distance rifle range	Minimal	Minimal
Range 2	Known distance pistol range	Minimal	Minimal*

Range Name	Range Type	Surface Water Environmental Concern	Groundwater Environmental Concern
Range 2A	Combat pistol range	Minimal	Minimal
Range 3	Rifle field expedient BZO grouping range	Minimal	Minimal
Range 3A	Multi-purpose rifle/pistol range	Minimal	Minimal*
Range 101	Small arms BZO	Minimal	Minimal*
Live-Fire MOUT Facilities			
Range 111	MOUT Assault Course	Minimal	Minimal*
Range 205	Live-Fire Convoy Operations Course	Minimal	Minimal*
Range 205A	Live-Fire MOUT Facility	Minimal	Minimal
Range 210	Live-Fire MOUT Facility	Minimal	Minimal*

Note:

* Ranking was modified based on consideration of additional range-specific factors and professional judgment.

Range Control oversees the scheduling and administration of the SARs present at MCAGCC Twentynine Palms. As discussed in **Section 3.2**, estimation of average annual lead loading at each SAR was based upon 5 years of expenditure data (2006 to 2010); key assumptions are discussed in that section.

As previously noted, O&T is responsible for the administration and oversight of the training operations conducted at MCAGCC Twentynine Palms. During the baseline assessment, expenditure counts for each SAR located at the MTU were provided by MTU personnel, as these records were kept separate from the main expenditure records. The REVA team noted in its review of the MTU expenditure data that recordkeeping procedures have changed since the baseline assessment; MTU personnel indicated that they maintain expenditure counts for certain units and not all users and forward all records for inclusion in the primary expenditure records. MTU's expenditure records are no longer maintained for each individual range; rather, a collective count for all ranges at the complex is recorded. MTU personnel provided guidance on how their counts may be divided among the complex's individual ranges. Because MTU data do not account for all range users, they produced different expenditure counts than the RFMSS data. However, the RFMSS data were not always the larger of the two counts, a discrepancy that was unable to be rectified. Consequently, a conservative approach was taken for each MTU range—the dataset that produced the larger lead loading rates was used for

this assessment; any data regarding incidental non-small-arms use at these ranges was discounted.

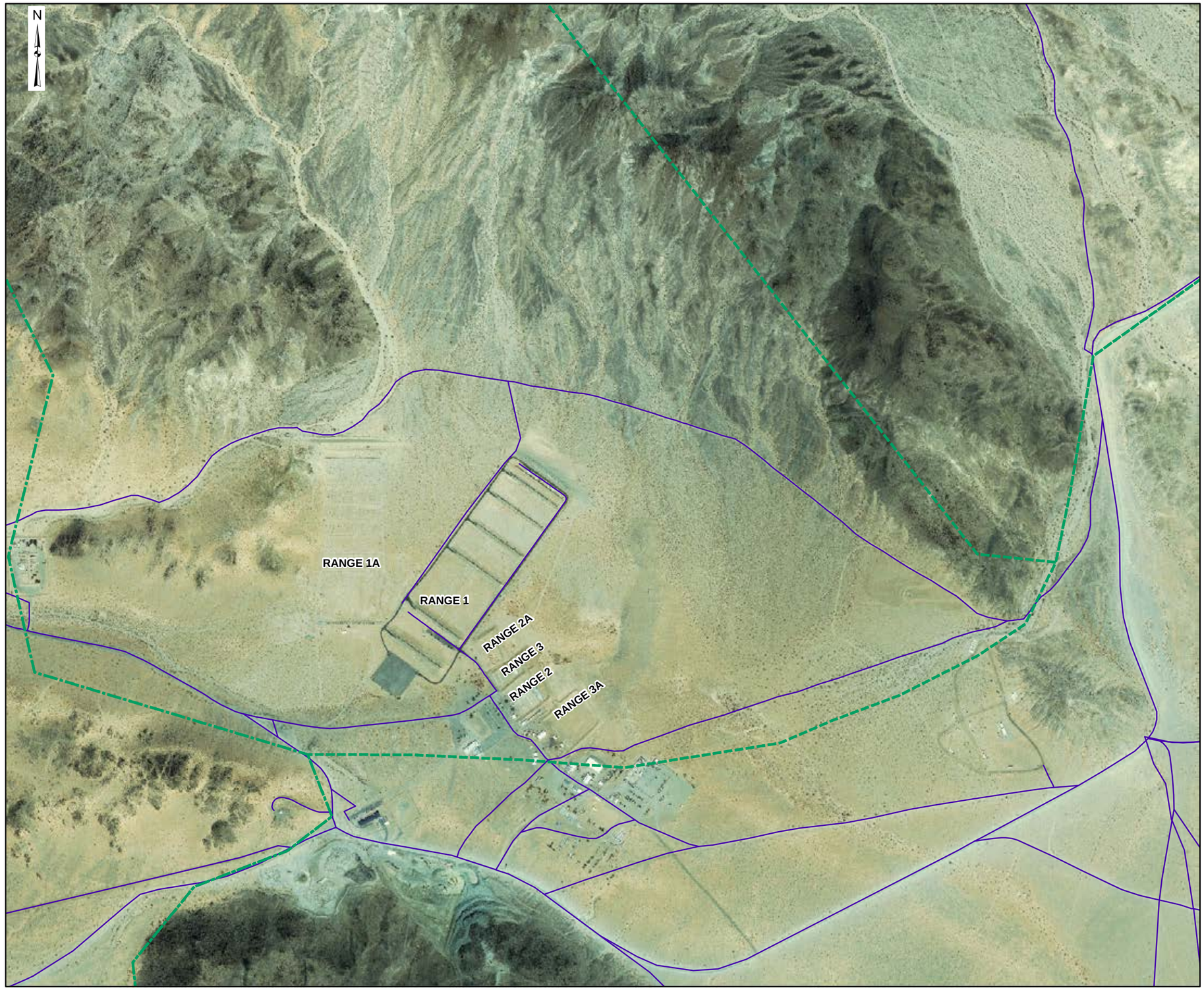
7.2. Small Arms Ranges

SARs are located in Range RTA, as shown 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 threatened and endangered species is similar between ranges, and the same data that were presented in the baseline report, as no changes in these characteristics were noted over the five-year period between assessments. The estimated lead depositional rates for each range were the primary difference between the baseline and five-year assessments.

Soil sampling at Range 105A was conducted following the baseline assessment to evaluate the potential for lead migration from SARs in an arid, desert environment (Malcolm Pirnie, 2011). Range 105A was selected given its lead loading rates and proximity to Deadman Lake playa. Soil sampling was conducted in October 2010 with a total of 12 samples (9 shallow, 2 deep, and one quality control) collected in the following manner:

- Two background shallow soil samples collected up gradient of the bermed area (SS-1 and SS-2)
- Five shallow soil samples (SS-3 through SS-7) located in the drainage features that potentially drain from the range
- One set of shallow soil samples and subsurface soil samples located within the berm (SS-8, SB-01 [1.5–2], and SB-02 [3.5–4]) and one paired shallow soil sample and subsurface soil sample located just behind the backstop berm (SS-9 and SB-03 [1.5–2])

The samples were analyzed for total lead and copper, pH, and total organic carbon. Lead concentrations ranged from an estimated 3.7 to 5,800 mg/kg in shallow soil and 2.3 to 71 mg/kg in the deeper soil sample. Lead concentrations in shallow soil from locations SS-03, SS-08, and SS-09 exceeded the relevant EPA RSLs (lowest level at 400 mg/kg) and/or California Human Health Screening Level (CHHSLs) (lowest level at 150 mg/kg). The deeper soil sample did not exceed screening levels. Lead and copper concentrations in soil on and immediately adjacent to the range were elevated, while the samples farthest from the range, both upstream and downstream, were much lower and below available screening levels. These results confirmed the anticipated conditions that metals associated with SAR use would not migrate a significant distance from the range in such an arid environment.



REVA
FIGURE 7-1
MCAGCC TWENTYNINE PALMS
SMALL ARMS RANGES WITHIN
MARKSMANSHIP TRAINING UNIT

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

Range Training Areas (RTAs)

Main Supply Routes

0 0.035 0.07 0.14 0.21
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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Information applicable across the installation is further detailed in **Section 7.3**. Additional site-specific data used to complete the qualitative evaluations of the SARs are provided in the site-specific SARAPs in **Appendix C**.

7.3. MTU Range 1 – Known Distance Rifle Range

7.3.1. Site Background

The MTU oversees the small arms training and requalification of Marines at MCAGCC Twentynine Palms. The MTU ranges consist of six SARs located in the Range RTA (**Figure 7-1**). Expenditure data at each range for 2006 through 2010 were obtained from the MTU for use in estimating lead loading.

Range 1 is used by the MTU for rifle proficiency and requalification at known distances. The range consists of several firing lines, earthen side containment berms, and an earthen rear impact berm for bullet containment. Marines behind the rear impact berm raise stationary targets for the shooters on the firing lines during training operations. The range has been used heavily in recent years, with over 9,000 lb of lead estimated to have been deposited in the rear impact berm each year from 2006 to 2010. This lead loading rate is significantly greater than the loading rate calculated during the baseline assessment (5,000–7,000 lb per year).

Due to the high training use of this SAR, a bullet trap was installed in 2000/2001 for greater capture and containment of lead fragments. However, the bullet trap was removed within 2 years of its installation due to range safety concerns; an increased rate of ricochet of expended rounds was observed when the trap was in place. Currently, sand is spread periodically across the face of the impact berm to minimize the formation of deep bullet pockets.

Surface runoff generated during storm events flows south from Range 1, then southwest for eventual discharge in the Mesquite Dry Lake playa, approximately 2.5 miles from the range. An earthen berm located behind the rear impact berm appears to serve as a partial engineered control by redirecting surface runoff away from the range. Most surface water quickly evaporates due to the high temperatures in the region; only limited infiltration occurs along the courses of surface drainages and less so through low permeability playa soils.

Groundwater depths on the MTU are not known, but the depth to groundwater is expected to be up to 400 ft bgs, given the elevation at the MTU (Battelle, 1998). There are no water supply wells near the MTU ranges.

Additional site-specific data used to complete the qualitative evaluation of Range 1 are provided in the SARAP tables in **Appendix C**.

7.3.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score (29 points). Limited precipitation rates and partial engineered controls (earthen berms) reduce the potential for lead transport. Although intense storms in the winter might cause runoff to act as a transport mechanism, lead from this range would not be expected to reach Mesquite Dry Lake (2.5 miles down gradient) in high concentrations or quantities. Soil sampling activities at Range 105A at the installation provide supporting evidence that lead transport in surface water from SARs is quite limited. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

The Groundwater Environmental Concern Evaluation Ranking resulted in a Moderate score (32–34 points). However, it is the professional judgment of the REVA assessment team that the overall concern for lead migration and exposure to groundwater receptors is more accurately categorized as a Minimal level. The groundwater pathway score is biased high by the sandy nature of the soils and the lack of clay in the soil unit. Previous sampling data indicate that lead migration on this range is limited to a maximum of 8 inches from the soil surface. In addition, the depth to groundwater and the lack of groundwater receptors in the area likely preclude any significant groundwater impacts. Therefore, on the basis of professional judgment, there is minimal potential for lead migration and impact to groundwater resources.

7.4. MTU Range 1A – Unknown Distance Rifle Range

7.4.1. Site Background

Range 1A is used to train Marines in long-range rifle firing at targets of unknown or variable distance. The range is the westernmost of the MTU ranges and extends from the south (location of the firing points) to the north (location of the rear targets and rear earthen impact berm) (**Figure 7-1**). The range was constructed in the early 2000s and has received a high level of use in recent years. The estimated annual lead deposition in the rear impact berm at this range is approximately 1,00 lb per year between 2006 and 2010. The average annual lead loading for this period is significantly less than the average recorded during the baseline assessment (3,600–6,600 lb per year).

Surface runoff generated during storm events flows south from Range 1A, then southwest for eventual discharge in the Mesquite Dry Lake playa, approximately 2.5 miles from the range. An earthen berm located behind the rear impact berm appears to serve as a partial engineered control by redirecting surface runoff away from the range. Most surface

water quickly evaporates due to the high temperatures in the region; only limited infiltration occurs along the courses of surface drainages and less so through low permeability playa soils.

Groundwater depths on the MTU are not known, but the depth to groundwater is expected to be up to 400 ft bgs, given the elevation at the MTU (Battelle, 1998). There are no water supply wells near the MTU ranges.

Additional site-specific data used to complete the qualitative evaluation of Range 1A are provided in the SARAP tables in **Appendix C**.

7.4.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score for this range (25 points). The range has been in use for a short period of time (less than 10 years), and the distance to the nearest intermittent surface water body (2.5 miles) makes it unlikely that lead from range operations will reach this point of exposure in significant concentrations or quantities. The lead loading rate significantly decreased since the time of the baseline assessment. In addition, recent soil sampling activities at Range 105A at the installation provide supporting evidence that lead transport in surface water from SARs is quite limited. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

The Groundwater Environmental Concern Evaluation Ranking resulted in a Minimal to Moderate score (28–30 points), primarily due to the depth to groundwater and the lack of groundwater receptors. In addition, soil sampling results at other MTU ranges indicate the vertical migration of lead is limited to a maximum of 8 inches from the soil surface. Therefore, there is minimal potential for lead migration and impact to groundwater from Range 1A. As such, the final overall score for this ranking is Minimal, based on professional judgment.

7.5. MTU Range 2 – Known Distance Pistol Range

7.5.1. Site Background

Range 2 is the primary pistol proficiency and requalification SAR at the MTU. The range is located in the center of the MTU range complex, between Ranges 3 and 3A (**Figure 7-1**). The range was one of the original three SARs established at the MTU in 1955. The range contains 5-, 15-, and 25-yard firing lines and is bounded laterally with earthen protective berms. The original earthen rear impact berm was replaced by a bullet

trap in 2000/2001. Lead was recovered from the original impact berm prior to the installation of the bullet trap.

The estimated deposition of lead at this range is approximately 6,600 lb per year between 2006 and 2010. The average annual lead loading for this range remains high and is similar to the upper estimated loading rate from the baseline assessment (3,800–7,000 lb per year). However, the majority of the rounds fired downrange are captured by the bullet trap. Maintenance personnel recover and recycle the lead fragments every 3 months.

All surface water that falls on the range is captured by a collection system located between the bullet trap and a rear earthen berm. The water is diverted to an existing natural drainage feature that runs between Ranges 2A and 3 and eventually discharges to the Mesquite Dry Lake, approximately 2.5 miles to the southwest. Surface water run-on to Range 2 is prevented by the rear and side berms. The majority of surface water evaporates due to the arid environment.

Groundwater depths on the MTU are not known, but the depth to groundwater is expected to be up to 400 ft bgs, given the elevation at the MTU (Battelle, 1998). There are no water supply wells near the MTU ranges.

Additional site-specific data used to complete the qualitative evaluation of Range 2 are provided in the SARAP tables in **Appendix C**.

7.5.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score (20 points). The presence of a bullet trap on this range greatly limits the potential for lead deposition and migration, as the majority of the lead is captured. Limited precipitation rates reduce the potential for lead transport, and there are no surface water receptors identified near the range. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

The Groundwater Environmental Concern Evaluation Ranking resulted in a Minimal score (28–30 points), primarily due to the depth to groundwater and the lack of groundwater receptors. Therefore, there is minimal potential for lead migration and impact to groundwater.

7.6. MTU Range 2A – Combat Pistol Range

7.6.1. Site Background

Range 2A, located between MTU Ranges 1 and 3, is used for training Marines in close-combat handgun operations. The range was established at the MTU at an unknown date; however, the ASR suggests that it was established between 15 and 35 years ago. The range contains several dozen target locations, with small earthen berms at the base of each target. A side berm is present on the northwest side for containment of fired rounds, as is a rear earthen impact berm. Training activities at this range generally result in less firing as compared to other ranges; this is reflected in the expenditure data obtained from the MTU. The estimated deposition of lead at this range was approximately 45 lb per year between 2006 and 2010. The average annual lead loading for this period is less than the average recorded during the baseline assessment (140–225 lb per year).

Surface water runoff on the range drains to the southwest through an existing natural drainage feature that eventually discharges to the Mesquite Dry Lake, approximately 2.5 miles to the southwest. Surface water run-on to Range 2A is prevented by the rear and side berms. The majority of surface water evaporates due to the arid environment.

Groundwater depths on the MTU are not known, but the depth to groundwater is expected to be up to 400 ft bgs, given the elevation at the MTU (Battelle, 1998). There are no water supply wells near the MTU ranges.

Additional site-specific data used to complete the qualitative evaluation of Range 2A are provided in the SARAP tables in **Appendix C**.

7.6.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score (23 points). This range has been operational for a shorter period of time compared to some of the other MTU ranges, and training activities result in only marginal deposition of lead in the impact berm. Limited precipitation rates and partial engineered controls (earthen berms) reduce the potential for lead transport, and there are no surface water receptors identified near the range. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

The Groundwater Environmental Concern Evaluation Ranking resulted in a Minimal score (26–28 points), primarily due to the depth to groundwater and the lack of

groundwater receptors. Therefore, there is minimal potential for lead migration and impact to groundwater.

7.7. MTU Range 3 – Rifle Field Expedient BZO Grouping Range

7.7.1. Site Background

Range 3 (called the BZO Grouping Range in the baseline assessment) is used by Marine training units for adjustment of sighting scopes on rifles. The range, located between Ranges 2 and 2A in the center of the MTU range complex, was established as a SAR in 1974 (**Figure 7-1**). The range consists of two firing lines, two side impact berms, and a rear bullet trap for capture and containment of fired rounds. The bullet trap was installed in 2000/2001; previously, an earthen impact berm was in place for bullet capture. An estimated 560 lb of lead were deposited annually at this range between 2006 and 2010, which is an order of magnitude increase over the estimated loading rate documented in the baseline report (35–50 lb per year).

All surface water that falls on the range is captured by a collection system located between the bullet trap and a rear earthen berm. The water is diverted to an existing natural drainage feature that runs along the north edge of the range's side berm and eventually discharges to the Mesquite Dry Lake, approximately 2.5 miles to the southwest. Surface water run-on to Range 3 is prevented by the rear and side berms. The majority of surface water evaporates due to the arid environment.

Groundwater depths on the MTU are not known, but the depth to groundwater is expected to be up to 400 ft bgs, given the elevation at the MTU (Battelle, 1998). There are no water supply wells near the MTU ranges.

Additional site-specific data used to complete the qualitative evaluation of Range 3 are provided in the SARAP tables in **Appendix C**.

7.7.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score (16 points). The presence of a bullet trap on this range greatly limits the potential for lead deposition and migration, as the majority of the lead is captured and removed. Limited precipitation rates and the presence of the earthen berms reduce the potential for lead transport, and there are no surface water receptors identified near the range. In addition, recent soil sampling activities at Range 105A and other historical sampling activities at the MTU provide supporting evidence that lead transport in surface water

from SARs is quite limited. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

The Groundwater Environmental Concern Evaluation Ranking resulted in a Minimal score (24–26 points), primarily due to the depth to groundwater and the lack of groundwater receptors. Therefore, there is minimal potential for lead migration and impact to groundwater.

7.8. MTU Range 3A – Multi-purpose Rifle Pistol Range

7.8.1. Site Background

Range 3A was established as a SAR in 1969 and is located adjacent to MTU Range 2 (**Figure 7-1**). Since the baseline assessment in 2006, Range 4 and Range 3A were combined into Range 3A. Part of the range consolidation included the removal of the side berm separating Ranges 3A and 4 and regrading to establish a continuous rear soil impact berm. The new range alignment includes firing lines at 5-, 10-, 15-, 15-, 25-, 35-, 50-, and 100-yard distances from the target area. Side berms are also present for safety purposes.

Lead loading at this range decreased from the baseline assessment; approximately 2,000 lb of lead were estimated to be deposited annually from 2006 to 2010, whereas the combined lead loading rate for Range 3A and Range 4 in the baseline was between 3,100 and 5,900 lb per year.

Surface water deposited by precipitation likely evaporates quickly due to the arid environment, although some infiltration into the well-drained sandy soils likely occurs as well. Runoff from intense storms that fall on the range may drain to the southwest and eventually discharge to the Mesquite Dry Lake, approximately 2.5 miles to the southwest. Surface water run-on to Range 3A is prevented by the rear impact berm.

Groundwater depths on the MTU are not known, but the depth to groundwater is expected to be up to 400 ft bgs, given the elevation at the MTU (Battelle, 1998). There are no water supply wells near the MTU ranges.

Additional site-specific data used to complete the qualitative evaluation of Range 3A are provided in the SARAP tables in **Appendix C**.

7.8.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score (29 points). Limited precipitation rates and partial engineered controls (earthen berms) reduce the potential for lead transport. Although intense storms in the winter might cause runoff to act as a transport mechanism, lead from this range would not be expected to reach Mesquite Dry Lake (2.5 miles down gradient) in high concentrations or quantities. In addition, recent soil sampling activities at Range 105A and other historical sampling activities at the MTU provide supporting evidence that lead transport in surface water from SARs is quite limited. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

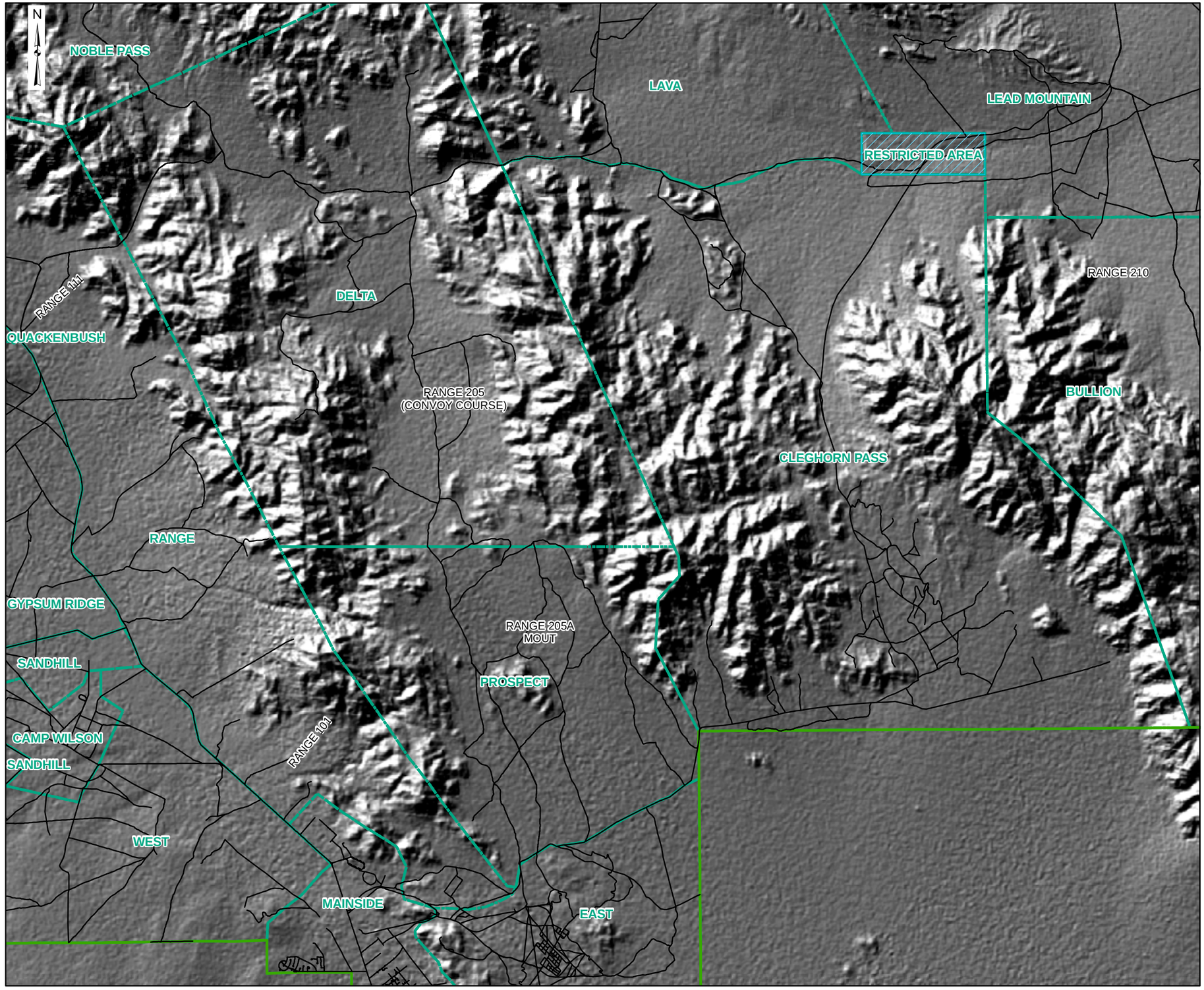
The Groundwater Environmental Concern Evaluation Ranking resulted in a Moderate score (32–34 points). However, it is the professional judgment of the REVA assessment team that the overall concern for lead migration and exposure to groundwater receptors is more accurately categorized as a Minimal level. The groundwater pathway score is biased high based on the sandy nature of the soils and lack of clay in the soil unit. Previous sampling data from nearby MTU ranges indicate that lead migration on this range is limited to a maximum of 8 inches from the soil surface. In addition, the depth to groundwater and the lack of groundwater receptors in the area likely preclude any significant groundwater impacts. Therefore, on the basis of professional judgment, there is minimal potential for lead migration and impact to groundwater resources.

7.9. Range 101 – Small Arms Battle Sight Zero

7.9.1. Site Background

Range 101 is located on the southern portion of the Range RTA (**Figure 7-2**). Since the baseline assessment in 2006, Ranges 101 and 101A were combined into Range 101 and renamed the Small Arms BZO range. The range was first noted in the 1984 Range Standard Operating Procedure for the installation and is used for boresighting and general weapons firing. Weapons fire is directed from the firing line to the northeast toward the base of the Bullion Mountains. The range consists of a small U-shaped BZO area with sand berms comprising three sides. A larger firing line is immediately adjacent to the BZO area. There is no rear impact berm at the back of the primary firing range area for collection of small arms projectiles.

Expenditure data for the years 2006 through 2010 were obtained from Range Control to estimate the amount of lead loading occurring at the range. Approximately 900 lb of lead



REVA
FIGURE 7-2
MCAGCC TWENTYNINE PALMS
RANGE 101 AND MOUT
FACILITIES

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- Restricted Areas
- Main Supply Routes

0 0.35 0.7 1.4 2.1
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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per year were deposited at Range 101 from 2006 to 2010. This lead loading rate is comparable to the combined lead loading rates for Ranges 101 and 101A recorded during the 2004–2005 period of the baseline report (700–1,200 lb per year).

Range 101 drains to the west through gullies that are dry except after heavy rains. Two large surface drainages bisect the northern and central sections of the range fan. Drainages discharge to Deadman Lake within the Range RTA, approximately 1.25 miles to the northwest. The majority of surface water evaporates due to the arid environment.

The depth to water at a well southwest of Deadman Lake is approximately 134 ft bgs; it is likely that the depth to water is greater where the range is located. The installation drinking water wells are located up gradient of the range and are hydrogeologically separated from the range by a large fault. The down gradient groundwater basin, Mesquite basin, is not used as a drinking water source because of high mineral content.

Additional site-specific data used to complete the qualitative evaluation of Range 101 are provided in the SARAP tables in **Appendix C**.

7.9.2. Assessment Results

Surface Water

The Surface Water Environmental Concern Evaluation Ranking resulted in a Minimal score (26–28 points) for this range. The range has been in use for a moderate period of time, minimal lead loading is occurring, and the distance to the nearest intermittent surface water body makes it unlikely that lead from range operations will migrate to this point of exposure in high concentrations or quantities. Recent soil sampling activities at Range 105A and other historical sampling activities at the MTU provide supporting evidence that lead transport in surface water from SARs is quite limited. In addition, Deadman Lake, the ultimate surface water exposure point, is considered to be completely contained on range. As the REVA considers potential MC releases and exposures to off-range receptors only, there are no surface water receptors for this SAR. Therefore, there is minimal potential for lead migration and impact to surface water.

Groundwater

The Groundwater Environmental Concern Evaluation Ranking resulted in a Moderate score (31–33 points), primarily due to the depth to groundwater and the lack of groundwater receptors. However, it is the professional judgment of the REVA team that the overall concern for lead migration and exposure to groundwater receptors is more accurately categorized as a Minimal level. The groundwater pathway score is biased high based on the sandy nature of the soils and lack of clay in the soil unit. Previous sampling data from nearby MTU ranges indicate that lead migration on this range is limited to a

maximum of 8 inches from the soil surface. In addition, the depth to groundwater and the lack of groundwater receptors in the area likely preclude any significant groundwater impacts. Therefore, on the basis of professional judgment, there is minimal potential for lead migration and impact to groundwater resources.

7.10. Live-Fire MOUT Facilities

7.10.1. Site Background

Range 111 is located in the northern end of Range RTA, southeast of Range 113. MOUT activities have been conducted at this location since 2001. Range 111 is a MOUT assault course with eight stations. Some of the stations include structures containing shock-absorbing concrete (SACON). One station is a BZO lane. Another station is a SACON grenade house. The grenade house station is operated under a deviated surface danger zone based on mitigating terrain.

Range 205 is a MOUT live-fire convoy operations course containing five stations that runs through the Delta and Prospect RTAs. The direction of the course is north, and all vehicles follow the prescribed convoy route. No live fire is allowed at station five, the improvised explosive device (IED) station. The direction of fire for all vehicle-mounted weapon systems is to the east/northeast at a range of 3000 m. Tanks, amphibious assault vehicles, and light armored vehicles use the range. Some stations include buildings constructed of SACON. With the exception of station one, targets are located east of the main supply route.

Range 205A is a live-fire MOUT facility in Prospect RTA. Range 205A includes SACON structures which allows for the use of small arms ammunition and practice grenades within buildings. The allowable munitions outside buildings include small arms ammunition and practice muntions. Direction of fire is not prescribed at Range 205A. However, the use of other direct, indirect, or aviation-delivered ordnance may be incorporated into the concept of operations provided the effects from these munitions do not impact the facility buildings and stay within the RTA.

Range 210 is a live-fire MOUT facility in Bullion RTA, which contains nine zones. The allowable weapons and munitions for Range 210 includes small arms ammunition, demolition blanks, simmunitions, practice grenades, pyrotechnics, IED simulators, and booby trap flash simulators. However, the use of other direct, indirect, or aviation-delivered ordnance may be incorporated into the concept of operations provided the effects from these weapons do not impact the facility buildings.

7.10.2. Assessment Results

The surface water and groundwater evaluation rankings for all live-fire MOUTs resulted in Minimal scores. The primary reasons for these scores are the minimal amount of time the ranges have been in use and the low potential for lead transport in surface water and groundwater based on site conditions and the chemical properties of lead.

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