5. Modeling Assumptions and Parameters

As part of the REVA five-year review effort, fate and transport screening-level modeling analyses were conducted for several MC loading areas identified at MCAGCC Twentynine Palms. The surface water and sediment screening-level modeling was conducted for all 18 identified MC loading areas at MCAGCC Twentynine Palms, and the groundwater screening-level modeling was conducted for 5 of the 18 identified MC loading areas (Range I, Range II, Range III, Range IV, and Quackenbush) at MCAGCC Twentynine Palms. The purpose of the fate and transport screening-level analyses was to determine the potential for MC release in surface water, sediment, and groundwater from the identified MC loading areas. If the results of the screening-level analyses indicate a potential release of MC, additional assessments, such as sampling, would be conducted. Otherwise, no further assessment would be conducted at this time, but the identified MC loading areas would be reassessed in the next five-year review to ensure that continued loading at the sites are not impacting surface water, sediment, and groundwater. The surface water, sediment, and groundwater screening-level modeling analyses methods and assumptions are presented in this section.

5.1. Surface Water and Sediment Modeling Assumptions

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

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

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

The mass loading of the indicator MC on the operational ranges was estimated as described in **Section 3**. In accordance with the REVA Part I surface water and sediment screening-level methodology, the entire annual MC load was converted to an average daily loading rate. This average daily loading rate was assumed to be loaded to the ground surface soil. The screening-level analyses were conducted for the 2006–2010 time period.

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

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

Table 5-1: REVA Trigger Values for MC

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

Note: µg/kg – micrograms per kilogram

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

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

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

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

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

ESTIMATION OF SOIL EROSION

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

$$A = RKLSCP$$

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

These factors were estimated for the MC loading areas at MCAGCC Twentynine Palms using available information, such as soil types, land use / land cover, and digital elevation data (MCAGCC Twentynine Palms, 2006; 2010). **Appendix A** lists parameter values used in estimating soil erosion for the MC loading areas.

ESTIMATION OF SURFACE WATER RUNOFF RATE

The annual surface water runoff rate from each loading area was estimated simply as the product of the average annual precipitation, the loading area, and a runoff coefficient. The average annual precipitation of 4.78 inches per year was evaluated from annual precipitation data obtained from MCAGCC Twentynine Palms (for the period 1948–2005). Runoff coefficients were selected from published tabular data (Caltrans, 2006) based on soil hydrologic group, slope, and land cover of the MC loading areas being analyzed (**Appendix A**).

ESTIMATION OF MC MASS AND CONCENTRATION IN SURFACE WATER RUNOFF

A multimedia partitioning model, CalTOX, was used to estimate the mass of MC transported from surface soil to surface water runoff. This model has the capability of simulating the major transport mechanisms that are likely to affect MC from their point of origin in surface soils to their release into surface water runoff. CalTOX was used to simulate the partitioning of MC loaded into various media (soil, air, and water) over time. The rate at which MC will partition among these media is dependent on both the chemical properties of the MC and the physical/hydrological properties of the site. CalTOX requires the input of landscape properties of the MC loading areas and chemical

properties of the MC (**Appendix A**). Values of landscape and chemical properties were selected based on local reports, soil surveys, mapping information, and the scientific literature. Estimates of soil erosion and surface water runoff were calculated as described above and entered into CalTOX.

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

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

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

5.1.1.2. Estimation of Munitions Constituents Concentrations Entering Playa Lakes

MC loading areas within MCAGCC Twentynine Palms drain to ephemeral streams that ultimately flow into playa lakes located within and outside of the MCAGCC Twentynine Palms installation boundary. MC concentrations in surface water runoff entering identified downstream receptor exposure locations (playa lakes) were estimated by the application of a simple, conservative mixing calculation. The total drainage areas upstream of the playa lakes were estimated (**Figure 5-1**). The MC loading areas were grouped by receptor exposure locations (i.e., watersheds of the various playa lakes), and the percentage of each loading area draining to the given receptor exposure location was approximated (**Table 5-2**). The estimated concentrations at the edge of the MC loading areas then were multiplied by the ratio of the loading area to the total drainage area of the identified downstream receptor exposure locations (playa lakes). The down gradient, mixed MC concentrations entering the receptor exposure locations in playa lakes within and outside of MCAGCC Twentynine Palms were estimated as area-weighted sums of the products of the runoff concentration and area of each upstream loading area draining to the playa lake:

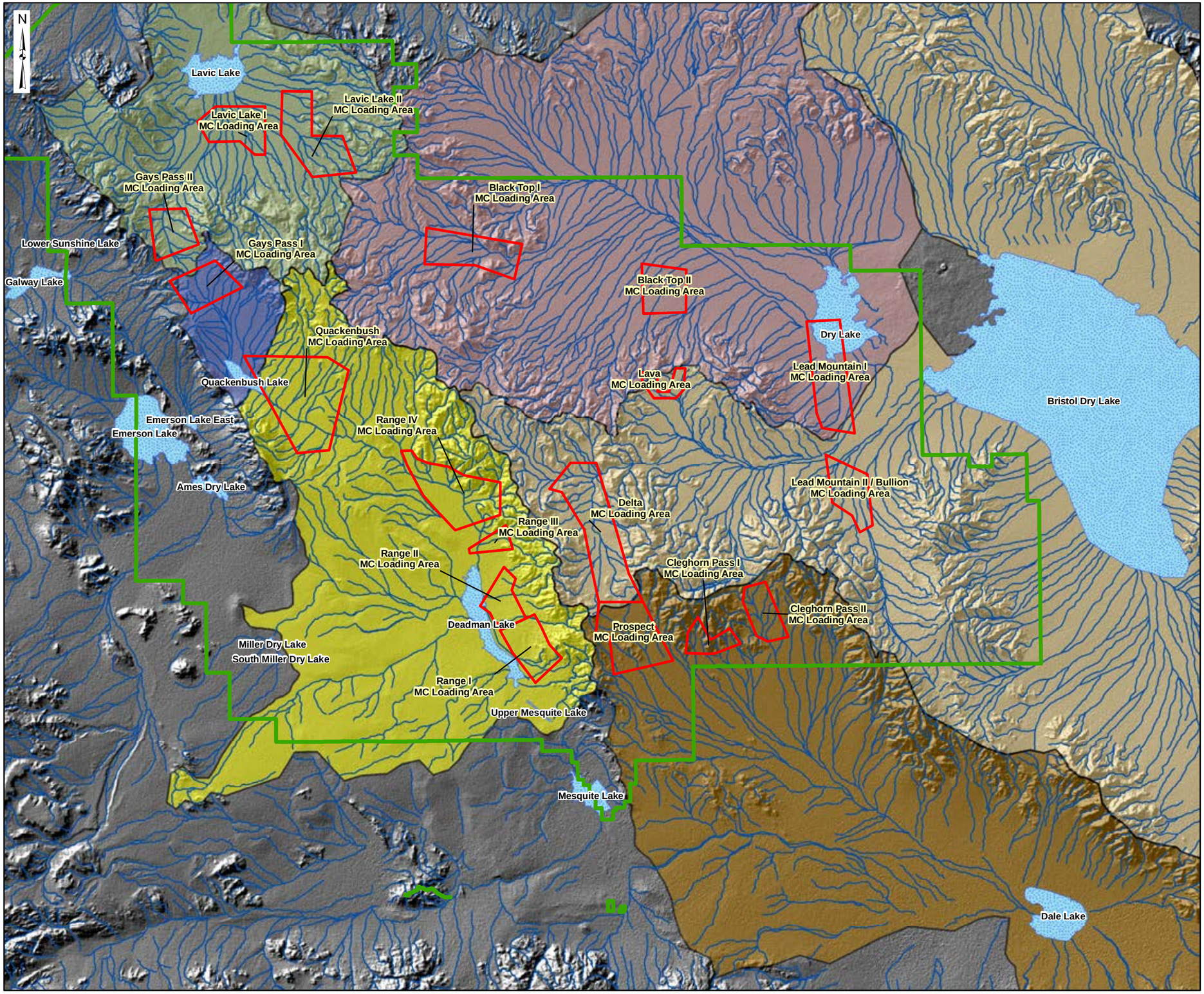

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FIGURE 5-1
SURFACE WATER FEATURES AND WATERSHED AREAS OF RECEPTOR EXPOSURE LOCATIONS

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

LEGEND

- INSTALLATION BOUNDARY
- MC LOADING AREA
- PLAYA LAKE (INTERMITTENT)
- STREAM/WASH (INTERMITTENT)

WATERSHED

- BRISTOL LAKE
- DRY LAKE
- LAVIC LAKE
- QUACKENBUSH
- DEADMAN LAKE
- DALE LAKE

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

Receptor Exposure Location	MC Loading Area Draining to Receptor Exposure Location	Approximate Percent of Loading Area Draining to Receptor Exposure Location
Dale Lake	Cleghorn Pass I	100
	Cleghorn Pass II	100
	Prospect	98
	Delta	1
Bristol Dry Lake	Lead Mountain II/Bullion	100
	Delta	99
	Lava	98
	Lead Mountain I	2
	Prospect	2
Dry Lake	Lead Mountain I	98
	Lava	2
	Black Top I	100
	Black Top II	100
Deadman Lake	Range I	100
	Range II	100
	Range III	100
	Range IV	100
	Quackenbush	90
Quackenbush Lake	Gays Pass I	99
	Quackenbush	10
Lavic Lake	Lavic Lake I	100
	Lavic Lake II	100
	Gays Pass II	100
	Gays Pass I	1

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

Where:

C_{mixed} = Concentrations entering receptor exposure locations in the playa lakes [micrograms per liter (mg/L)]
C_{runoff} = Concentration in runoff from loading areas (mg/L)

A_{LA} = Area receiving MC loading (m^2)
A_{DA} = Total drainage area of receptor exposure locations (playa lakes) (m^2)

An inherent assumption of this method is that all areas other than MC loading areas contribute runoff that has negligible MC concentrations. This provides a simple estimate of the potential for estimated concentrations to be reduced by mixing with other runoff prior to entry into the playa lakes. This approach conservatively assumes no reduction of MC through MC decay in surface water and mixing with the volume of water within the lakes.

5.1.2. Sediment Screening-Level Approach at MC Loading Areas

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

For MC loading areas where MC concentrations in sediment at the edge of the MC loading area were estimated to be above the REVA trigger value, additional screening analysis was carried out to estimate MC concentration in sediment at a downstream receptor exposure location in the playa lakes. This involved using RUSLE to estimate the total annual mass of sediment transported to the downstream receptor exposure location from areas upstream of the receptor exposure location (mass of sediment eroded within the drainage area of the receptor exposure location). The sediment MC concentration at the downstream receptor exposure location in the playa lakes was estimated to be equivalent to the MC mass leaving the MC loading area divided by the total sediment mass transported to the downstream receptor exposure location. The cumulative sediment MC concentration from different MC loading areas draining to the same receptor exposure location was estimated by taking the sum of the MC mass in sediment leaving the individual MC loading areas and dividing it into the sediment mass eroding into the receptor exposure location as follows:

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

Where:

$C_{sed,mixed}$ = MC concentration in sediment entering receptor exposure locations in the playa lakes [micrograms per kilogram (µg/kg)]
$M_{MC,LA}$ = MC mass in sediment entering playa lake from the individual MC loading areas [micrograms per day (µg/d)]

$M_{sed,DA}$ = Sediment mass eroded within the drainage area to the receptor exposure location in the playa lakes [kilograms per day (kg/d)]

Additional calculations were performed to account for MC accumulated in the sediment of playa lakebeds as a result of water evaporating from the playas. Because water that accumulates in playas is primarily lost to evaporation, MC washed into the playas potentially can precipitate and accumulate in the sediment of the playa bed. To estimate the MC mass that would accumulate in the sediment of the playa lake bed, it was conservatively assumed that the total annual average MC mass transported to the playa lake with surface water runoff (both dissolved and associated with sediment, estimated from **Section 5.1.1.1**) would remain in the sediment of the playa bed. This mass was divided by the total sediment transported to playa lake environment ($M_{sed,\ DA}$) to estimate the accumulated sediment concentration in the playa bed. The accumulated sediment concentration in the playa lake bed was calculated as follows:

$$C_{sed,accum} = \sum M_{runoff,\ LA} / M_{sed,\ DA}$$

Where:

$C_{sed,accum}$ = Sediment concentration accumulated in the playa lake bed (µg/kg)

$M_{runoff,\ LA}$ = MC mass in surface water runoff (obtained from **Section 5.1.1.1**) entering playa lake from individual MC loading areas (µg/d)

The approach used for estimating the accumulated sediment concentrations in the playa lake beds was highly conservative because it discounted loss terms such as volatilization and degradation in the accumulated sediment. Furthermore, it only accounted for land surface erosion (RUSLE) and neglected streambed erosion, which can be significant in the environment of MCAGCC Twentynine Palms. This is because a higher total sediment mass transported within the drainage areas of the playa lake ($M_{sed,\ DA}$) would produce a lower MC concentration in the sediment of the playa lake ($C_{sed,accum}$).

5.2. Groundwater Modeling Assumptions

The purpose of the groundwater analysis in the REVA program is to make best use of the available information to infer whether indicator MC (RDX, HMX, TNT, and perchlorate) can be transported in groundwater from loading areas to receptors. Both conceptual and quantitative methods are used. The initial step is a qualitative analysis of the groundwater conditions based on the CSM, described in detail in **Section 4**, including the identification of potential exposure pathways, migration routes, and potential receptors (human and ecological). When this qualitative analysis indicates there is potential for MC migration from loading areas to groundwater receptors, a screening-level MC

transport analysis is performed to quantitatively estimate potential concentrations of indicator MC in groundwater migrating to a receptor or beyond the installation boundaries. This quantitative screening-level analysis method uses multiple conservative assumptions, is more likely to overestimate than underestimate MC concentrations, and is used to determine whether particular MC loading areas merit additional investigation. The groundwater screening-level analysis methods employed for MCAGCC Twentynine Palms follow the approach described in the *REVA Reference Manual* and the *Assessment of Models for Evaluating Fate and Transport of Munitions on Operational Ranges* and are discussed in this section (HQMC, 2009; Malcolm Pirnie, 2005).

5.2.1. Qualitative Analysis

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

- Military munitions expenditure data
- GIS data (MCAGCC Twentynine Palms FMD GIS data)
- IRP site data
- INRMP
- USGS topographic maps and regional groundwater resource reports
- USDA NRCS soil survey
- Drinking water vulnerability assessment report
- Precipitation data

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

5.2.2. REVA Groundwater Analysis Procedure

A screening-level fate and transport analysis of potential MC migration via groundwater was conducted as part of the vulnerability assessment for MCAGCC Twentynine Palms. The analysis was conducted for five MC loading areas that were selected for groundwater modeling based on their current use of munitions containing HE and their proximity to potential future groundwater receptors. The modeled areas include Range I, Range II, Range III, Range IV, and Quackenbush MC loading areas. These MC loading areas are all located in the Deadman Lake subbasin where MCAGCC Twentynine Palms has potential future plans to draw water for drinking water use. The screening-level analysis was accomplished in two main steps:

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

An additional step involving saturated zone groundwater modeling typically is carried out, as part of the screening-level analysis, to determine the potential for MC in groundwater to be transported to groundwater receptor exposure points. This additional step was not performed here because results of the vadose zone modeling (step 2 of the analysis) indicated no current concern of MC migration to groundwater. Additionally, there are no current water supply wells within the study area and a complete pathway to ecological receptors is unlikely. However, the construction and development of water supply wells within the study area within the Deadman Lake subbasin is being considered. If implemented, potential for migration through the saturated zone will be reconsidered as part of the following REVA five-year review period.

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

5.2.2.1. Initial Groundwater Screening Analysis

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

The initial groundwater analysis is performed as a spreadsheet-based mass balance calculation. The basic input data are the estimated average annual MC loading rates at the MC loading areas (presented in **Section 6**) and the estimated low and high infiltration rates (recharge) at the modeled MC loading areas as follows.

A low recharge rate of 0.096 inches per year (in/yr) was estimated at all modeled MC loading areas. This recharge rate is based on the assumption that recharge is evenly distributed across the MC loading areas and is estimated from the annual groundwater inflow rate into the Surprise Spring basin (Londquist and Martin, 1991).

High recharge rate values of 2.39 to 2.77 in/yr were estimated at individual MC loading areas modeled and used to account for potential higher recharge that can occur around ephemeral streambeds and local depressions, where runoff and standing water is concentrated. The recharge rates in these areas, which constitute a small portion of the total MC loading areas, were assumed to be the annual precipitation rate less site runoff (ranging from 50% to 58% of precipitation).

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

5.2.2.2. Vadose Zone Modeling

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

Results obtained from the low and high recharge rates estimated in the initial groundwater screening analysis (**Section 5.2.2.1**) were used to simulate MC transport to the water table, representing two modeled scenarios. The MC loading areas modeled were sorted into two groups (Group A and B) based on similar hydrologic properties for the vadose zone. Results for the worst-case scenario for each group of MC loading areas are presented under the screening-level analysis results section (**Section 6**). All four MC were modeled for migration through the vadose zone at MC loading areas from each group with the worst-case scenario.

Local soils generally consist of sandy loam, sand, and gravelly coarse sand. The relevant physical and chemical properties of the vadose zone soils, MC, and climate that were used as input parameters to VLEACH are presented in **Appendix A**. **Figure 5-2** presents groundwater features and locations of the modeled MC loading areas.

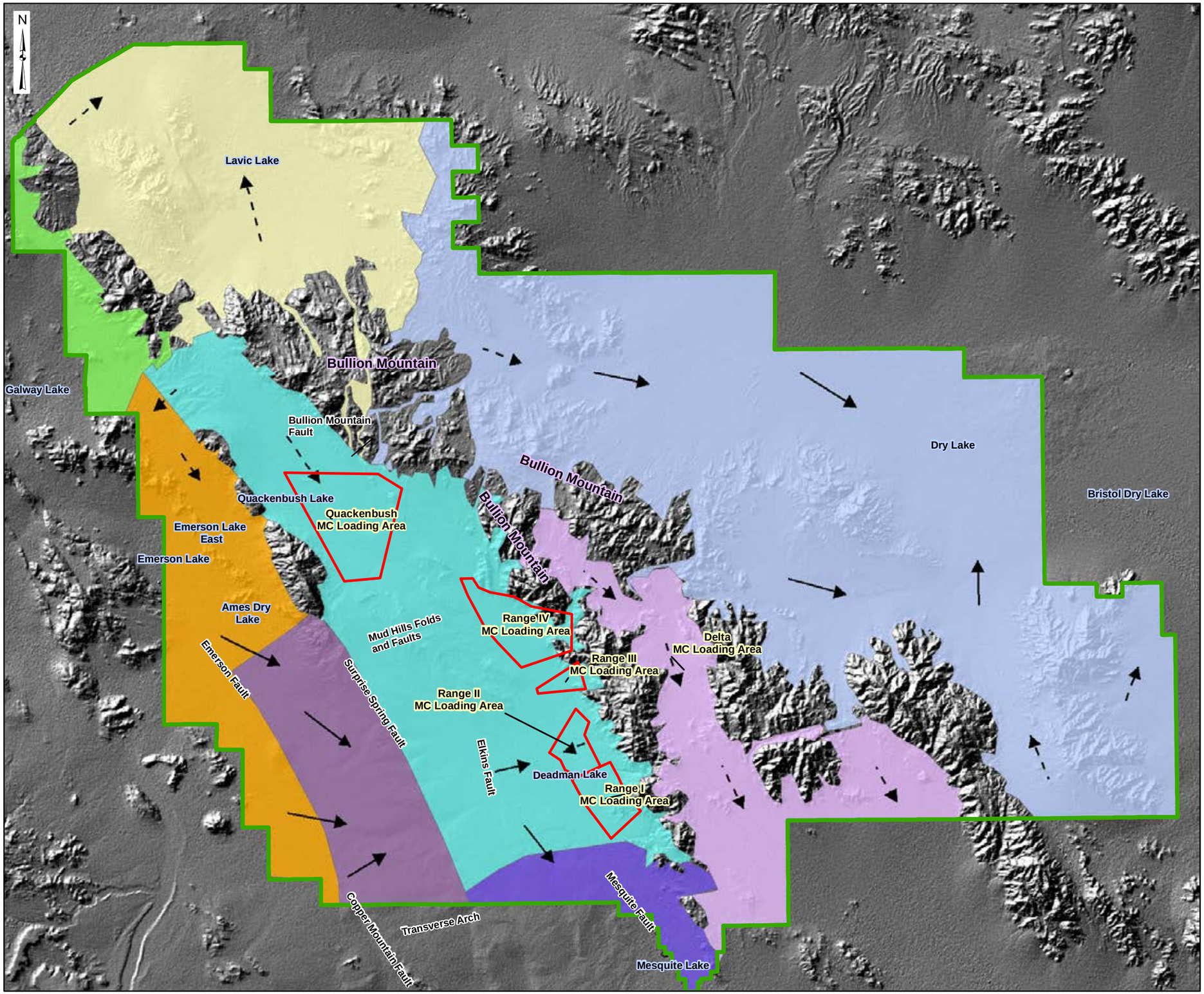

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FIGURE 5-2
GROUNDWATER FEATURES AND LOCATIONS OF THE MODELED MC LOADING AREAS

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

LEGEND

- MC LOADING AREA
- PLAYA LAKE (INTERMITTENT)
- EXPOSED BEDROCK
- GEOLOGIC FAULT

TWENTYNINE PALMS BASIN

- BESSEMER VALLEY SUBBASIN
- DEADMAN LAKE SUBBASIN
- GIANT ROCK SUBBASIN
- SURPRISE SPRING SUBBASIN
- TWENTYNINE PALMS VALLEY SUBBASIN

BRISTOL VALLEY BASIN

INTRAMOUNTAIN BASIN

- DALE VALLEY SUBBASIN
- LAVIC VALLEY SUBBASIN
- GROUNDWATER FLOW (KNOWN)
- GROUNDWATER FLOW (INFERRED)

NOTE: GROUNDWATER FLOW DIRECTIONS BASED ON SOURCE INFORMATION LISTED BELOW AND PROFESSIONAL JUDGMENT WHERE NO DATA EXISTS.

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
Groundwater Flow Direction Based on: Schaefer, 1978; Koehler, 1983; Londquist & Martin, 1991; Izbicki & Michel, 2004, Stamos, 2004; Londquist & Martin, 1989; and Lewis, 1972.

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Infrastructure Water Environment Buildings

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