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U.S. Army Training and Testing Area Carrying Capacity (ATTACC) For Munitions (AFM)

User Manual

Allan Stewart, Mike Brown, and Alan B. Anderson

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Allan Stewart and Mike Brown

CALIBRE Systems, Inc.
6354 Walker Lane, Suite 500, Metro Park
Alexandria, VA 22310-3252

Alan B. Anderson

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
PO Box 9005
Champaign, IL 61826-9005

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ABSTRACT: The Army Training and Testing Area Carrying Capacity (ATTACC) program is a methodology used for estimating the impact of military use of maneuver lands on Army installations. The methodology was developed to determine land rehabilitation and maintenance costs associated with land-based testing and maneuver training as part of the Army's Sustainable Range Program.

Results of characterization work on ranges around the country indicate that, under certain conditions and loading regimens, ranges may pose a threat to ground and surface water quality. The ATTACC for Munitions (AFM) program is an extension of the base ATTACC methodology. AFM is in development to estimate environmental carrying capacity based on munitions constituent load on Army live-fire ranges. The AFM methodology has been developed to predict munitions constituent accumulation and location for expended munitions from live-fire military training activities. The functional principles of the AFM methodology are to:

- Estimate live-fire range status by relating training munitions load, range condition, and range management practices
- Provide decision support to installation managers for optimizing range use

AFM quantifies training munitions load based on HQDA stationing, organizational, and training databases. Distribution of munitions loads throughout a given live-fire range complex is analyzed using Geographic Information Systems (GIS) and characterized utilizing the Munitions Items Disposition Action System. The analysis calculates the munitions impact and constituent load for any given live-fire range area. Range condition is a function of climate, soil, and hydrology.

The munitions impact, constituent load, and range condition are modeled using AFM For ArcGIS v2 to attain expected concentrations of munitions constituents and corresponding risk due to exposure through soil- and water-related pathways in spatial dimensions. Site-specific conditions are calculated and used as input parameters for determining fate and impact of constituent residues. To establish range status (concentration of constituents of potential concern (CoPC) relative to CoPC threshold), the output of the calculation is balanced against standards for sustainable operation of the live-fire ranges and the risk of exposure to the munitions constituents.

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Preface

This study was conducted for the U.S. Army Corp of Engineers under 622720A896, “Base Facility Environmental Quality,” project “Munitions Carrying Capacity,” 2JD935 (P2-120178). The technical reviewer was Dr. William D. Severinghaus, CEERD-CVT.

The work was jointly performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL) and the University of Illinois (UI). The CERL Principal Investigator was Alan B. Anderson. Alan B. Anderson is Chief, CN-N, and Dr. John T. Bandy is Chief, CN. The associated Technical Director is Dr. William D. Severinghaus. The Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

Results of characterization work at ranges around the country indicate that, under certain conditions and loading regimens, munitions constituents left on ranges may pose a threat to ground and surface water quality. As a part of a broader program to help manage ranges in a sustainable manner, the U.S. Army has developed model-based tools that focus on predicting the impact of training on training land and evaluating natural resources and environmental quality.

The Army's environmental technology requirements describe the critical research, development, test, and evaluation needs for accomplishing the Army's mission with the least impact or threat to the environment. These requirements were reviewed for their impacts to readiness and quality of life, impact or threat to the environment, and timeliness needed for the Army to maintain compliance with environmental regulations. *Sustainable U.S. Army Live-Fire Range Design and Maintenance* is a top conservation user requirement. The requirement defines the need to develop a model that (1) includes a range maintenance cost predictive tool for all active live fire ranges, (2) is based upon Army Training and Testing Area Carrying Capacity (ATTACC) methodology of use vs. condition, (3) estimates soil erosion caused by the use of ordnance and range maneuver training, and (4) accounts for mission activities related to site-specific conditions, including weather, terrain, and other environmental factors.

A related user research requirement titled *Land Capacity and Characterization* is the third priority conservation user requirement. This user requirement defines the Army's need to estimate training land carrying capacity. The user requirement describes the ATTACC methodology as designed to provide scientifically based information to the land managers to support sound decision making based on sustainable training requirements. Twenty-eight exit criteria were identified in the Land Capacity and Characterization user requirement. Several of the exit criteria define a need to include a munitions component in the ATTACC methodology.

Sponsored by Headquarters, Department of the Army (HQDA) G3/5/7, the U.S. Army Engineer Research and Development Center Construction Engineering Research Laboratory (ERDC-CERL), Army Training Support Center (ATSC), and

CALIBRE Systems, Inc., created the ATTACC program, a model-based tool developed as part of the Integrated Training Area Management (ITAM) program to estimate the impact of military use of maneuver lands on Army installations. The methodology was developed to determine land rehabilitation and maintenance (LRAM) costs associated with land-based testing and maneuver training based on executed and predicted training requirements.

The ATTACC for Munitions (AFM) Model is an extension of the basic methodology and is being developed to estimate environmental carrying capacity based on munitions constituent load on Army live-fire ranges. The model is to determine range rehabilitation and maintenance costs and to predict munitions constituent accumulation and location for expended munitions from live-fire military training activities. The long-term objectives of the AFM model are to:

- Estimate live-fire range carrying capacity by relating training munitions load, range condition, and range management practices
- Provide decision support to installation managers for optimizing range use while minimizing maintenance and avoiding remediation activities
- Provide a means to estimate costs for maintenance and remediation activities.

The munitions impact, constituent load, and range condition are modeled to attain expected concentrations of munitions constituents and corresponding exposure risk through soil and water in spatial dimensions. Site-specific conditions set parameters for receptors and corresponding exposure unit areas. To establish carrying capacity thresholds, the output is balanced against standards for sustainable operation of the live-fire ranges and for the risk of exposure to munitions constituents. Identification and measurement of training range carrying capacity provides decision makers with the information necessary to make range management decisions to prioritize risk and make efficient use of resources to support training (Figure 1).

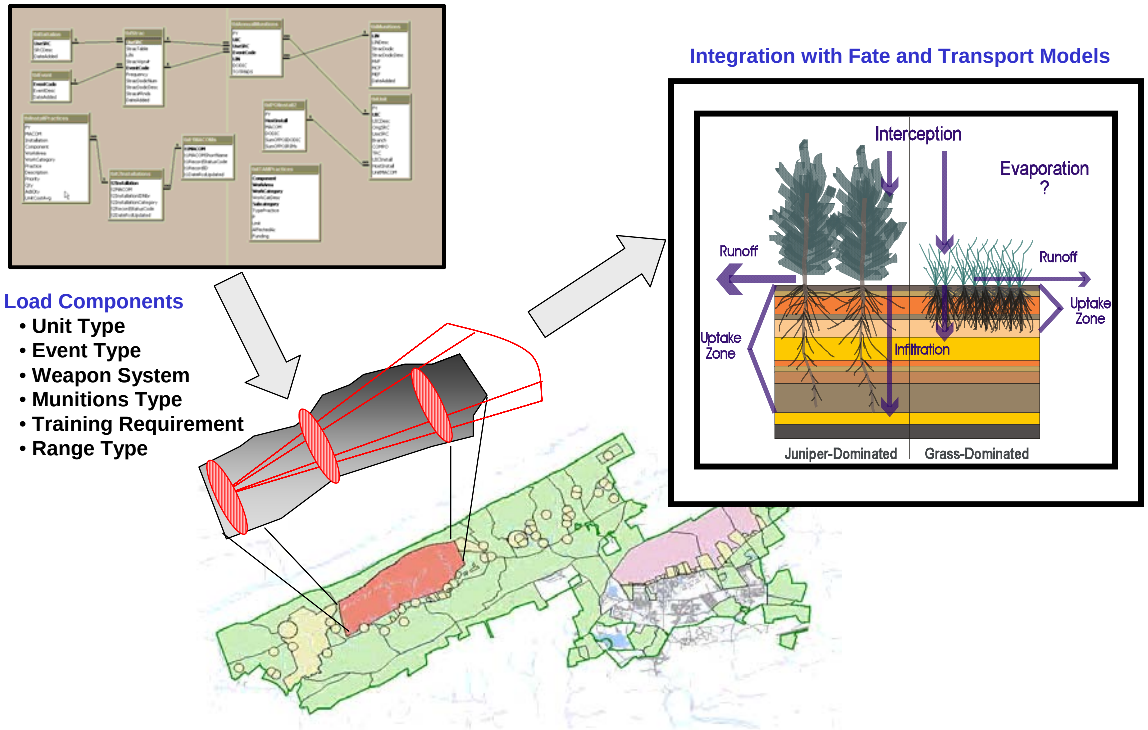

Figure 1. Range risk assessment process.

The AFM model requires a munitions load input, quantity and types of rounds or more often amount and type of constituent. The munitions load is input to the Army Risk Assessment Modeling System to account for different fate and transport pathways of the associated constituents.

The AFM methodology was developed in three phases:

- Phase I, ATTACC Munitions Development
- Phase II, Model Development
- Phase II, Training Loads Update.

Phase I, ATTACC Munitions Development

Phase I, ATTACC Munitions Development, was completed in April 2004 and captured all available information related to munitions activities and the potential for constituent accumulation on ranges. The munitions training load characterization component identifies training locations, events, weapons type and number, munitions type and number, and the munitions constituents type and quantity. The training load characterization component incorporates multiple data sources:

- Standards in Training Commission (STRAC) as outlined in Department of the Army Pamphlet (DA Pam) 350-38;
- Battalion Level Training Module (BLTM);

- Army Range and Training Land Program (RTLP) Requirements Module (ARRM);
- Conventional Weapons effects model;
- Army Training Manuals; and
- Jane's ammunition and weapon systems publications.

Phase II, Model Development

Phase II included development of a model that incorporated the information gathered in Phase I and translated it into potential effects based on case studies and on existing models that characterize contaminant effects, transport, and fate and are currently used to assess clean-up requirements at military sites. Phase II involved completion of three overall tasks: (1) addition of munitions constituent data from the Munitions Items Disposition Action System (MIDAS); (2) automation of the Phase I geographic information system (GIS) prototype contaminant distribution protocols; and (3) identification, evaluation, recommendation, and prototype creation for potential environmental fate and transport models currently used to assess cleanup requirements at military installations. Phase II was completed in April 2005.

Phase III, Training Loads Update

Phase III updated training loads to include legacy data; updated GIS representations to match user needs; and defined carrying capacity models for live-fire training. In addition decision support tools were developed that allow for entry of site-specific data, but also have default value options so that predictions can be provided even with limited site data, to predict potential environmental impacts from training activities on ranges.

The goal of the decision-support tool is to provide qualitative ranking of threat levels (i.e., likelihood that applicable environmental criteria are to be exceeded) based on the planned training activities for the range. The ability to quantify where risks exist, where risks may exist, and more importantly, where risks do not exist, will allow decision makers to focus mitigation resources where the greatest benefits can be achieved for training and the environment.

Objective

The objective of this AFM technical manual is to describe how military range managers can use the AFM model to determine the effects of military munitions on

Army ranges. This handbook will (1) familiarize the user with the AFM methodology, and (2) provide step-by-step instructions to run the AFM application.

Approach

This methodology, databases, and software were developed based on U.S. Army user requirements. User group input during development played an important role in assessing the status of the project in meeting these requirements. An ongoing effort to validate the data, models, and output of the model is underway by the U.S. Army Environmental Center.

Scope

This report demonstrates the AFM software for an example database. The methodology is applicable for any U.S. Army installation and data are provided for all U.S. Army Sustainable Range Program (SRP) installations with active training ranges.

Mode of Technology Transfer

The information in this report will be provided to U.S. Army personnel responsible for military land management.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Introduction

Basic Principles

An objective of the Army's Sustainable Range Program (SRP) has been to develop a method for estimating live-fire training range carrying capacity to facilitate range management decisions. Based on the ATTACC methodology, the AFM program extends the methodology to estimate environmental carrying capacity based on the estimated munitions constituent load on Army live-fire ranges. The functional principles of the AFM model are as follows:

- estimate live-fire range status by relating training munitions load, range condition, and range management practices
- provide decision support to installation managers for optimizing range use.

Range status is the amount of training munitions and subsequent constituents that a given live-fire range can accommodate in a sustainable manner. Range condition is the result of the comparison of CoPC soil concentration to known thresholds. AFM combines theory with a specific process and decision support tool to identify training range condition, predict munitions use requirements, and estimate (based on the past) the amount of constituents over one or multiple years remain on Army installation ranges.

AFM for ArcGIS uses HQDA and national level data to estimate training requirements, training schedules, and range environmental conditions. For AFM to remain useful, regular updates to datasets are required. Potential enhancements to AFM may allow for integration with other range management tools (e.g., automated range complex master plan). Future developments may also include the development of the range risk assessment and maintenance (RRAM) portion of AFM. The RRAM enhancement would provide a model for estimating maintenance costs for the management of munitions residue on ranges. Additionally, all methodology used in AFM can be enhanced to include a web-based interface.

Operational Hardware and Software

For the AFM for ArcGIS application to function properly, the following computer configurations are required.

System Requirements

- Platform – PC Intel
- Operating System - Windows NT 4.0 with Service Pack 6a (or) Windows 2000 (or) Windows XP (Home Edition and Professional) (must have Access software)
- Memory – 256 megabytes (MB) Random Access Memory (RAM) or higher
- Processor – 800 megahertz (MHz) or higher
- ESRI ArcGIS installed – ArcView (9x) or higher
- Compact disc (CD) reader (internal or portable)

AFM for ArcGIS Files

The AFM Model is provided on a CD. The Model contains four integrated databases (AFM, ARRM, ORIS, and RUSLE) for ease in updating and performing calculations. AFM_II_v2.mxd is the customized ESRI ArcMap application.

AFM (ATTACC For Munitions)

AFM_II_v2.mdb – This is the AFM for ArcGIS system database. This database contains the information required to utilize AFM for ArcGIS. Modifications to this file are not recommended.

AFM_GDB.mdb – This is an ESRI Personal Geodatabase of soil densities and half-life regions used in AFM for GIS.

ARRM (Army RTLP Requirements Model)

ARRM_2005.mdb – This database contains the data derived from the ARRM. Specific parameters include units, events, and locations.

🗁**ORIS (Operational Range Inventory Sustainment)**

🖫 ORIS.mdb – This is an ESRI Personal Geodatabase of installations and ranges used in AFM for GIS.

🗁**RUSLE (Revised Universal Soil Loss Equation)**

🖫 RUSLE.mdb – This is an ESRI Personal Geodatabase of installations and ranges used in AFM for GIS.

Note that these files must all reside within the same parent directory.

The AFM for ArcGIS is large since the databases include all Army live-fire installations. The model requires the computer to have enough memory and processing capability to perform complex calculations. The AFM for ArcGIS has been developed as a customized ESRI ArcMap document. The AFM Model is not classified but, due to sensitivity of data sets, is currently regarded as FOR OFFICIAL USE ONLY (FOUO).

Handbook Structure

This handbook includes four main sections:

- Section 1, Introduction, describes the purpose of AFM for ArcGIS and the requirements to implement it.

- Section 2, AFM Overview, provides the "big picture" for implementing AFM.

- Section 3, Calculating Range Status
    - describes the steps to measure the training load associated with live-fire training events,
    - describes the steps to estimate the ecological state of the range in terms of RS, the effects of munitions impacts and constituents remaining,
    - describes required range condition data and installation maps, and
    - identifies data sources.

- Section 4, Fort Munitions – an Example, provides an example of start-up, use, and output of AFM activities at an installation.

Appendices to this report supplement the content of sections by providing supporting definitions and details. Appendix A provides additional information related to

AFM. Appendix B is a list of acronyms and abbreviations used in this report. Appendix C is a glossary of some terms related to the AFM Model. Appendix D describes RRAM. Appendix E provides a system overview of the AFM Model using logic flow diagrams and database descriptions.

3 AFM Overview

AFM Components

Figure 2 illustrates the three components that comprise the AFM methodology. These AFM components are:

- *Training Load*. Training Load is the estimated mass of munitions fired on training ranges, derived from Army training doctrine. AFM measures training load in terms of munitions use on Army live-fire ranges.

- *Range Condition*. Range condition includes the environmental factors that affect the condition of the range. Range condition includes soil, climatic, and topological factors and measures the concentration of constituents on ranges. AFM measures range condition in terms of the range status produced by impact of the munitions, constituents remaining, and thresholds.

- *Range Risk Assessment and Maintenance*. Range maintenance is the collection of RRAM practices and their associated costs, which will mitigate the effects of the constituents. AFM measures range maintenance in terms of management practices, costs, and effectiveness measures.

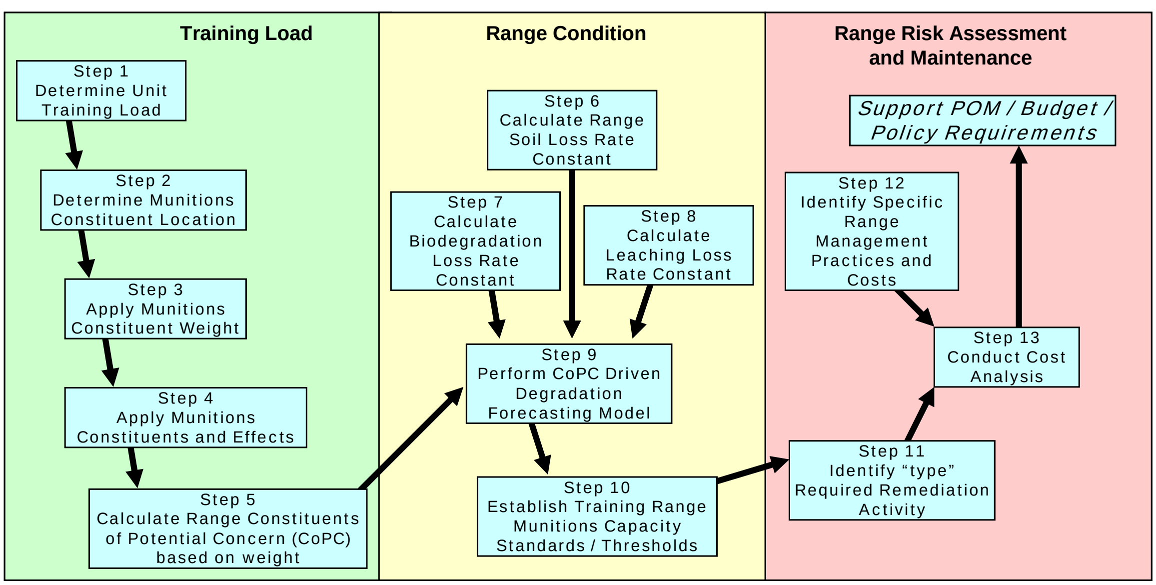

Figure 2. AFM components.

AFM estimates the training load (i.e., munitions fired on ranges) and the range condition (annual soil loss, biological degradation rate for CoPCs, soil permeability) for a single or multiple live-fire training ranges at an installation. These values provide the data to determine the concentration of CoPCs, which leads to calculating the status of the range as it relates to established constituent thresholds.

Relating Training Load to Range CoPC Concentrations and Thresholds

The objective of this portion of the AFM is to calculate the average concentration of CoPCs that would be anticipated across the range as a result of the projected level of training activity if no legacy chemicals were in place. Because the volume of soil at the range is constant for the most part, the calculated concentration could also be added to a baseline concentration (i.e., naturally occurring background levels for some constituents) to provide a prediction of the resulting average concentration once the training is complete.

To calculate the concentration of the CoPC resulting from projected training levels, AFM queries to obtain the expected mass loading of CoPC for that range in kilograms per year (kg/yr). The mass loading value from AFM is divided by the soil mass to calculate the average concentration of the CoPC across the range mixing zone in parts per million (ppm) if no loss mechanisms are present (e.g., degradation and migration). AFM then applies the average temperature and precipitation levels at the site using national data sets. The program then assigns the degradation rate for the CoPC for a period equivalent to one-half year and calculates an estimate of residual concentration after degradation. Finally, AFM calculates estimated mass of annual soil erosion using the Revised Universal Soil Loss Equation (RUSLE). Given a value for mass of soil lost through erosion, the AFM calculates a transport rate and further adjusts the predicted concentration of CoPC in the soil to account for particulate-borne transport losses.

At this point, the operator will have the predicted average concentrations of CoPC in the range mixing zone based on the result of training activities and the effects of degradation and transport out of the mixing zone. This average is referred to as range status. This concentration is then compared with the threshold concentrations for applicable exposure pathways (direct contact with soil, drinking water, and aquatic life/surface water). With the application of the thresholds, the range status becomes the range condition. The objective is to determine if a single year's training will lead to different potential threat levels grouped as:

1. Green (concentration is an order of magnitude below the minimum risk threshold and adverse impacts are not expected)

2. Amber (concentration is within an order of magnitude of the minimum risk threshold and characterization/monitoring is advised)
3. Red (concentration is more than an order of magnitude higher than the minimum risk threshold and management changes or range maintenance is advised).

The operator will also have the option of running the model for a range of years. In this mode, the results of the previous year's estimation are brought forward and adjusted to accommodate another year's added inputs as well as degradation and transport out of the mixing zone. The operator is asked to specify planned years of training. Given these values, AFM takes the estimated concentrations from the prior year and applies the degradation and transport rates to estimate how much of the residual concentration will remain at the end of the year. To that amount, AFM adds the mass of CoPC expected with the scheduled training level for the present year and calculates resulting concentrations. To the extent that steady-state conditions have not been reached, it is anticipated that the estimated concentrations will increase with each year's training activity. Once steady-state conditions have been reached (if ever), it is anticipated that the concentrations will not change until the training schedule is changed.

Figure 3 is an example of how the use of munitions on a range will increase the amount of CoPC remaining after live fire. This increase in concentrations will cause the range status to worsen due to continual use, but will eventually reach a steady state. Steady state is the point at which the CoPC concentration in soil is sufficiently high for annual degradation and transport losses to equal the mass loading from training. The line on the graph illustrates a relationship between the amount of munitions fired (training load) and range status (CoPC concentration) for the range(s) being evaluated over time.

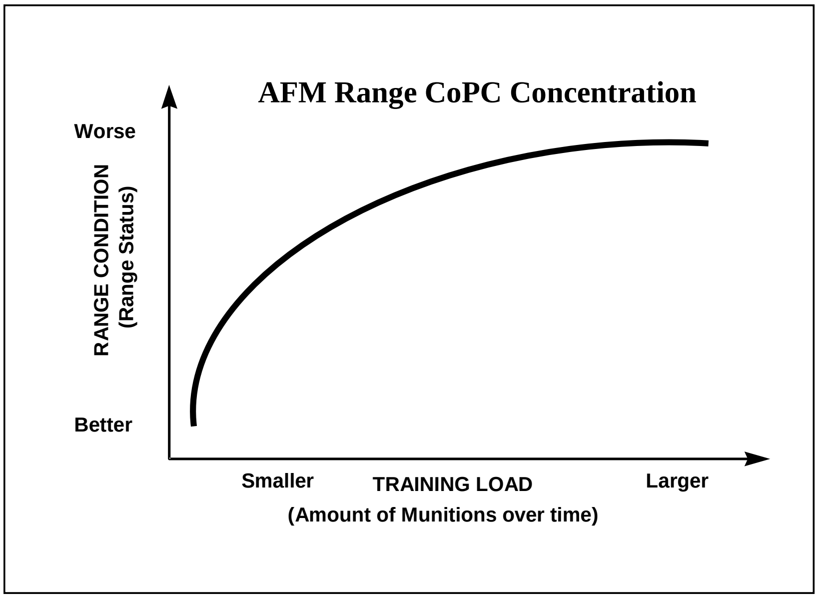

Figure 3. Range of CoPC concentration.

Larger amounts of munitions by type (using the Department of Defense Identification Code [DODIC]) indicate more impact to the training ranges, whereas smaller amounts of munitions indicate less impact to training ranges. A worsening range status indicates a concentration of constituents remaining on the range that is less acceptable (i.e., poses greater risk to human health), whereas a better range status indicates constituent levels that are more acceptable (i.e., poses smaller risks to human health).

AFM uses national or local threshold standards for allowable concentrations of CoPCs in soil. These threshold standards or levels are used in determining the status of the range based on continual munitions usage and can be modified by the application administrator. Through continual use of the range, the concentration of a specific CoPC will increase until equilibrium is achieved. As the concentration increases towards equilibrium, the thresholds could be exceeded. AFM depicts the range status as green, amber, or red. When the range status is red, the CoPC concentration is equal to or exceeds the established threshold for one or more of the CoPC analyzed. The range status is amber when the CoPC concentration is equal to or exceeds a value one order of magnitude less than the established threshold for one or more of the CoPC analyzed. The range status is green when the CoPC concentration is less than one order of magnitude times the established threshold for one or more of the CoPC analyzed. AFM will show the range status based on the highest level (worst score) for any of the analyzed CoPCs. Figure 4 illustrates how a range, through continual use, will have the status change based on the concentration of CoPCs.

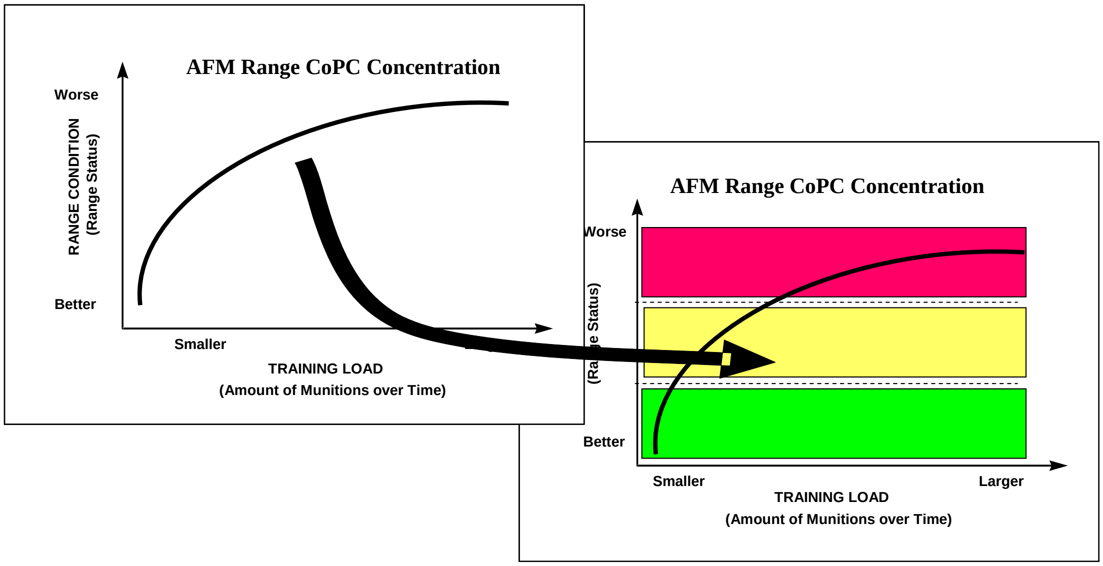

Figure 4. Estimating training range carrying capacity thresholds.

Applying Range Management Practices

To improve the range status (lower the concentration of CoPCs), range management practices can be performed. This portion of the AFM methodology has not been developed, but is explained in general in Appendix D. Range management practices (soil removal, bullet traps, etc.) are used to lower the concentration levels to avoid exceeding threshold levels. The practices do not change the relationship line of concentration to use, but moves the line outward – allowing the same amount of range use, but lowering the concentration of CoPCs. Use of assessments and practices allows for the continual amount of training that a given parcel of range can accommodate in a sustainable manner. This implies a reasonable and prudent level of maintenance and rehabilitation. Figure 5 illustrates how a range, using mitigation practices (line indicated by arrow), can be sustained without exceeding specific concentration thresholds. Appendix D contains more details.

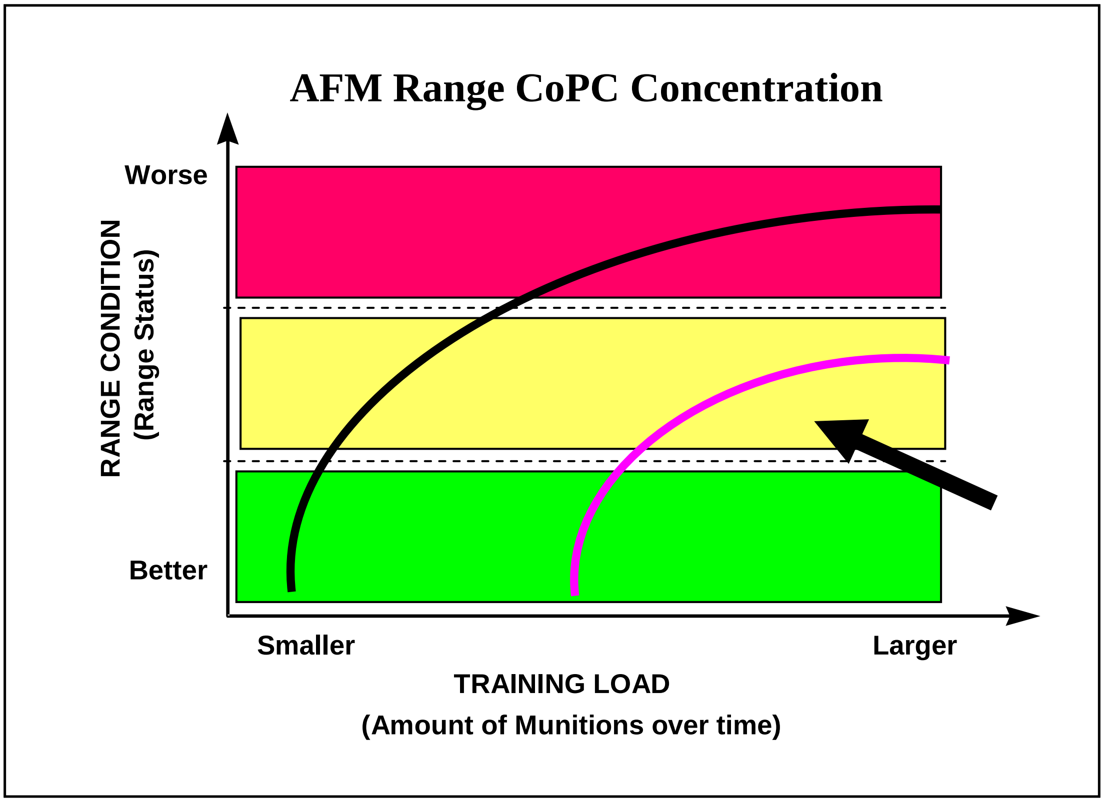

Figure 5. Estimating training range carrying capacity thresholds after applying Management Factors.

4 Training Load and Range Status

Introduction

AFM for ArcGIS models training load, loss mechanisms (degradation and migration), and GIS to estimate the concentration of CoPCs. Training Load, the estimated mass (weight) of CoPC resulting from munitions fired on training ranges, is derived from Army training doctrine and scientific calculations and data. Live-fire activities include individual training events, unit training events, testing activities, and institutional training. Specific examples of mission activities include individual weapon gunnery, basic combat training, and crew live-fire training; each being a part of the training load at an Army installation.

Training Load

Figure 6 illustrates the steps to measure and calculate training load.

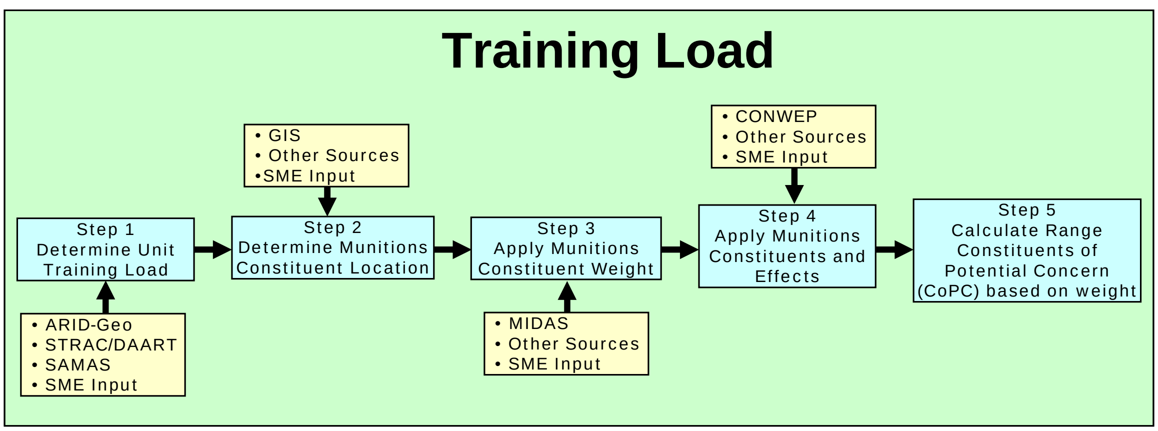

Figure 6. Steps to measure training load.

Step 1 - Determine Unit Training Load

The first step in AFM processing of information is determining the units included in the training load.

Determine Unit Training List and Range Location

The list of units that train at specific installations can be found in the HQDA Structure and Manpower Allocation System (SAMAS) database. The SAMAS data originate from the HQDA FORCES database. The data include the type-unit (by Standard Requirements Code [SRC]), the Unit Identification Code (UIC), and Tables of Organization and Equipment (TOE). This information is integrated with the Army Stationing and Installation Plan (ASIP) to determine the location of the unit for training. The information is related within the ARRM.

Training location data are provided in the ARRM database. These locations may or may not be the sites where training occurs by training event. For AFM, locations are based on the availability of specific type-FCC ranges extracted out of the Army Range Inventory Database for GIS (ARID-Geo). In many instances, the training location and range type provided from ARRM (dictating a modernized type-FCC [Facility Category Code] range) did not match any available ranges at the unit training location. To develop a link to the GIS-based data in ARID-Geo, a crosswalk was required to match the installation type-FCC found in ARRM with the available FCC found in ARID-Geo. Figure 7 is an extract of how the allocation of unit training is developed for each installation impacted. In the example below, those units that were training at Pine Bluff Arsenal, according to ARRM must be substituted by an installation with the appropriate type-ranges. The ARRM-assigned units have Pine Bluff as the home installation, but have multiple sites at which training is accomplished. The AFM application manages information used to designate the correct training site to apply the munitions training load.

ArrmInstallationName	ArrmFcc	HostInstallFCC	HostInstall
PINE BLUFF ARSENAL	17801	17810	PINE BLUFF ARSENAL
PINE BLUFF ARSENAL	17806	17804	PINE BLUFF ARSENAL
PINE BLUFF ARSENAL	17822	17810	PINE BLUFF ARSENAL
PINE BLUFF ARSENAL	17829	17810	PINE BLUFF ARSENAL
PINE BLUFF ARSENAL	17833	17833	CAMP J.T. ROBINSON MTA
PINE BLUFF ARSENAL	17859	17868	POLK
PINE BLUFF ARSENAL	17882	17882	CAMP J.T. ROBINSON MTA
PINE BLUFF ARSENAL	17884	17884	CAMP J.T. ROBINSON MTA
PINE BLUFF ARSENAL	17885	17886	PINE BLUFF ARSENAL

Figure 7. Home locations to training sites.

Determine Unit Training Events and Munitions Expended

AFM derives the munitions by type and quantity using an output from the DA Ammunition Requirements Tool (DAART). The DAART information is derived from the STRAC tables found in DA PAM 350-38 and is provided through the ARRM. The STRAC data within DAART provide for type-ammunition by weapons system, number of times the weapon system is used, and total amount of munitions expended to perform annual training requirements of the unit. The STRAC tables are based on the main branches of the Army (Infantry, Armor, Combat Support, etc.). The use of STRAC provides the ammunition used by units to perform training events to either qualify or sustain marksmanship on firing ranges. The two types of munitions use in ARRM are:

- The *standard set* of munitions use is the amount a unit fires, during a specific event with a specific weapon, to meet MINIMUM standards. In some cases, Army branches have not developed a minimal amount of munitions use. These units rely on the amount established in the strategy set of munitions use.

- The *strategy set* of munitions use is the MAXIMUM amount a unit can fire for the event and weapon. The list is designed so that the amount of munitions provided will meet ALL training event standards.

Through coordination with ATSC, the default setting for AFM uses 80 percent of the strategy set of data. This percentage reflects the most common amount of munitions used during the course of a year. A sample extract of ARRM data is shown in Figure 8.

UnitName	ArrmFcc	Dodic	UnitType	WeaponType	Weapon	WPNQualifier	TotalStrat
A CO, 2-121 INF (MECH)	17801	A064	Infantry	M249 AR	M249 AR	with EST	216
A CO, 2-121 INF (MECH)	17806	AA33	Infantry	M16/M4 Rifles	M16/M4 Rifles	CCO	8,160
A CO, 2-121 INF (MECH)	17806	AA33	Infantry	M16/M4 Rifles	M16/M4 Rifles	with EST	9,200
A CO, 2-121 INF (MECH)	17812	AA11	Infantry	M21/M24 Sniper	M21/M24 Sniper	All	741
A CO, 2-121 INF (MECH)	17822	AA49	Infantry	M9 pistol	M9	with EST	160
A CO, 2-121 INF (MECH)	17833	A064	Infantry	M249 AR	M249 AR	with EST	2,376
A CO, 2-121 INF (MECH)	17833	A131	Infantry	M240B MG	M60/M240B MG	with EST	6,776
A CO, 2-121 INF (MECH)	17833	A557	Infantry	M2 .50 Cal MG	M2 .50 Cal MG	All	280
A CO, 2-121 INF (MECH)	17834	B584	Infantry	MK-19 GMG	MK19	All	124
A CO, 2-121 INF (MECH)	17842	A358	Infantry	AT-4	Squad	Rifle / Recon Plt	720
A CO, 2-121 INF (MECH)	17859	A059	Mech Inf	M16/M4 Rifles	M16/M4 Rifles	Rifle / Recon Plt	11,826
A CO, 2-121 INF (MECH)	17859	A063	Mech Inf	M16/M4 Rifles	M16/M4 Rifles	Rifle / Recon Plt	1,944
A CO, 2-121 INF (MECH)	17859	A064	Mech Inf	M249 AR	M249 AR	Rifle / Recon Plt	6,660
A CO, 2-121 INF (MECH)	17859	A131	Mech Inf 44 M2	Bradley Fight Veh	Platoon	M2 IFV	2,250
A CO, 2-121 INF (MECH)	17859	A131	Mech Inf	M240B MG	M60/M240B MG	Rifle / Recon Plt	3,300
A CO, 2-121 INF (MECH)	17859	A131	Mech Inf 44 M2	Bradley Fight Veh	M2 IFV	All	10,500
A CO, 2-121 INF (MECH)	17859	A146	Mech Inf 44 M2	Bradley Fight Veh	Platoon	M2 IFV	480
A CO, 2-121 INF (MECH)	17859	A146	Mech Inf 44 M2	Bradley Fight Veh	M2 IFV	All	2,240
A CO, 2-121 INF (MECH)	17859	A598	Mech Inf	M2 .50 Cal MG	M2 .50 Cal MG	Rifle / Recon Plt	100
A CO, 2-121 INF (MECH)	17859	B519	Mech Inf	M203 GL	M203 GL	Rifle / Recon Plt	252
A CO, 2-121 INF (MECH)	17859	G878	Mech Inf	Hand Grenade	Squad	Rifle / Recon Plt	72
A CO, 2-121 INF (MECH)	17859	L602	Mech Inf 44 M2	Bradley Fight Veh	Platoon	M2 IFV	96
A CO, 2-121 INF (MECH)	17859	L602	Mech Inf 44 M2	Bradley Fight Veh	M2 IFV	All	448
A CO, 2-121 INF (MECH)	17860	A131	Mech Inf 44 M2	Bradley Fight Veh	Platoon	M2 IFV	1,350
A CO, 2-121 INF (MECH)	17860	A131	Mech Inf 44 M2	Bradley Fight Veh	M2 IFV	All	7,700
A CO, 2-121 INF (MECH)	17882	G878	Infantry	Hand Grenade	Soldier	No Rfl/Recon Plt	480
A CO, 2-121 INF (MECH)	17882	G878	Infantry	Hand Grenade	Soldier	Rifle / Recon Plt	870
A CO, 2-121 INF (MECH)	17884	B519	Infantry	M203 GL	M203 GL	with EST	420

Figure 8. Sample ARRM data.

Step 2 - Determine Munitions Constituent Location

GIS software is used to display the range characteristics and the locations of munitions residue. The GIS portrayal provides the location of the range on the installation using data from the ARID-Geo database.

Based on the established training munitions load developed during Step 1, the total munitions use at the installation will be applied to the specific range the DODICs are fired on. This total of munitions expended by DODIC multiplied by the constituent mass per DODIC provides a summed amount of constituents.

To determine the location of CoPCs on the type-range, AFM first uses the U.S. Army Environmental Center's (USAEC) Environmental Management System (EMS) grouping of ranges. The EMS groups consist of different FCCs placed in general categories based on the type of munitions fired and the weapons used. These groupings are used by GIS as a guide to general range configurations that lead to munitions impact locations. A general summation of the range groupings is presented in Figure 9.

EMS_Sub-Group	FCC_DESC
DEMOLITION	DEMOLITION, ENGINEER QUAL
HIGH EXPLOSIVE W/FIXED FP	GRENADE LAUNCHER, ANTI-ARMOR
IMPACT AREAS DUD, NON-DUD & BOMB	IMPACT & BOMBING AREAS
SMALL ARMS RG W/DISMNT MOVEMENT	LIVE FIRE AND MANEUVER
SMALL ARMS RG W/FIXED FP	RIFLE, PISTOL, MACHINE GUN, SKEET
TNG FAC (AERIAL)	AERIAL GUNNERY
TNG FAC W/FIXED FP-DIRECT FIRE	INDIV TANK/FIGHTING VEHICLE, AIR DEFENSE GUNNERY, RDT&E
TNG FAC W/FIXED FP-INDIRECT FIRE	MORTAR, FIELD ARTILLERY
TNG FAC W/MTD MOVEMENT	COLLECTIVE TANK/FIGHTING VEHICLE, AIR DEFENSE GUNNERY, RDT&E

Figure 9. EMS range groupings.

Additionally, the munitions fired are usually similar (by DODIC), based on the type grouping. For example, small arms ranges with fixed firing points use munitions of mostly small caliber that are non-explosive and have similar characteristics. Three basic distribution types are used within GIS to capture the EMS groupings and the expended munitions contents to include CoPC's location: radius, small arms direct, and indirect /collective.

- *Radius*. The EMS grouping for radius ranges includes all demolition type ranges. The ranges are portrayed using the boundaries of the range using ARID-Geo, with all munitions constituents residing within the range. The percent of constituents produced using demolition or mine munitions is 100 percent within the demolition range or multiple demolition ranges. These ranges are assumed bermed so that any spread of CoPC is retained within the immediate range area.

- *Small arms direct*. It is assumed that all small arms ranges have berms beyond the end of the target line, thus containing the munitions constituents to a limited area. This assumption allows the constituent generated from firing to be located within the boundary of the range. On some installations, multiple same-FCC ranges fire the same type munitions. Using GIS, the munitions are distributed among these same FCC ranges based on the range distance from the cantonment area. For example, if three zero-rifle ranges are on the installation, a percentage of distance is applied to each range. This calculation is portrayed in Figure 10.

a) Total distances to all ranges from range control (RC) RC to Range A = 7,200m RC to Range B = 12,000m RC to Range C = 9,000m
Total distance = 28,200m
b) Distance normalized to Range A distance Rg A = 1 Rg B = 0.6 Rg C = 0.8
Total Rg normalization = 2.4
c) Divide each range normalization by "2.4" for % munitions fired
Rg A = 41.67% of total munitions
Rg B = 25% of total munitions
Rg C = 33.33% of total munitions

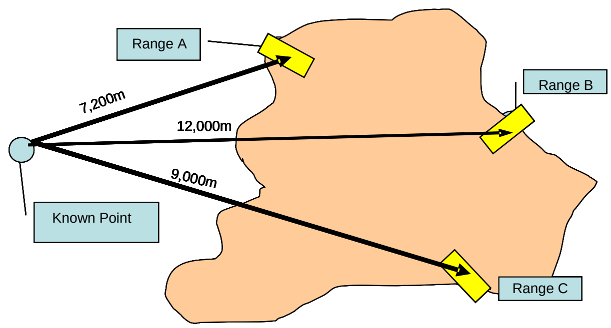

Figure 10. Multiple small arms range (FCC) munitions distribution.

- *Indirect/collective*. For indirect, collective, and fire and maneuver ranges, the area of expended munitions to include CoPCs location includes the range and the impact area into which the munitions are fired. These ranges are NOT normally bermed. As with small arms, if there are multiple FCC ranges, the first calculation is of a percent of munitions fired on each range. The second calculation is to determine the distribution of the munitions. As the ranges are not bermed, the target line is not at the end of the range like small arms fixed ranges (within the ARID-Geo). Currently, AFM uses the range area coupled with the impact area to determine munitions distribution. The firing point CoPC can be separated from the target point CoPC, especially when the FCCs are for indirect fire.

Future AFM developments will allow GIS to be used to more accurately determine the CoPC location. A target point can be set as a direct line from the firing point to the center of the impact area, with 80 percent of the maximum range of a charge four explosive indirect projectile applied. For collective and movement ranges, 80 percent of the maximum range of the munitions is determined, firing at the center of the impact area. Based on actual installation target points, these pre-calculated target points can be shifted to actual locations. Figure 11 illustrates the method for determining target point location.

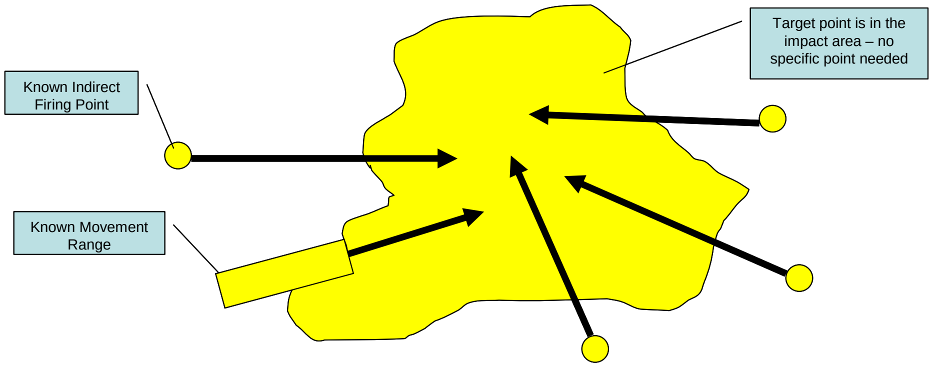

Figure 11. Multiple indirect/movement range (FCC) munitions distribution.

One modification to the USAEC EMS groupings above is in the training facility with fixed firing point. The category was subdivided into direct and indirect fire as different munitions and weapons systems are used. Appendix E contains a diagram (Figure E-3) of the process flow the program uses to determine the distribution of munitions on ranges at the installation.

Step 3 - Apply Munitions Constituents Weight

Munitions constituents in the form of components (to include CoPCs) are the remaining material of expended munitions at a firing point and target point for each DODIC. The amount and type of component/constituent for each DODIC is taken from the MIDAS database. CoPCs are derived from the types of units firing and number and types (by DODIC) of munitions used. The constituents are located at the firing points (mainly propellant residue) and downrange, mostly around or past the target line.

The amount of munitions fired by a unit will impact the ranges with the shown constituent weights on an annual basis. The mass of CoPCs associated with the unit-training load remain the same regardless of where the event occurs. AFM accounts for the variable impact of CoPCs in different ecological settings after training load has been established.

Figure 12 is an extract of the munitions constituents table, listing those constituents for the DODIC AA44, a 5.56mm ball munitions. The table shows two areas on the range — the firing point and the target point. This separation is made because different constituents are located on different parts on the range. Most constituents associated with firing points are propellant residues. Target point constituents account for the impact and subsequent residue of the projectile once expended. Currently AFM calculates CoPCs and sums the weight at the firing point, then the target point. AFM will match the total weight at each location against a prescribed standard (threshold) set by the user. If either location contains CoPC weights above this threshold – the entire range status changes.

Dodic	DodicDescription	ConstituentLoc	ConstituentDesc	CoPC_Wt	UOM	CleanFactor	CoPC_NetWt	UOM
AA44	CTG 5.56MM BALL	FIRING POINT	BARIUM	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	FIRING POINT	COPPER	4.31	g	0.00	0.00	g
AA44	CTG 5.56MM BALL	FIRING POINT	COPPER	0.01	g	1.00	0.01	g
AA44	CTG 5.56MM BALL	FIRING POINT	LEAD	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	FIRING POINT	ZINC	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	FIRING POINT	ZINC	0.05	g	1.00	0.05	g
AA44	CTG 5.56MM BALL	FIRING POINT	DIPHENYLAMINE	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	FIRING POINT	NITROCELLULOSE	0.03	g	1.00	0.03	g
AA44	CTG 5.56MM BALL	FIRING POINT	NITROGLYCERIN	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	TARGET POINT	BARIUM	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	TARGET POINT	COPPER	1.14	g	1.00	1.14	g
AA44	CTG 5.56MM BALL	TARGET POINT	LEAD	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	TARGET POINT	LEAD	2.07	g	1.00	2.07	g
AA44	CTG 5.56MM BALL	TARGET POINT	ZINC	0.13	g	1.00	0.13	g
AA44	CTG 5.56MM BALL	TARGET POINT	DIPHENYLAMINE	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	TARGET POINT	NITROCELLULOSE	0.00	g	1.00	0.00	g
AA44	CTG 5.56MM BALL	TARGET POINT	NITROGLYCERIN	0.00	g	1.00	0.00	g

Figure 12. Munitions Constituent Table extract.

These data are located in the AFM Munitions Constituents Table. Information provided in this table includes the weight and type of constituents remaining on the range based on firing. The information provided is developed using the parts and component lists found in MIDAS. The weight of the constituents is based on a single round fired. The amount of constituents (by type) is multiplied by the total number of rounds (cumulative) to estimate the amount of the total constituent load found on the range. For dud-producing munitions, all of the explosive compounds are expected to survive when the round fails to explode. A factor of 0.01 percent constituent remaining of the original chemical weight is assumed for high order detonation. A factor of 40 percent constituent is assumed to represent what remains after a low order detonation event. The total weight (99.9 percent) of the metals found in the explosive round is applied (the same for non-explosive munitions). It is assumed that 0.1 percent of munitions remain in the firing point area due to contact of the round with the barrel rifling.

Additionally, a clean-up factor is applied. The clean-up factor varies depending on the type of constituent. The factor is a number from 0.001 to 1. The lowest factor represents the smallest amount of constituent remaining (the largest amount of clean up). On direct fire ranges, the shell cartridges are usually removed at the end of firing. Some are not picked up because they are buried, hidden from view, or located downrange. The clean-up factor for this constituent is 0.001 (1 in every 1,000 cartridges is left on the range). Whereas the chemical propellant residues are not removed and receive a 0.999 (most of the chemicals remain in the soil). As most DODICs impact on the range, in berms or impact areas, they are usually not removed. The clean-up factor downrange is set as 0.999. If the range is for indirect fire, the downrange clean-up factor is 1 — no clean up is done.

Step 4 - Apply Munitions Constituents and Effects

Munitions effects are those reactions between the round and the soil as it is impacted. The effects of the munitions themselves (penetration, velocity, etc.) are taken from the Conventional Weapons (CONWEP) munitions effects website or other sources.

Information provided in this table contains the DODIC weights, dimensions, and effects of the munitions impact. The impact of type-munitions causes either an explosive crater or a projectile hole. In the case of explosive munitions, there is also a dud rate – where the round does NOT explode, but buries itself in the ground. These data are derived from HQDA sources, field manuals, and the CONWEP website. Additionally, dud-producing DODICs have a high/low order of detonation rate – when the explosive munition impacts the ground, the projectile will detonate fully or only partially. A low-order detonation is more serious, environmentally, as the toxic constituents inside the munitions can contaminate the area around impact far more than a full detonation, whereas full detonation consumes nearly all constituents in the explosion. Figure 13 provides an extract of three DODICs with each munitions factor applied. AFM uses different portions of the table to determine penetration into the soil of the munitions, cratering, explosive weights, etc. Much of the information has been extracted from U.S. Army training manuals and the CONWEP web site.

DodicDescription	DodicWt	UOM	PropWt	UOM	ExplodeWt	UOM	ProjWt	UOM	MuzVel	UOM	ImpctVel	UOM
CTG 9MM BALL M882	12.31	gm	0.34	g	0.00	g	8.04	g	341.00	m/s	272.80	m/s
CTG CAL .38 SPEC BALL M41	13.15	gm	0.31	g	0.00	g	8.55	g	289.56	m/s	231.65	m/s
CTG CAL .45 BALL M1911	21.45	gm	0.32	g	0.00	g	15.16	g	249.94	m/s	199.95	m/s

DodicDescription	CraterDp	UOM	PeneDpth	UOM	AvRg	UOM	MaxRg	UOM	Dud%	LoDet%	HiDet%
CTG 9MM BALL M882	0.00	cm	2.89	cm	150.00	m	3,000.00	m	0.00	0.00	1.00
CTG CAL .38 SPEC BALL M41	0.00	cm	2.48	cm	600.00	m	3,000.00	m	0.00	0.00	1.00
CTG CAL .45 BALL M1911	0.00	cm	2.78	cm	150.00	m	2,500.00	m	0.00	0.00	1.00

Figure 13. Munitions Constituent Factors Table extract.

Step 5 - Calculating Range CoPC based on Weight

To calculate the concentration of munitions constituents resulting from projected training levels, AFM calculates expected mass loading of each munitions component and CoPC for the selected range or ranges. This calculation is the sum of each component and CoPC found on the range. The cumulative amount, by weight, of materials on the range equals the training load placed on the range. The training load weight is the initial step in determining the range condition (see next section -

Range Condition). Figure 14 provides a sample of the cumulative weight of munitions components and CoPCs on two rifle ranges.

Site Name	Range Name	FCC	Constituent Desc	SumOfWeight	UOM
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	BARIUM	0.00	gm
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	COPPER	49,819.07	gm
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	DIPHENYLAMINE	19.11	gm
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	LEAD	179,117.60	gm
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	NITROCELLULOSE	1,585.97	gm
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	NITROGLYCERIN	125.61	gm
FORT MUNITIONS	RANGE 18 (MIKE RECORD FIRE)	17806	ZINC	7,776.63	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	BARIUM	0.00	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	COPPER	10,666.08	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	DIPHENYLAMINE	4.14	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	LEAD	37,897.12	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	NITROCELLULOSE	338.17	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	NITROGLYCERIN	27.36	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	VARIOUS NITRATES	1.63	gm
FORT MUNITIONS	RANGE 21 (BAKER 10/25)	17801	ZINC	1,663.56	gm

Figure 14. Sample CoPC weights on ranges.

Range Condition

To calculate the range condition based on the concentration of munitions constituents resulting from projected training levels, AFM calculates expected mass loading of each munitions component, then determines environmental effects on the CoPC for the selected range or ranges. Figure 15 shows the steps to estimate range condition.

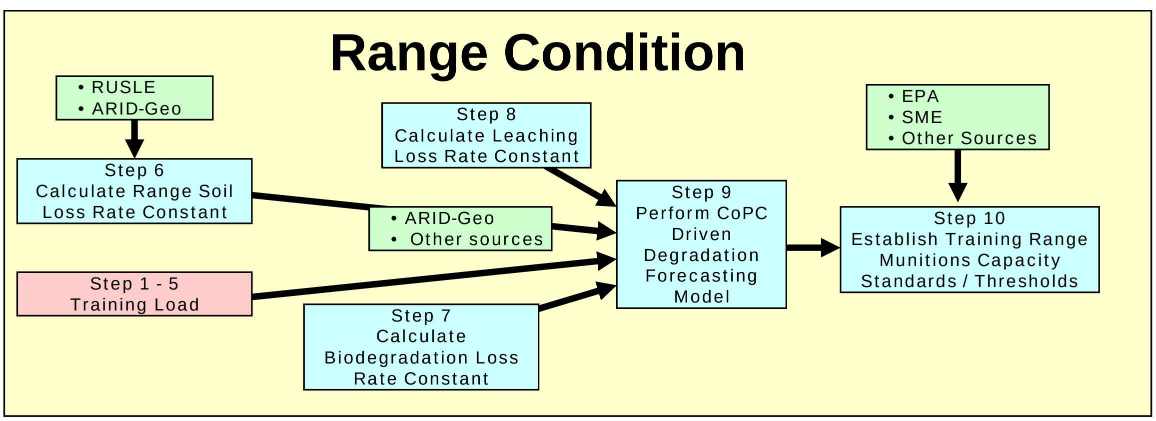

Figure 15. Range condition.

As part of the AFM methodology, the steps to estimate and predict the range condition occur independently from the steps for measuring an installation's training load. The training load is used as input to a forecasting model (Step 9). Additional environmental constants are applied for soil loss, leaching, biodegradation, and partitioning. When the calculation of training load is combined with environmental constants, it is possible to determine the range status for a 1-year period. The forecasting model allows the user to add multiple years and/or training requirements to more accurately determine the actual amount of CoPCs on the ranges. Finally, AFM applies established capacity standards and thresholds to the range status to determine range condition. This condition is portrayed using GIS on the installation map as green, amber, or red shading to match the three status ratings.

Step 6 - Calculate Range Soil Loss Rate Constant

Soil loss rates used by AFM are based on erosion. Erosion rates are estimated using a modification of the RUSLE. The AFM Model utilizes GIS to perform RUSLE calculations. Each factor has an associated spatial feature class. As information that is more accurate becomes available, the RUSLE feature classes can be updated. The AFM Model converts the calculated RUSLE soil loss value from tons/acre/year to the associated transport loss rate constant (Kt) in units of 1/days. The RUSLE dataset delivered with the AFM model is defined below and in Appendix E.

The Adapted RUSLE is defined as A=R*K*LS*C*P where:

A = soil loss per unit area (tons ac^{-1} yr^{-1})

R = rainfall and runoff factor ([hundreds of ft-tons] in. ac^{-1} $hr^{-1}yr^{-1}$)

K = soil erodibility factor (tons hr [hundreds of ft-tons]$^{-1}$ in.$^{-1}$)

LS = slope length and steepness factor (dimensionless)

C = cover and management factor (dimensionless)

P = support practice factor (dimensionless).

- *R Factor*. Soil erosion is greatly influenced by the intensity and duration of precipitation events and by the amount and rate of the resulting runoff. The R factor is the rainfall and runoff factor or intensity of erosion for a specific location. The R factor is a quantitative expression of the intensity of erosion of local average annual precipitation and runoff. The R factor incorporates the amount, intensity, and duration patterns of precipitation. Differences in R factor values reflect differences in precipitation patterns between regions. Larger R factor values indicate more erosive weather conditions.

- *K Factor*. The soil texture, organic matter content, structure, and permeability largely determine a soil's erodibility. The soil-erodibility factor (K) is the rate of soil loss per rainfall erosion index unit under standardized conditions. Higher K factor values indicate more easily erodible soils.

- *LS Factor*. The rate of soil erosion is greatly affected by the local topography of an area. The LS factor provides a quantitative representation of both the slope length and steepness. Slope steepness and length values for the LS equations can be determined from topographic maps, digital elevation models (DEM), average values from soil mapping units, or from direct field measurement. Mathematical equations for calculating the LS factor have been developed and incorporated into GIS applications.

- *C Factor*. The cover factor (C) reflects the degree of erosion protection provided by vegetative cover. The cover factor describes the density and structure of the vegetative canopy cover and kind and amount of cover in contact with the soil. The C factor is a ratio of soil loss from range under specified conditions to the corresponding soil loss from clean-tilled continuous fallow range under otherwise identical conditions. An increase in the cover factor represents a decrease in ground and/or canopy cover and an associated increase in the estimated erosion rate.

  ARID-Geo contains a vegetation cover class for each range included with the model. Each cover class is assigned a C factor value to be used in the RUSLE calculation. Figure 16 provides the C Factors used within AFM for calculation purposes.

ARID-Geo	Description	C Value	Notes (USDA tech Release # 51, Sept 1977)
BARREN	BARREN	0.2000	Table 2. "C Factors for Permanent Pasture, Rangeland, Idle land, and Grazed Woodland" No appreciable canopy, type G, 20% ground cover
FOREST	FOREST	0.0005	Table 3. "C" Factors for Undisturbed Woodland (100% to 75% effective canopy – average of 0.001 and 0.0001)
HEAVY_GRASS	HEAVY GRASS WITH NUMEROUS SHRUBS	0.0030	Table 2. "C Factors for Permanent Pasture, Rangeland, Idle land, and Grazed Woodland" Appreciable brush or bushes, type G, 50% canopy, 95-100% ground cover
HEAVY_SHRUBS	HEAVY SHRUBS WITH TREES	0.0060	Table 3. "C" Factors for Undisturbed Woodland (35%-20% effective canopy – average of 0.003 and 0.009)
LOW_GRASS	LOW GRASS AND FEW SHRUBS	0.0030	Table 2. "C Factors for Permanent Pasture, Rangeland, Idle land, and Grazed Woodland" Canopy of tall weed or short brush, type G, 50% canopy, 95-100% ground cover
SHRUBS	SHRUBS WITH SOME TREES	0.0060	Table 3. "C" Factors for Undisturbed Woodland (35%-20% Effective canopy -average of 0.003 and 0.009)

Figure 16. C factor values used in AFM.

- *P Factor*. The range management practices factor (P) is a quantitative expression of the mitigating effect that conservation practices have on the erosion process. Range management practices are not defined for AFM and all P factor values equal 1. Thus, AFM assumes only migration and degradation factors to reduce CoPC concentrations. Based on results of a sensitivity analysis conducted on single-year runs of AFM, it is clear that the ranges most likely to move into amber or red status are those on which munitions with significant lead content are fired. Should bullet traps, periodic screening of soils, berm removal, or other similar practices be implemented, these practices would act as a second loss mechanism that could expand range capacity. Alternately, because the greatest risk arises from direct contact with lead-contaminated soil by range operators or soldiers, range capacity effectively could be increased by imposing practice guidelines that reduce contact with soil (e.g., use of protective clothing or limitations of time on range). These management practices could be modeled in AFM though the P factor, or by imposing a higher threshold concentration indicative of the reduced exposures that would be allowed.

Figure 17 summarizes many of the currently available data sources for each of the factors in the RUSLE and for calculating erosion status. For further detailed descriptions on these RUSLE factors, data sources for measuring range condition, and discussion of data layer development, see Appendix F.

RUSLE FACTOR	DESCRIPTION	DATA SOURCES
R	The rainfall and runoff factor or erosivity factor for a specific location.	• United States Mean Annual R-factor, 1971-2000 • http://www.ocs.orst.edu/pub/maps/Precipitation/rfactor/U.S./us_maps.html
K	The soil-erodibility factor (K) is the rate of soil loss per rainfall erosion index unit under standardized conditions.	• NRCS State Soil Geographic Data Base (STATSGO)
LS	A quantitative representation of the effect of the local topography on erosion rates. This factor includes both the slope length and steepness.	• NRCS State Soil Geographic Data Base (STATSGO) provides minimum and maximum slopes for soils. Average slope has been calculated • GIS process to calculate slope length.
C	The cover factor (C) reflects the degree of erosion protection provided by vegetative cover.	• ORID-GEO
P	The conservation practices factor (P) is a quantitative expression of the mitigating effect that conservation practices have on the erosion process.	• Value set to 1.

Figure 17. RUSLE factors and data sources.

Step 7 - Calculate Biodegradation Loss Rate Constant

The Biodegradation Loss Rate Constant (Kb) relates to the type of constituent being processed, environmental regions, and area media. Figure 18 provides examples of Kb values used in AFM. Appendix E identifies how the constant is converted to a per day value.

CoPC	Region	Media	Half Life (years)
RDX	COOL HUMID	SOIL	0.321
RDX	COOL ARID	SOIL	1.288
RDX	WARM ARID	SOIL	7.299
RDX	WARM HUMID	SOIL	0.781
TNT	WARM HUMID	SOIL	0.004
TNT	COOL HUMID	SOIL	0.004
TNT	COOL ARID	SOIL	0.004
TNT	WARM ARID	SOIL	0.004

Figure 18. Kb values used in AFM.

Kb is directly related to the specific constituent being processed. Appendix E identifies how available half-life data are converted to a degradation rate constant in the appropriate units. Two different methods are used to derive half-life estimates from which loss rate constants are derived. For organic constituents at firing points (e.g., nitrocellulose and nitroglycerine), the residue is left on the soil in the form of thin films of fallout after a round is fired. These films are subject to degradation from microbiotic metabolism. Empirical data are available for the estimated range of half-life values for such films based on a variety of laboratory and field experiments. Half-lives will vary with temperature and moisture levels. For the purposes of AFM, the range of observed values for firing point residues have been assigned to climate regimes (warmer, wetter climates given the shorter half-lives; colder, dryer climates, the longer half-lives within the range).

At target points, organic residues result from the failure of portions of the explosive charge to detonate. The unburned residues are cast off in chunks or nodules that are not as readily attacked by microbiota. Research at ERDC Cold Regions Research Engineering Laboratory (ERDC-CRREL) has indicated that the degradation of these nodules is a function of their dissolution in infiltrating waters. Dissolution is the rate determining step. Once dissolved, degradation occurs shortly thereafter. As such, degradation at target points has been modeled using an empirical relationship for dissolution as a function of the frequency and duration of rainfall events.

The apparent half-lives derived from the dissolution model were then converted to first order degradation loss rates, as in the case of the firing point residues.

Step 8 – Calculate Leaching Loss Rate Constant

For organic chemicals, the apparent half-life is the net result of both degradation and transport. As such, it results from chemical and biological degradation, particulate transport in runoff, and leaching from infiltration. In general, one of the two transport mechanisms (transport in runoff or leaching from infiltration) will dominate for a specific chemical compound and the other can be ignored. In other words, for soluble chemicals in humid ranges, leaching will be the dominant transport mechanism, while for relatively insoluble chemicals and in arid ranges, particulate transport will dominate. For inorganic chemicals, degradation can be ignored. Because the metallic contaminants associated with ranges are of low solubility, particulate transport is expected to be the primary loss mechanism controlling the loss rates.

CoPC Partitioning

Each constituent to be included in the AFM model requires a Partitioning Loss Rate Constant (Kd). The Kd parameter is very important in estimating the potential for the adsorption of dissolved contaminants in contact with soil. As typically used in fate and contaminant transport calculations, the Kd is defined as the ratio of the contaminant concentration associated with the solid to the contaminant concentration in the surrounding aqueous solution when the system is at equilibrium. Soil and geochemists knowledgeable of sorption processes in natural environments have long known that generic or default Kd values can result in significant error when used to predict the absolute impacts of contaminant migration or site-remediation options. Example Kd values used in AFM are provided in Figure 19.

To test the sensitivity of AFM output to a range of reasonable values for selected parameters, three separate Monte Carlo analyses were run on the AFM. The results of the analysis indicate that, in the absence of degradation, Kd is the only input parameter that has sufficient uncertainty and influence over results to warrant additional effort to increase the precision of the value put into the model.

Constituent	CARSN	Kd
RDX	121-82-4	0.1954
TNT	118-96-7	1.834
HMX	2691-41-0	1.853
DIPHENYLAMINE	122-39-4	1.887
TETRYL	479-45-8	2.141
COPPER	7440-50-8	22
LEAD	9439-92-1	100

Figure 19. Kd values used in AFM.

CoPC Leaching

The Leaching Loss Rate Constant (Kl) is calculated from annual rainfall, recharge, and partitioning loss rates. GIS is used to perform spatial queries to calculate the average rainfall recharge rates. These datasets are stored in the AFM_GDB.mdb personal geodatabase located in the Database folders. The calculation of Kl is further defined in Appendix E.

The leaching loss rate is generated from calculations estimating the concentration of CoPC in infiltration as a result of partitioning between the soil and infiltrating precipitation and the volume of infiltration expected each year. The product of the concentration and volume is a mass of CoPC that will be lost through leaching each year. When that loss per year is divided by the total mass of CoPC present in the range soil, it yields the loss rate constant.

CoPC Partitioning Calculation

Studies have shown that chemical residues in soil will partition themselves between the dissolved phase and an adsorbed phase on the surface of soil particles when those particles are in the presence of water. The relationship between the two phases is defined as the partition coefficient (Kd). For many chemical constituents, the Kd is relatively constant for any given soil and is calculated as the ratio of the equilibrium concentrations of the two phases (i.e., the ratio of the concentration in soil to the concentration in water in contact with that soil):

$$\text{Kd} = [(\text{Con of CoPC in soil}) / (\text{Con of CoPC in Water})]$$

Given the relatively constant nature of the relationship, the concentration in one phase can be calculated if the Kd and the concentration in the other phase are known. Consequently, AFM includes a database in which the Kd for each CoPC has been entered. Alternately, the operator can input a site-specific value if one is available. The Kd is then multiplied by the estimated concentration in soil for that constituent to calculate the concentration of the CoPC in any infiltrating water (leachate). (The value of Kd will vary with soil type. Hence, use of the AFM database in lieu of site-specific values can give rise to a level of imprecision. Fortunately, the results of the sensitivity analysis indicate that the range of imprecision is small and has little impact on overall results.)

CoPC Leaching Calculation

The Leaching (Kl) Loss Rate Constant is calculated from annual rainfall, recharge, and estimated CoPC concentration in leachate. GIS is used to perform spatial queries to calculate the average rainfall recharge rates. These datasets are stored in the AFM_GDB.mdb personal geodatabase located in the Database folder. The estimated mass loss to leaching is calculated as the product of the leachate concentration and the leachate volume. The leaching loss rate in units of 1/year is then calculated as the ratio of the annual loss rate to the total mass of that CoPC in the soil-mixing zone. The leaching loss rate can be converted to 1/days units by dividing by 365:

Kl = [(Kd)(Con CoPC in Soil)(Annual Recharge)]/[Mass CoPC in Soil]

Because Mass of CoPC in Soil = (Con of CoPC in Soil)(Mass of Soil in Mixing Zone)

Kl = [(Kd)(Annual Recharge)]/[Mass of Soil in Mixing Zone]

The calculation of the leaching rate constant is further defined in Appendix E.

Step 9 – Perform CoPC Driven Degradation Forecasting Model

To calculate the concentration of munitions constituents resulting from projected training levels, AFM calculates expected mass loading of each CoPC for the selected area (range or ranges) in pounds on an annual basis. This loading is based on the training load, with the soil, leaching, and biodegradation loss constants applied. The mass loading value is divided by the soil mass (range area x average depth of penetration for munitions fired) to calculate the average concentration of each CoPC across the range mixing zone in parts per million if there are no loss mechanisms present (e.g., degradation and migration). Biodegradation (Kb), leaching (Kl), and transport (Kt) loss rate constants are applied for each CoPC based on the half-life assigned for the temperature and precipitation levels for the location. The loss rate constants are summed to provide the total loss rate constant (Ks = Kb + Kt + Kl). Assuming that loading and losses are ongoing throughout the year, the final concentration at the end of the year is estimated. This process is more thoroughly defined in Appendix E.

Based on this calculation, the forecasting model provides the user the opportunity to add multiple-year usage to the data calculations. This multiple year calculation will use the annual data and multiply the results over a user-specified period of use, change the percentage of munitions use (default 80 percent of STRAC strategy), or change the training load of units by a percentage. Changing these data will more accurately portray the actual use of the range over multiple years or training.

The calculation of CoPCs on the range(s) and the changes of years or usage on the ranges determine the range status. The status portrays the use of the range by training units (amount of munitions) over a user-specified time. Figure 20 shows how the increase in munitions use over time will degrade the range environmental status.

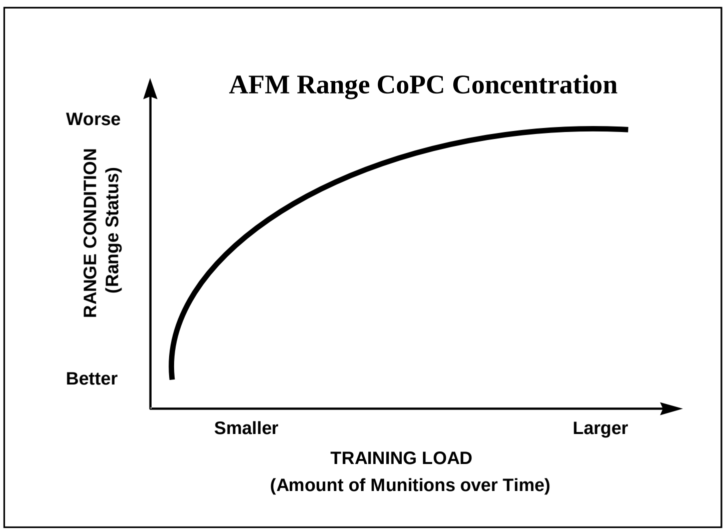

Figure 20. Range status changes based on munitions use.

Step 10 – Establish Training Range Munitions Capacity Standards and Thresholds

Risks arising from contaminants in soil are proportional to their concentration. Under current risk assessment guidelines, risks are deemed unacceptable when the concentration exceeds a designated threshold for each relevant pathway. For the purposes of the AFM work, three pathways were identified for analysis: (1) Direct human contact with soil, (2) Human ingestion of ground water that has been contaminated as a result of leaching from soil, and (3) Exposure of ecological receptors to sediment contaminated by particles in runoff over contaminated soil. Soil concentration thresholds were selected from existing criteria for soil direct contact pathway (recreational use criteria from the Risk Assessment Information System, Oak Ridge National Laboratory). For the groundwater pathway, soil thresholds were derived from drinking water standards or related health-based limits and use of a standard dilution/attenuation factor in the same manner as the Kd described in *Step 8 - Calculate Leaching Loss Rate Constant*. Threshold values for sediments were selected from a recent ecological risk assessment conducted on the Pellham Range at Fort McClellan, GA.

Ranges are then categorized based on how estimated soil concentrations compare with the threshold concentrations:

- Green – less than an order of magnitude below threshold; no action required
- Amber – within an order of magnitude of the threshold in either direction; range should have soil samples taken to confirm model results
- Red – greater than ten times the threshold; range requires rehabilitation or changes in management approach.

After applying the loss rate constants, each constituent concentration is compared with a known threshold to identify range condition. As the range is used over time, the amount (weight) of CoPCs will increase, unless equilibrium has been reached. Taking in the constants applied to the training load, the range may pass through a green status, to amber, then to red. These status changes are a direct reflection of the amount of CoPCs remaining on the range. As a predictive tool, the user can, in Step 9, forecast the use of the range (munitions) and calculate future range status. Applying the CoPC thresholds, AFM will calculate when the range, without any mitigating practices applied, will change the range condition. Figure 21 portrays an example of how a range condition is changed.

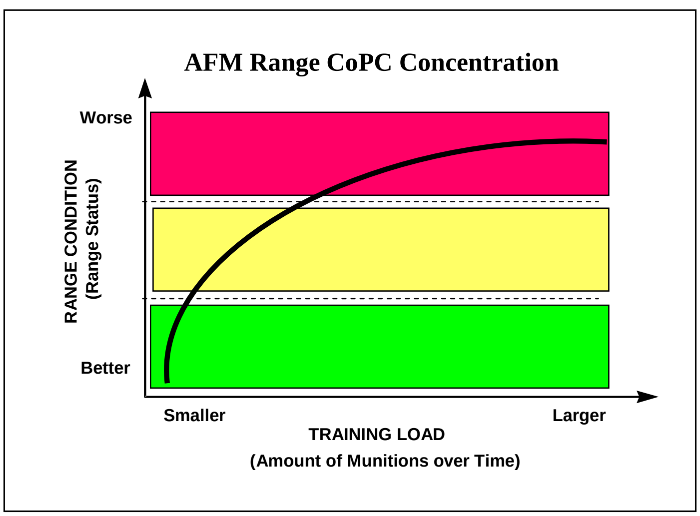

Figure 21. Range condition based on munitions use.

Figure 22 is a sample of range conditions based on training load and the addition of environmental constants and thresholds.

Constituent	Media	Status	Min (PPM)	Max (PPM)
DINITROTOLUENE	SOIL	RED	1320	0
DINITROTOLUENE	SOIL	AMBER	13.1	1320
DINITROTOLUENE	SOIL	GREEN	0	13.1
ETHYLBENZENE	SOIL	RED	15501	0
ETHYLBENZENE	SOIL	AMBER	155	15500
ETHYLBENZENE	SOIL	GREEN	0	154
HEXACHLOROETHANE	SOIL	RED	15101	0
HEXACHLOROETHANE	SOIL	AMBER	151	15100
HEXACHLOROETHANE	SOIL	GREEN	0	150
LEAD	SOIL	RED	15000	0
LEAD	SOIL	AMBER	150	15000
LEAD	SOIL	GREEN	0	150
NITROCELLULOSE	SOIL	RED	1000001	0
NITROCELLULOSE	SOIL	AMBER	10000	1000000
NITROCELLULOSE	SOIL	GREEN	0	9999
NITROGLYCERIN	SOIL	RED	1000000	0
NITROGLYCERIN	SOIL	AMBER	10000	1000000
NITROGLYCERIN	SOIL	GREEN	0	10000
RDX	SOIL	RED	160	0
RDX	SOIL	AMBER	1.6	160
RDX	SOIL	GREEN	0	1.6
TNT	SOIL	RED	24000	0
TNT	SOIL	AMBER	240	24000
TNT	SOIL	GREEN	0	240

Figure 22. Example concentration thresholds.

5 AFM Fort Munitions – Example

Introduction

The AFM Model is quite large due to the amount of software, data, and calculations it contains. The Model requires that the computer have enough memory and processing capability to perform calculations. The AFM Model has been developed as a stand-alone module.

The AFM Model is not classified, but due to some cumulative data sets, is currently regarded as FOR OFFICIAL USE ONLY. Upon further examination of the data, the government may change this status.

Loading the AFM Model

To operate AFM, place the AFM CD/DVD in the computer's CD/DVD drive. The model is equipped with a self-extracting tool. When prompted, browse the computer file system and choose where the model will be placed. It is recommended that the model be placed directly on the root directory of your computer hard drive (typically the C: drive) with other programs. The model will not provide an icon at this time with which to launch the databases. Once the drive/folder is selected, click on the extract button. All programs will be extracted to that file and a main file folder will be developed containing the model and databases. You do NOT need to provide a new folder for the model. The extraction tool will provide a new folder automatically. As previously stated, all databases and links MUST reside in the same folder.

Starting the AFM Model

To access AFM, open Windows Explorer and navigate to the folder containing the Model (recommended C:\AFM). Double click the AFM subfolder and double click the ArcMap file named AFM_II_v2.mxd. The AFM FOUO screen will appear (Figure 23). Click "Yes" if you agree and wish to continue.

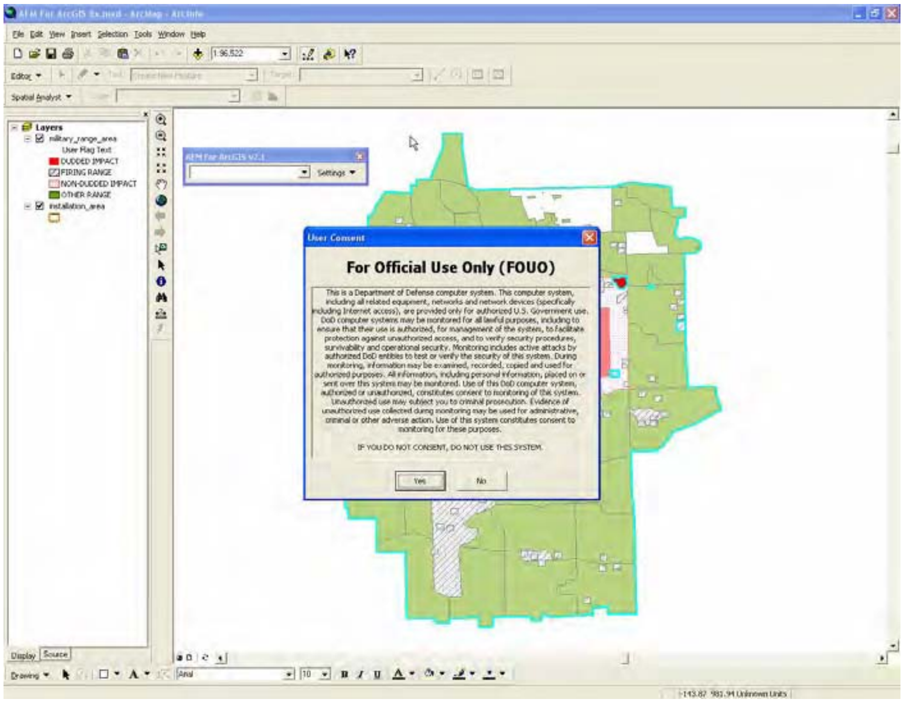

Figure 23. FOUO screen.

The AFM start-up screen will appear (Figure 24). This screen remains while the computer loads the model. Ability to continue is based on the processing capability of the computer.

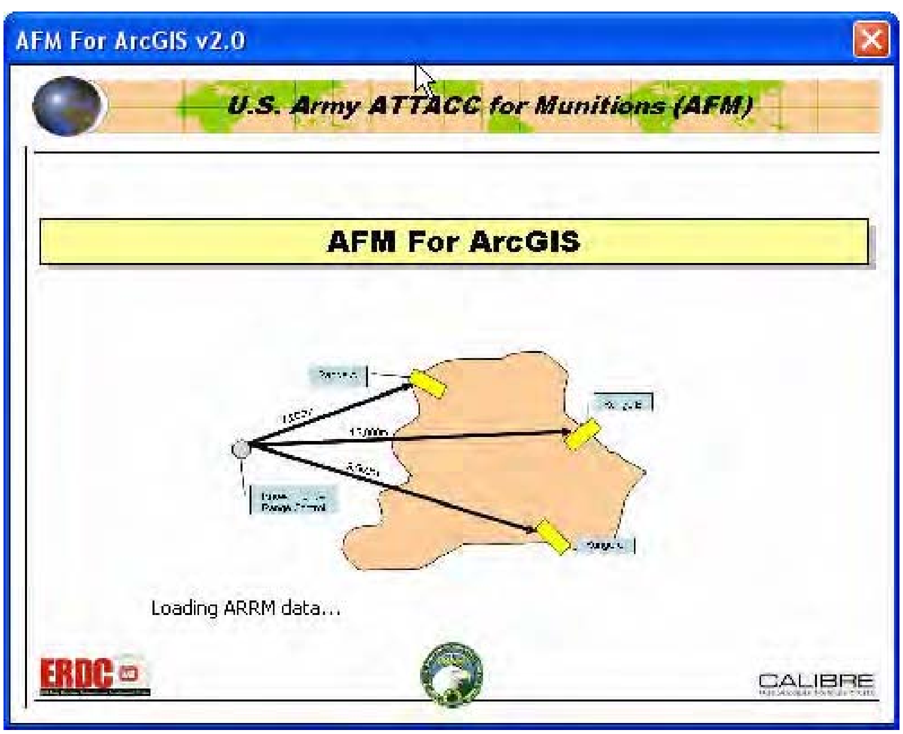

Figure 24. Start-up screen.

Range Configuration and Training Load

The AFM model starts by prompting the user to define the training load. Load definition consists of selecting training ranges to be evaluated, the Army units training, and the number of munitions fired (by DODIC).

Range Configuration

After the model is loaded, a screen with a GIS-drawn outline of Fort Hood appears with a window named "AFM For ArcGIS v2.1." The user must select the installation for evaluation (Figure 25). To select the installation, click on the down arrow within the window to select the site. For this handbook, the fictitious Fort Munitions is used.

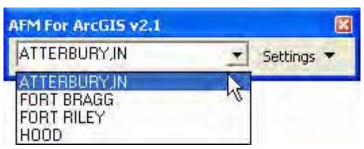

Figure 25. Installation selection screen.

Once the site is identified, GIS uses ORID data to draw the installation boundary on the screen (Figure 26). The drawing includes firing ranges, maneuver ranges, and cantonment areas. A window labeled Ranges will be provided to start the training load definition process.

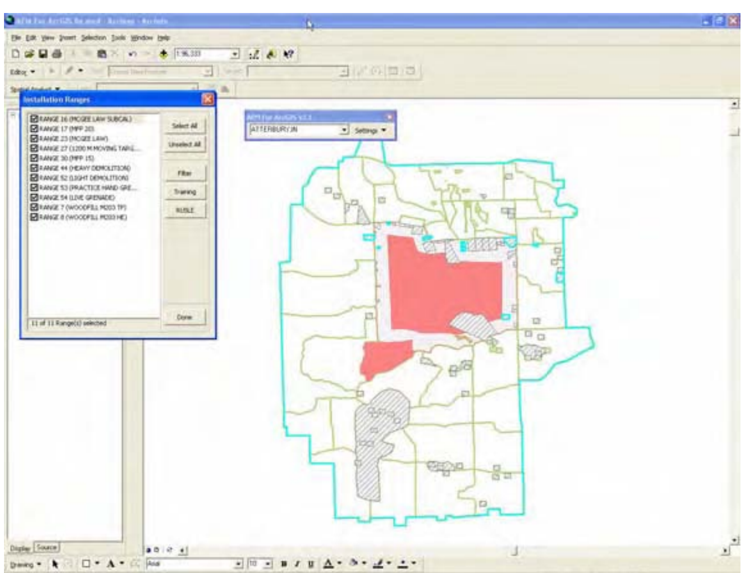

Figure 26. Initial training load definition screen.

NOTE: If another installation is to be evaluated, return to the "AFM For ArcGIS v2.1" window and select the new installation.

Within the Range window, the installation's ranges are listed. All the ranges are selected (checked). The user can de-select any range. Viewing the screen, the map for the site shows the selected ranges highlighted in "neon blue" (Figure 27).

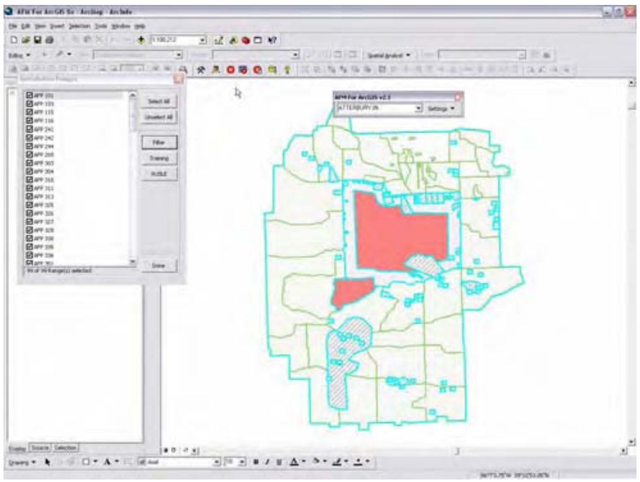

Figure 27. Range identification screen.

As some sites have numerous ranges, a filter has been developed so the user can evaluate only a portion of the ranges. To filter for selections, the user can use a list by either FCC or Environmental Management System Groups. To filter, click on the Filter button shown in the Range window (Figure 28).

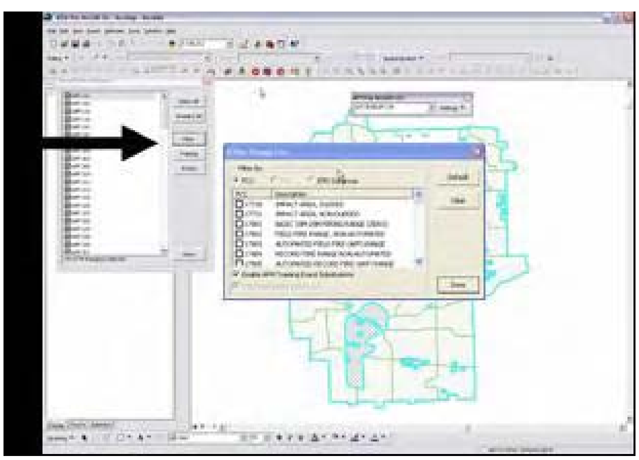

Figure 28. Filter button.

The program defaults to filtering by FCC. Click on EMS Subgroups and check the boxes for "Demolition" and "High Explosive, with Fixed FP." Click on Done to proceed. The filter calculates the ranges and automatically populates the FCC filter with the same type-FCC selection. Click on Filter by FCC. Scroll down and the corresponding FCCs associated with the EMS groups selected have been checked. When selections are made click Done.

The GIS-drawn installation screen shows the installation with the selected user-filtered ranges. The installation boundary and selected ranges are highlighted in neon blue (Figure 29).

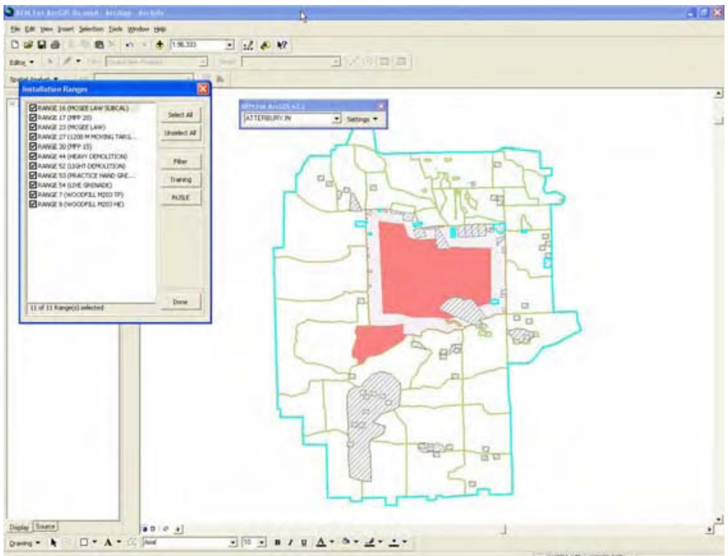

Figure 29. Range identification screen.

The first part of training load determination is complete. The next step is to determine the Army units training on the installation.

Training Load

To begin, click on the Training button in the Range window. A second window will appear and provide a list of all units that use the filtered ranges (Figure 30).

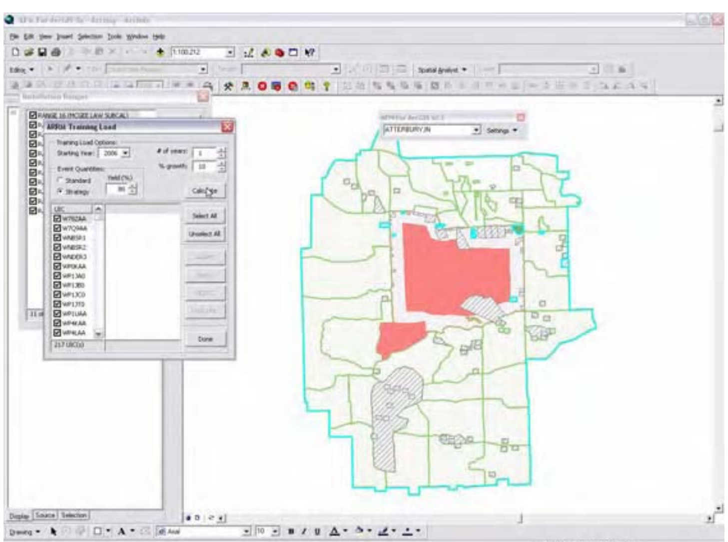

Figure 30. Units display screen.

The program defaults to having all the units selected (checked). This list can be changed by de-selecting some units, de-selecting all units (Deselect All button), or returning to all units by clicking on the Select All button. This completes the second portion of training load determination. Do NOT push the Done button at this time. The program uses the information evaluated by the user (training units) to continue calculations.

Selecting Munitions

The program will now calculate the summed number of munitions, by type-DODIC, used by these units in performing the training events.

Before clicking on the calculate button to determine munitions use, the user can change the start year (all years based on current 2006 doctrine), the number of years for calculations, the percent growth in munitions use year-by-year, and/or the quantity of munitions used. The quantity is defaulted to the strategy developed under STRAC.

The strategy is the maximum number of munitions that CAN be allocated and used by units. The standard numbers are the MINIMUM number of munitions that can be allocated. Through coordination with the Army, approximately 80 percent of the strategy for munitions use is allocated. This number is reflected in the window, but can be changed.

To calculate the sum of munitions used on these ranges, click on the calculate button (Figure 31).

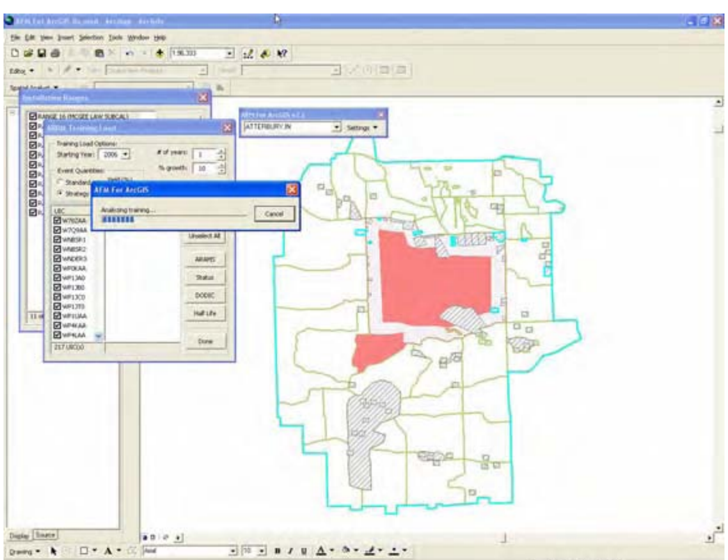

Figure 31. Munitions calculation screen.

The program is now calculating munitions use. Figure 32 shows a blow-up of the resulting calculation. This window is used to determine calculations explained in the next section, **Range Condition**:

- ARAMS output reports
- Range Status (condition) and report
- A list of DODICs and each munition's details (constituents, weights, penetrations, crater size, etc.)
- Half-life of each of the constituents of concern.

NOTE: This window completes the calculation of Training Load. Do NOT click on Done unless you are finished with the AFM model. This window is used to perform all additional calculations and MUST remain open to perform follow-on tasks.

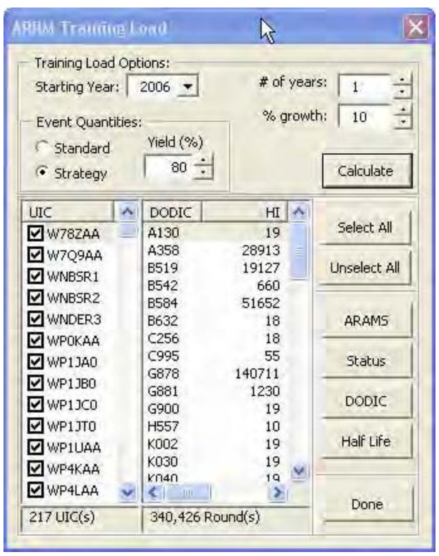

Figure 32. ARRM training load screen.

Range Condition

Range Condition under AFM is the ecological state of the range. AFM uses the scientific calculations from RUSLE to assist in determining the current condition of the range. RUSLE is used for military installations because soil erosion is a quantifiable variable that is easily understood by both military trainers and natural resources managers. Although other measures of land condition (e.g., vegetation composition) exist, soil erosion is a good general indicator.

Estimate Range Status

To calculate the status of ranges, the user must perform actions defined in the section titled *Training Load* to determine the training load of the ranges needing analysis. Using the examples provided in the *Training Load* section (page 39), finalized by the ARRM Training Load window, click on the Status button.

A Range Status window will open with a listing of the ranges that are to be evaluated. To evaluate the status of the ranges selected, click the Calculate button (Figure 33).

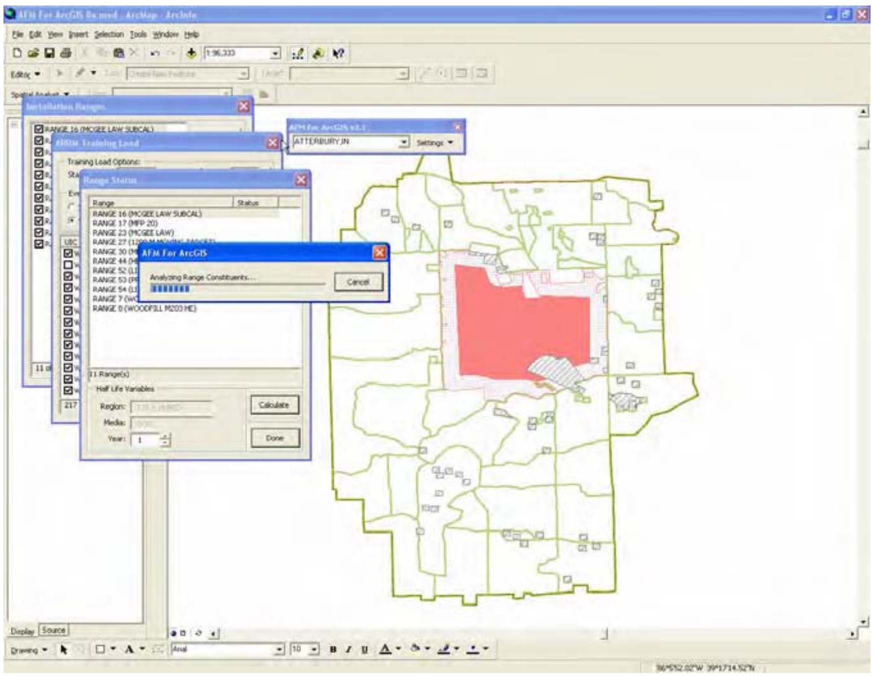

Figure 33. Range status screen.

The program is now calculating range status based on numerous calculations noted above. The user will first be asked whether the graphics should be deleted — click the No button. The next warning will be generated from the report form that is about to be displayed (Figure 34). This is a security warning; click on the Open button. Two windows will become available. The first window will be the report form. The report is printer friendly, and can be exported to hard copy. The second window shows the range status, which is easily viewed to see which ranges may need further analysis.

The windows shown in Figure 34 are blow-ups of the resulting calculation. Click Done or close the report window when finished.

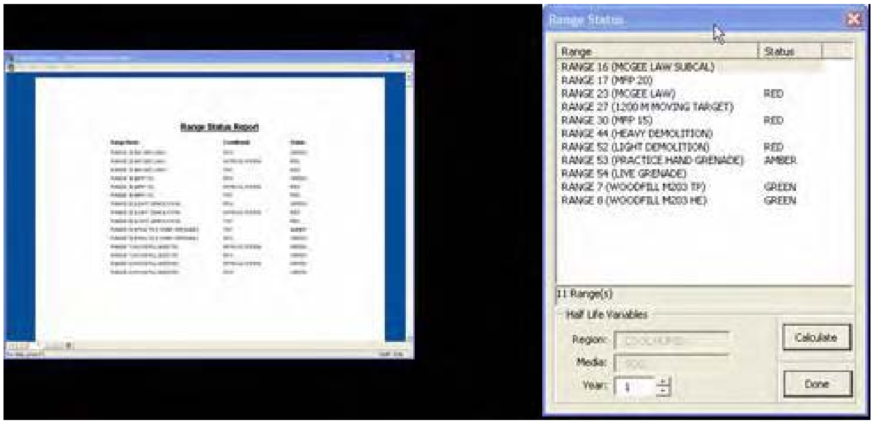

Figure 34. Range report screens.

View DODIC Details

The AFM has details of each DODIC used by trainers and outlined in the STRAC. Many DODICs are used as substitutes within the training community, but the detailed characteristics of these different DODICs are very similar to the established STRAC munitions. Details of each DODIC used on the selected ranges can be viewed from the ARRM Training Load window by clicking on the DODIC button (Figure 35). To view all DODICs used by AFM, see DODIC Data, page 47.

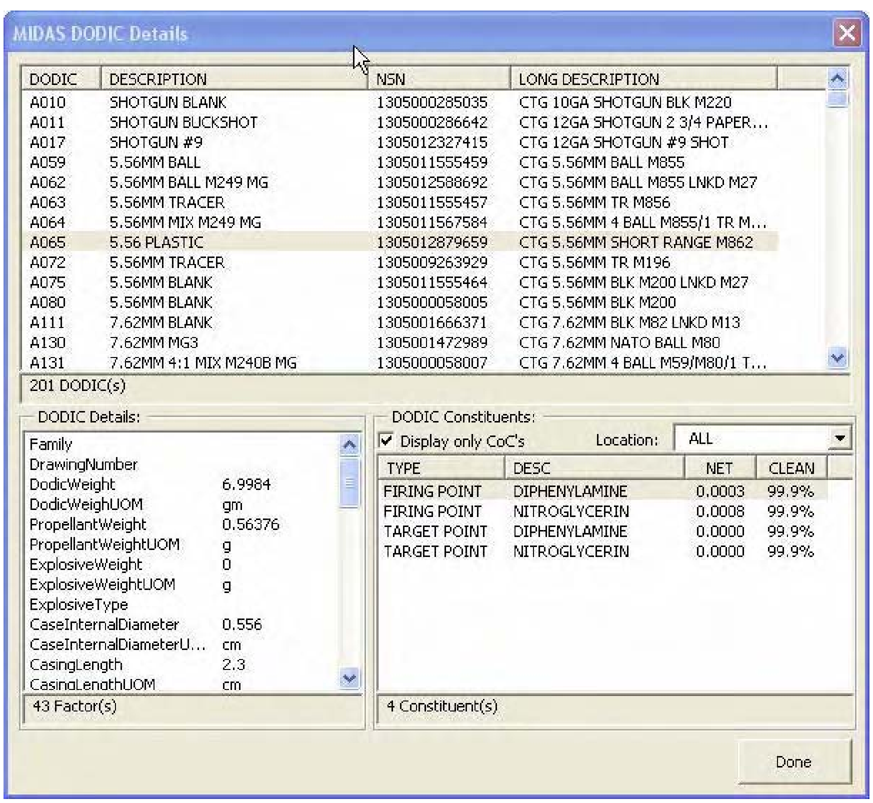

Figure 35. DODIC screen.

By default, the window shows only the upper portion of the information. To view specific DODIC information, click on the DODIC. When finished, click the Done button.

Calculate and View ARAMS Output

One of the essential parts of the range condition evaluation is that, if a condition DOES turn from green to amber or red, the user has the opportunity to evaluate the condition using the ARAMS. To provide input to the ARAMS tool, AFM develops an ASCII* file for direct loading into ARAMS. The information needed by ARAMS is usually at the EMS level of detail. When evaluating ranges, it is suggested that the evaluation be conducted at this level. To produce the ARAMS ASCI-II file, click on the ARAMS button, then the Export button (Figure 36). This will export a file to the computer for ARAMS use. Click the Done button when complete.

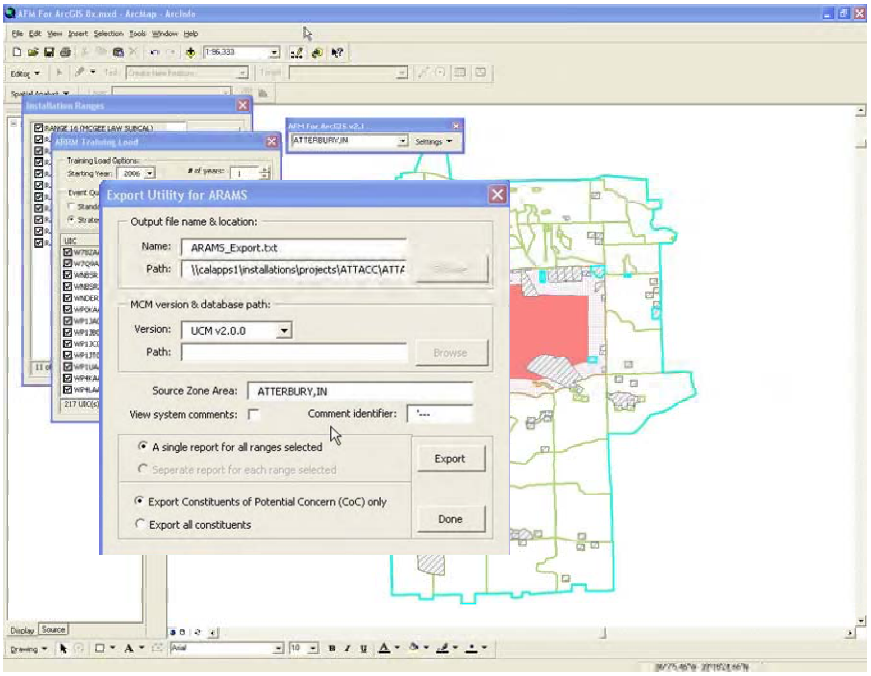

Figure 36. ARAMS screen.

NOTE: the AFM defaults to only the constituents of concern determined by the Army. To export all constituents, select the All button. It is advised to export only the constituents of concern, as the file developed is quite large. Exporting all constituents will develop a file possibly too large for ARAMS to evaluate.

* ASCII = American Standard Code for Information Interchange

View Other Data Table Information

To view the data that AFM uses from other databases, the user should return to the screen where the installation was originally selected (Figure 37). This action will assist the model by not having to maintain different calculations while viewing the referenced data.

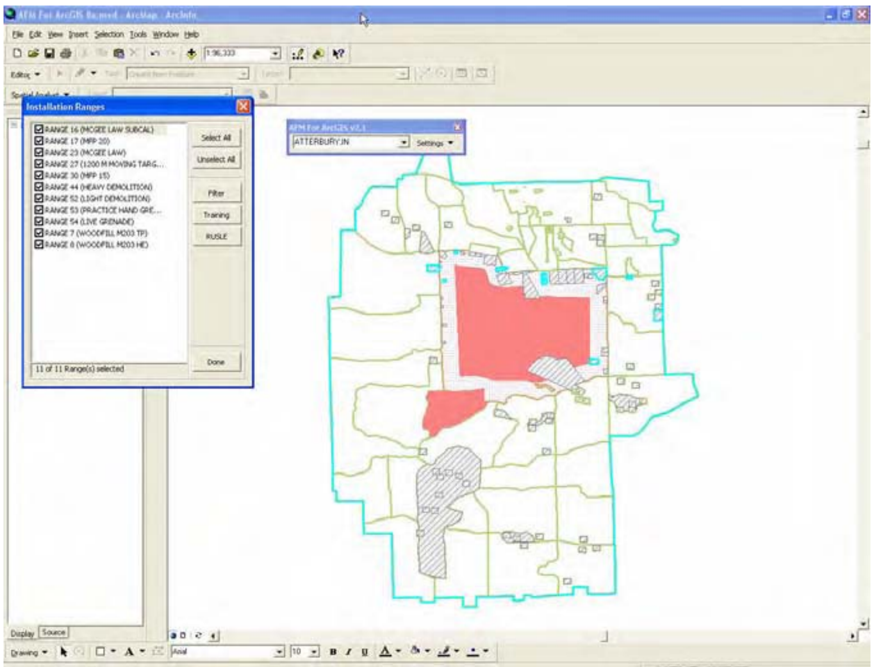

Figure 37. AFM main screen.

To view other data sources, click on the small "AFM For ArcGIS v2.1" window and click the Settings button (Figure 38).

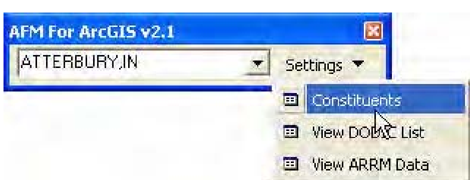

Figure 38. AFM database access screen.

Constituents Data

To view the reference data as it pertains to Constituents, click the Constituents button (Figure 39).

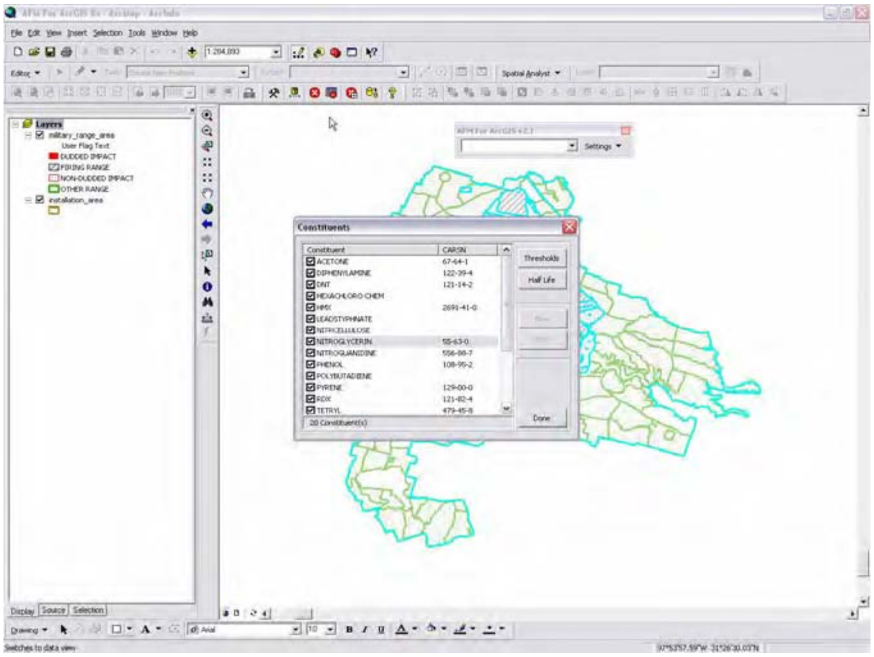

Figure 39. Constituents reference data screen.

The window contains the constituents with the Constituents of Concern checked. From this window, the user can view the constituent thresholds and half-lifes. To view either, click the appropriate button (Figures 40 and 41). If either table is blank, AFM needs more data. For this example, the user has selected the constituent Nitroglycerin. When finished, click the Done button.

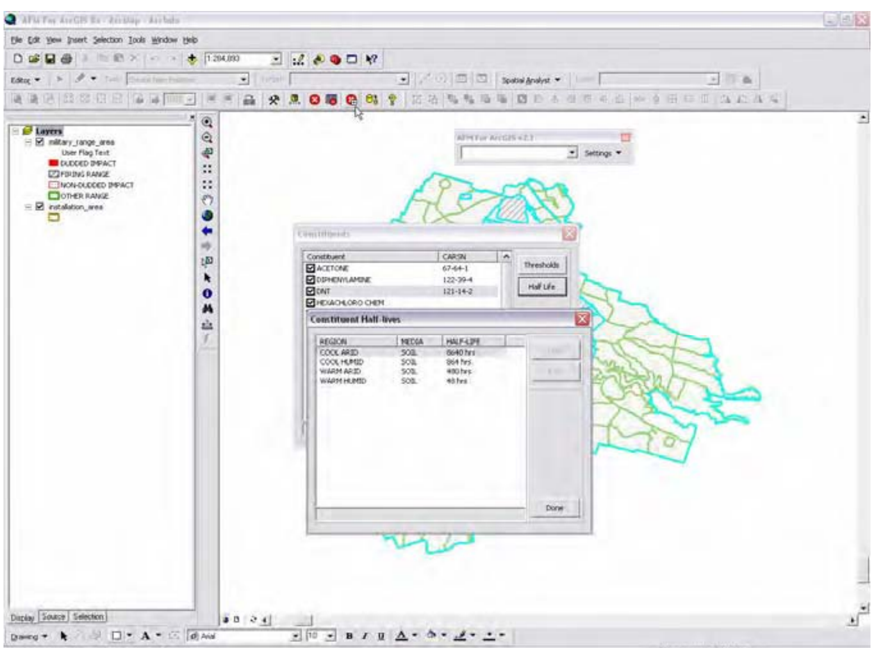

Figure 40. Threshold screen.

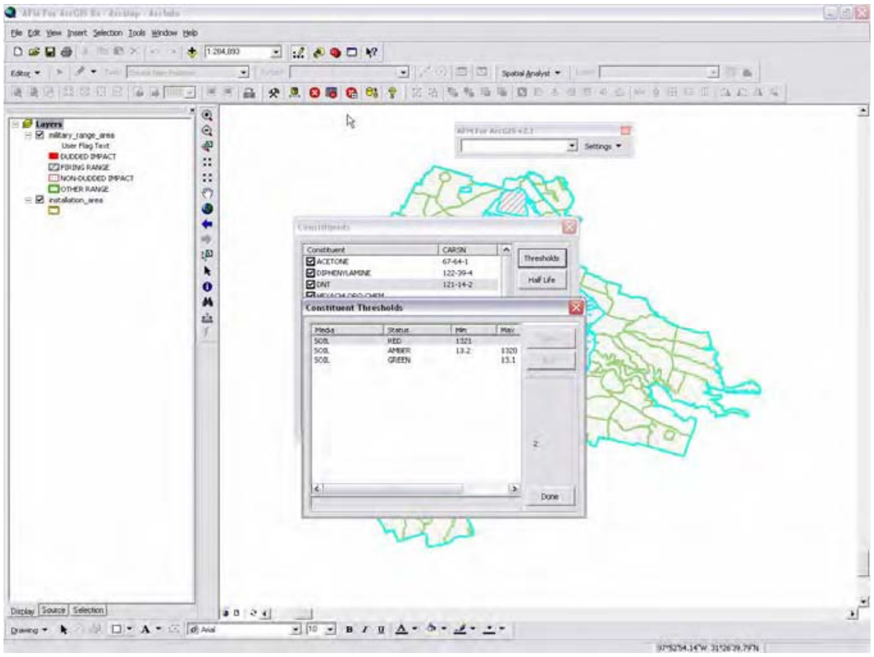

Figure 41. Half-life screen.

DODIC Data

Previously, the user could view the DODIC list while developing the training load. The DODIC list provided during that operation provided only the DODICs applied to the range selection criteria. To view the entire DODIC list, click on the Settings button as above, and then click on the View DODIC List button (Figure 42).

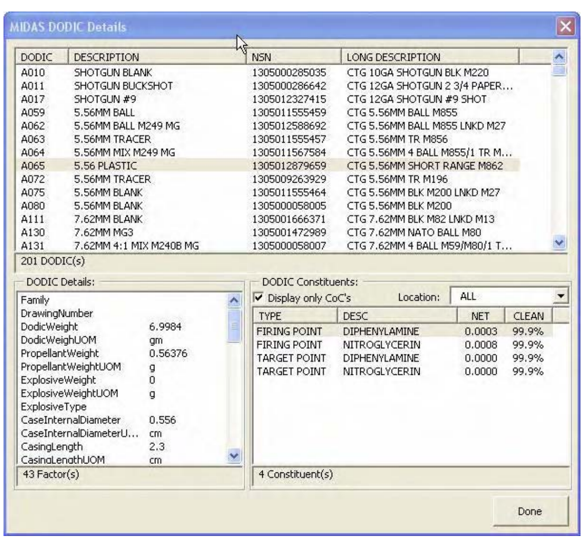

Figure 42. DODIC data screen.

As before, click on the DODIC that is to be viewed and the detailed data will be displayed. Click the Done button when finished.

Training Unit Data

The training unit data are provided in a separate database linked to AFM. These data are extracted from the ARRM database and cross-walked to like range facilities at different installations. To view all the data associated with the unit (name, type, events, DODICs, STRAC tables, etc.) click on the View ARRM Data button (Figure 43).

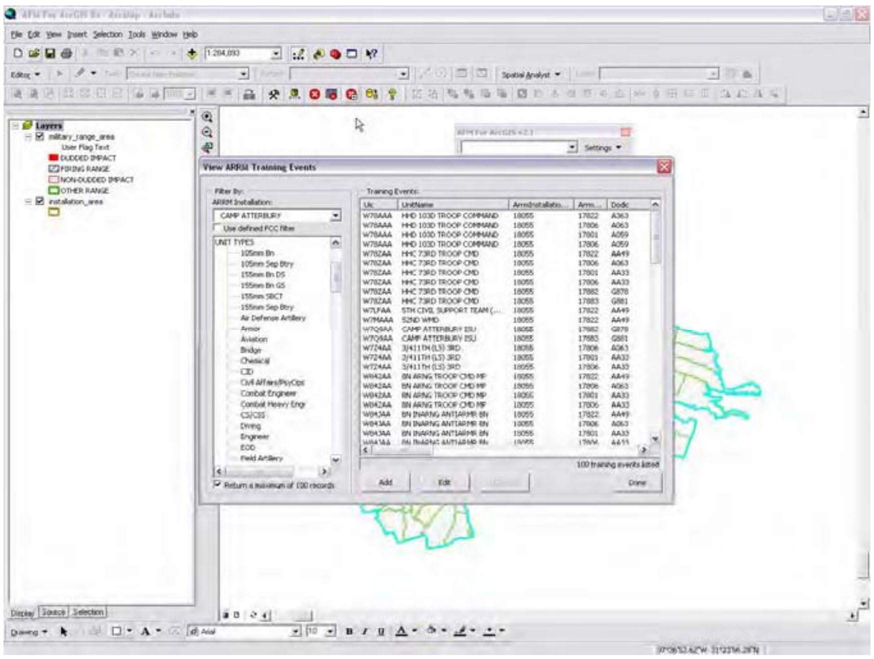

Figure 43. ARRM data screen.

Closing the AFM Model

To close the AFM model, the entire ArcGIS software must be closed. To close the program and AFM model, navigate to the upper right corner of the window and click the red "x" on the navigation bar. A window will appear asking if the user wants to save the work (currently disabled). Click the No button to close the model (Figure 44).

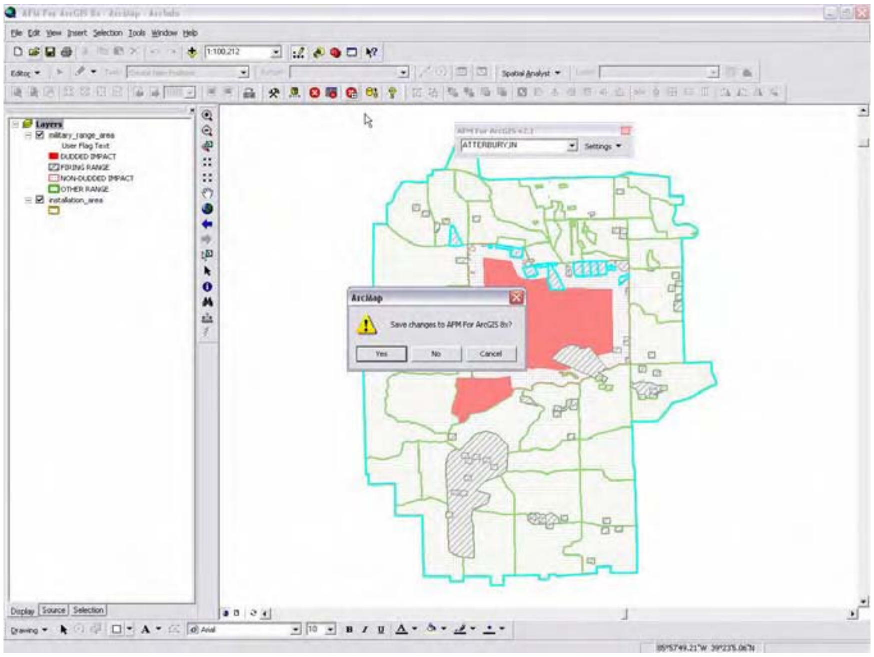

Figure 44. AFM closing screen.

Appendix A: AFM-Related Publications

This Appendix includes related publications, such as Army Regulations (ARs) and literature citations associated with the content of this Handbook. The content of this appendix is to provide sources of additional information. The reader does not have to read the publications to understand the ATTACC for Munitions (AFM) Handbook.

Department of the Army. AR 200-2, Environmental Effects of Army Actions, 1988

Department of the Army. AR 210-20, Master Planning for Army Installations, 2005

Department of the Army. AR 210-21, Army Training Ranges and Training Range, 1997

Department of the Army. AR 350-19, The Army Sustainable Range Program, 2005

Department of the Army Pamphlet 350-38, Standards in Training Commission (STRAC), 1993

Department of the Army. Field Manual (FM) 25-100, Training the Force, 1988

Department of the Army. FM 25-101, Battle Focused Training, 1990

Department of the Army. 1999. Integrated Training Area Management (ITAM), Procedural Manual, Implementing Draft, August 1999.

Department of the Army. Training Circular 25-1, Training Ranges, 2004

Department of the Army. Training Circular 25-8, Training Ranges, 2004

Gibbs, T., Popolato, A., eds., 1980. LASL Explosive Property Data. University of California Press: Berkeley, CA.

Lynch, J. C. 2002. Dissolution kinetics of high explosive compounds (TNT, RDX, HMX). ERDC/EL TR-02-23, U.S. Army Engineer Research and Development Center: Vicksburg, MS.

Lynch, J., J. Brannon, and J. Delfino. 2002a. Dissolution Rate of High Explosive Compounds. *Chemosphere*, 47, 725-734.

Lynch, J., J. Brannon, and J. Delfino. 2002b. Effects of Component Interactions on the Aqueous Solubilities and Dissolution Rates of the Explosive Formulations Octol, Composition B, and LX-14. *J. Chem. Eng.*, 47, 542 -549.

Miyares, Paul H., and Thomas F. Jenkins. 2000. Estimating the Half-Lives of Key Components of the Chemical Vapor Signature of Land Mines. ERDC/CRREL TR-00-17. U.S. Army Engineer Research and Development Center: Hanover, NH.

U.S. Army Environmental Center (AEC). 1999. Army Training and Testing Area Carrying Capacity Manual.

U.S. AEC. Range Condition Trend Analysis (LCTA) II, August 1996 Report, August 1997.

U.S. AEC. Range Condition Trend Analysis (LCTA) II, January 1996 Report, March 1996.

U.S. Department of Agriculture. 1977. Soil Conservation Series. Procedure for Computing Sheet and Shill Erosion on Project Areas. Tech Release No. 51 (Rev 2), September 1977.

Appendix B: Acronyms and Abbreviations

Appendix B provides a listing of abbreviations that includes office symbols, acronyms, and abbreviations commonly used throughout the U.S. Army and within the AFM Program.

Abbreviation	Meaning
AFM	Army Training and (ATTACC) for Munitions
AMC	Army Materiel Command
ARID-Geo	Army Range Inventory Database for GIS
ARRM	Army RTLP Requirements Module
ASIP	Army Stationing and Installation Plan
ATSC	Army Training Support Center
ATTACC	Army Training and Testing Area Carrying Capacity
BLTM	Battalion Level Training Module
CONWEP	Conventional weapons
CoPC	Constituent of Potential Concern
DAART	Department of the Army Ammunition Requirements Tool
DAMO-TRS	Training Simulations Division, ODCSOPS, HQDA
DCSOPS	Deputy Chief of Staff for Operations and Plans
DEM	Digital elevation models
DLG	Digital line graph
DODIC	Department of Defense Identification Code
DOE	Department of Energy
DOT	Director of Training
DPTM	Directorate of Plans, Training, and Mobilization
EMC	Environmental Management Class
EMS	Environmental Management System
ERDC-CERL	Engineer Research and Development Center Construction Engineering Research Laboratory
ERDC-CRREL	Engineer Research and Development Center Cold Regions Research Engineering Laboratory
ESRI	Environmental Systems Research Institute, Inc.
FCC	Facility Category Code
FOUO	For Official Use Only
GIS	Geographic information system
GPS	Global positioning system
HQDA	Headquarters, Department of the Army
ITAM	Integrated Training Area Management Program
Kb	Biodegradation Loss Rate Constant

Abbreviation	**Meaning**
Kd	Partitioning Loss Rate Constant
Kl	Leaching Loss Rate Constant
Ks	Total Loss Rate Constant
Kt	Transport Loss Rate Constant
LRAM	Land Rehabilitation and Maintenance
MIDAS	Munitions Items Disposition Action System
MIMS	Maneuver Impact Miles
NATSGO	NRCS National Soil Geographic Data Base
NIMA	National Imagery and Mapping Agency
NRCS	Natural Resource Conservation Service
ODCSOPS	Office of the Deputy Chief of Staff for Operations and Plans
OPTEMPO	Operating Tempo
ORID	Operational Range Inventory Database
ORIS	Operational Range Inventory Sustainment
POC	Point of Contact
RDP	Range Development Plan
RC	Range Condition
RRAM	Range Risk Assessment and Maintenance
RS	Range Status
RTLP	Range and Training Land Program
RUSLE	Revised Universal Soil Loss Equation
SAMAS	Structure and Manpower Allocation System
SDSFIE	Spatial Data Standards for Facilities, Infrastructure, and Environment
SME	Subject Matter Expert
SRC	System Resource Codes
SRP	Sustainable Range Program
STATSGO	NRCS State Soil Geographic Data Base
STRAC	Standards in Training Commission
SURGO	NRCS Soil Survey Geographic Data Base
T-BUD	Training Budget
TM	Thematic Mapper
TOE	Tables of Organization and Equipment
UIC	Unit Identification Code
USAEC	United States Army Environmental Center
USATSC	United States Army Training Support Center
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation

Appendix C: Glossary of Terms

ATTACC for Munitions (AFM)	A database of munitions fired during live fire events by Army units, used to calculate the amount of munitions constituents remaining on the ground over a 1-year or multiple-year use.
Carrying Capacity Thresholds	The maximum training load (i.e., MIMs) that an installation (or training area) can support without posing an unacceptable risk to human health or the environment.
Conservation Practices (P) Factor	The quantitative expression of the mitigating effect that conservation practices have on the erosion process.
Erosion	The wearing away of geological formations and soil.
Event	A training event, either in generic terms (e.g., Field Training Exercise), or including type unit and echelon (e.g., Armor BN CPX).
Geographic Information System (GIS)	A system to manage spatial data and develop maps made up of a series of different data layers. Data layers can be individually selected and combined to generate a new map display. Each data layer, or theme, also has its own unique database associated with it. This allows queries to be conducted on the theme layers. In AFM, a GIS estimates range condition and draws the range condition curve.
Isoerodent Map	Contour maps of rainfall and runoff factor values.
Range Condition	The ecological state of the range. AFM measures *range condition* in terms of the e*rosion status*.
Mission Activity	Individual training events and institutional training that occurs on a given parcel of range.

Rainfall and Runoff Factor	Quantitative expression of the erositivity of local average annual precipitation and runoff. Soil erosion is greatly influenced by the intensity and duration of precipitation events and by the amount and rate of the resulting runoff. The R value incorporates total precipitation, intensity, and duration patterns of rainfall. Differences in the R factor reflect differences in precipitation patterns between regions. Larger numbers for the R factor indicate more erosive weather conditions. R values can be obtained from published isoerodent maps or calculated from historic weather data.
Range Condition Thresholds	Range status values established by each installation to reflect local environmental conditions, management objectives, funding restrictions, and mission priorities.
Revised Universal Soil Loss Equation (RUSLE)	Most widely used erosion prediction model currently available. The RUSLE is used throughout the world for a variety of purposes and under many different conditions simply because it seems to meet the need better than any other model.
Slope Length and Steepness (LS) Factor	Rate of soil erosion as affected by the local topography of an area. The LS factor provides a quantitative representation of both the slope length and steepness. Slope steepness and length values for the LS factor can be determined from topographic maps, digital elevation models, average values from soil mapping units, or from direct field measurement.
Soil Erodibility (K) Factor	Rate of erosion per unit value of the rainfall and runoff factor for standardized conditions. Larger values of the K factor reflect greater soil erodibility. K factor values are generally determined for each soil series in an area. K factor values for many soil series are published in local and regional soil surveys from the Natural Resource Conservation Service (NRCS). K factor values for soils can also be estimated from soil samples collected in the field.
Training	The entire range of mission activities which require, and/or affect, "training ranges." In that regard, the definition applies to the test and maneuver activities conducted on Army Materiel Command (AMC) installations.
Training Area Map	A map delineating range units used for scheduling and conducting military training.

Training Range Carrying Capacity	The amount of training that a given parcel of range can accommodate in a sustainable manner with a reasonable and prudent level of maintenance and rehabilitation. The optimum capacity is a balance of usage, condition, and level of maintenance.
Training Load	Training load is the collective impact of all military activities that occur on a given parcel of range. Training load is derived from Army training doctrine. AFM measures *training load* in terms of *maneuver impact miles.*

Appendix D: Range Risk Assessment and Maintenance (RRAM)

Introduction

The third portion of the AFM methodology (RRAM) has been conceptually developed but was not implemented into the software based on guidance from the AFM user group. The following description of RRAM is based on the ATTACC methodology that has been modified to meet the needs of AFM.

Range maintenance is the combination of risk assessment (determining range status and goals) and the collection of maintenance practices and their sum total benefit in mitigating the effects of constituents both on the range and transported off the range. AFM measures RRAM in terms of the type of practice, costs, affected acres, and associated P values. Figure D-1 shows the steps to measure and implement range ecological maintenance costs. Yearly projected range status can be calculated by training range, type-FCC, type-EMC, or for the entire installation. To tie the RRAM assessment to the training budget (T-BUD), range ecological maintenance practices should be collected at the range level. Once yearly range status is calculated for each range, an assessment of the range is developed, and mitigating practices can be determined.

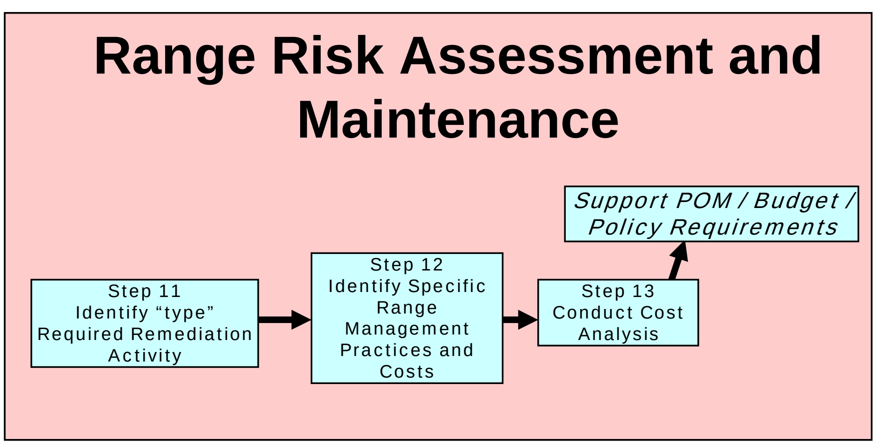

Figure D-1. Range risk assessment and maintenance approach.

Step 11 - Identify "type" Required Remediation Activity

If AFM identifies areas that potentially exceed future capacity, more robust and detailed risk assessment models are often required to evaluate potential issues. AFM produces input files for the Army Risk Assessment Modeling System (ARAMS). ARAMS is an Army developed computer-based, modeling, data delivery, and analysis system that integrates multimedia fate/transport, exposure, intake/uptake, and effects of military relevant compounds, explosives, and other constituents to assess present and future human and ecological health impacts/risks associated with chronic exposure. The benefit of ARAMS is that the object oriented interface allows site-specific transport pathways and receptors to be evaluated based on the same training load of AFM.

For costing and funding purposes, a range status goal is chosen to accomplish a desired range condition that reflects realistic funding goals. Once the predicted future range status value (symbolized by RS in the following equations) is determined, the value is compared with the desired range status (referred to as the range status goal). Larger range status values reflect a worsening range status, whereas smaller range status values reflect an improving range status.

Identify RS Delta

The difference between the predicted range status and the range status goal results in a delta. This delta is a numeric representation of the degree to which the predicted range status varies from the range status prediction. As an example, the difference between the predicted range status of 2.1 and the range status goal of 1.3 results in a delta value of (-) 0.8.

RS Goal –RS Prediction = RS Delta

RS Goal 1.3 –RS Prediction 2.1 = RS Delta (-) 0.8

A (-) designates that a shortfall situation exists and that the predicted range status exceeds the range status goal. Figure D-2 illustrates the relationship between the range status goal and the range status prediction based on training load and ensuing constituent mass.

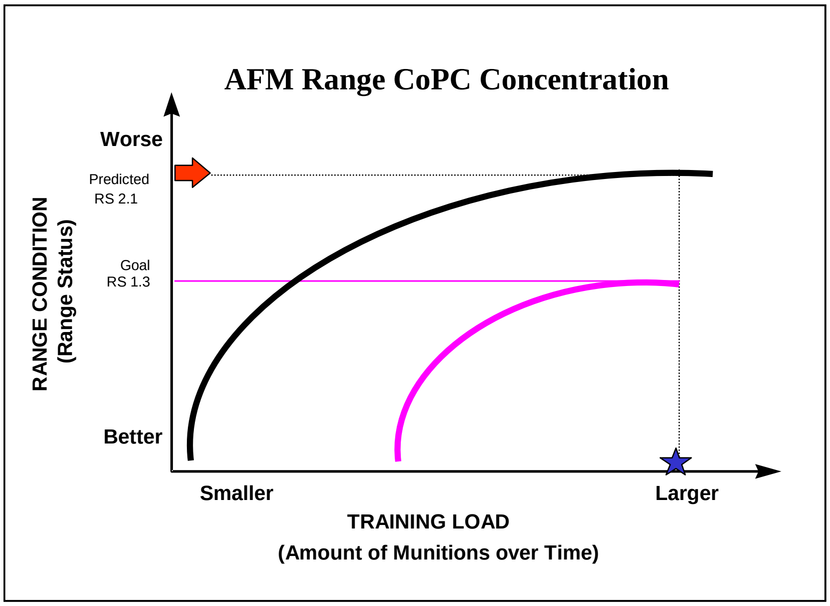

Figure D-2. Relationship between predicted values and goals.

Calculate Percent Shift in Range Status

To calculate the percent shift in the range status, translate the difference between the predicted range status and the range status goal (i.e., the range status delta) into a percentage. The percentage is the shift in range condition curve required to meet the range status goal and maintain the same training load. To translate the range status delta into a percentage, a ratio is taken between the delta and the predicted erosion status.

In the previous example, a 0.8 range status delta was required to meet the range status goal of 1.3. Therefore, the range status delta is translated into the shift in the range condition curve as follows:

% Shift in Land Condition Curve = RS Delta / RS Prediction

% shift in Range Condition curve = 0.8 / 2.1

% shift in Range Condition curve = 38.1%

This example implies that the range status line needs to shift 38.1 percent. The largest arrow in Figure D-3 points to the required shift in the range condition to accommodate the same amount of training load and decrease the erosion status from 2.1 to the erosion status goal of 1.3. Note that the range condition curve does not change its shape; its position on the range condition axis (i.e., the Y-axis) changes.

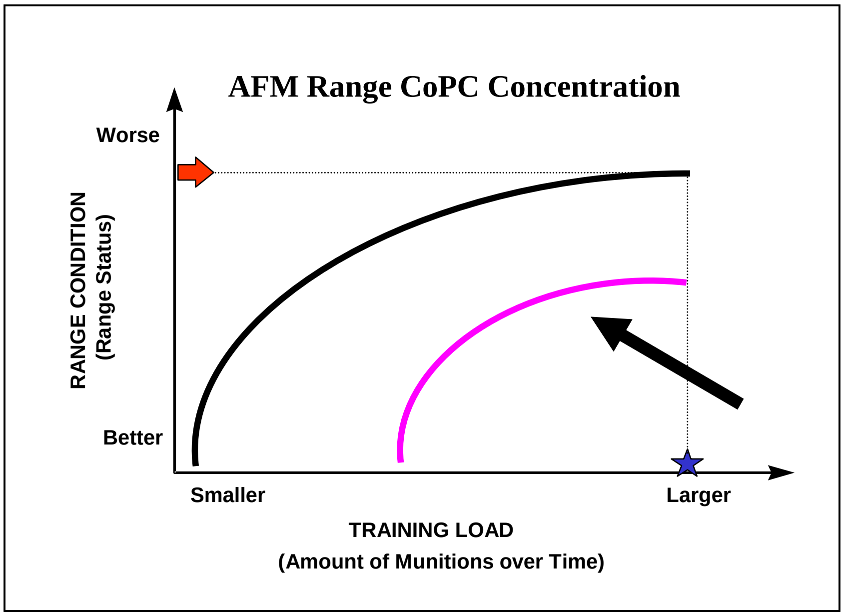

Figure D-3. Curve shift required to meet goals.

Step 12 - Identify Specific Range Management Practices and Costs

RRAM practices are those maintenance investments that are funded through the T-BUD component of the Sustainable Range Program (SRP). They are defined as operations or structures that slow runoff water velocity and mitigate the effects of constituents, thus reducing the amount of constituents in the soil, leaching into the water table or carried by runoff waters. The maintenance investment practices on military ranges include, but are not limited to, revegetation, surface scraping, and sediment retention structures.

The AFM range status line represents the relationship between the training load and range status (amount of constituents). The execution of range maintenance practices and their resulting level of effectiveness mitigate constituent effects and shift the range status line without affecting training load.

Identify Type Practices

For the purposes of AFM, RRAM practices are defined as operations or structures that mitigate the effects of constituents, thus reducing the amount of constituents in the soil and water. The basic type of RRAM practice is to repair contaminated range areas.

Repair practices are those that directly affect range constituent weights and the benefit of which can be quantified to "shift" the range condition curve. Soil and constituent removal is an example of a repair practice.

Figure D-4 provides an example of type-RRAM practices. These practices are for use as examples only until RRAM is developed. The first column lists RRAM practices. The second column is the unit of measure for the construction of the RRAM practice. The third column provides the total acres affected by one unit of the RRAM practice. The fourth column is the "P" value (effectiveness) of the practice.

Practice	Unit of Measure	Affected Acres/ Unit Quantity	P (Effectiveness Measure)
Removal of soil (2")	Acre	1.00	0.15
Removal of soil (5")	Acre	1.00	0.10
Hydroseeding	Acre	1.00	0.75
Construction and maintenance of water holding areas	Acre	1.00	0.85

Figure D-4. Example list of RRAM practices.

Determine RRAM Benefits

AFM quantifies the benefits of an RRAM practice, based on the mitigating effect that a practice has on the range. The location of the operation on range, design, and maintenance practices are components that influence the effectiveness of RRAM practices in reducing constituent contamination of soil and/or water.

The effectiveness measurement (or P factor), associated with each RRAM practice has a value from 0.00 to 1.00, where smaller values represent practices that are more effective.

The P factor value is the only variable that can shift the range status line. Consequently, a P factor value of 0.85 indicates that the range maintenance practice will reduce soil and water contamination by 15 percent (1.00 - 0.85 = 0.15).

Develop a Cost Function

To develop a cost function, AFM combines the cost of the practices with their ability to mitigate soil and water contamination.

Initially, practices are identified and their total quantities are recorded. A simple calculation determines the number of acres affected by the RRAM practices and their relative impact to the total affected acres. AFM determines a weighted average by totaling the weighted affected acres per practice. Next, AFM calculates the total practice costs by multiplying the quantity by the unit cost.

Finally, the total cost of the RRAM practices is divided by the weighted average change in P. For the purposes of this calculation, changes in P values are assumed to be linearly related to changes in cost. The result is a cost value for a one percent change in P.

Step 13 - Conduct Cost Analysis

When AFM calculates the cost to shift the range condition curve by 1 percent, a total repair practices costs is calculated. In previous steps, AFM determined that a 38.1 percent shift in the range condition curve was needed to accommodate the training load and return the range condition to its range status goal of 1.3.

Calculate Total Range Repair Requirement

The total repair requirement is the cost to change the predicted erosion status from 2.1 to the starting erosion status of 1.3. Multiplying the percent shift by the cost to shift the curve 1 percent, determines the total repair requirement. A cost of shifting the curve by 1 percent was calculated at $3,234.

Total repair requirement = (% shift) x (Cost to achieve 1% change in Curve)

Total repair requirement = (38.1% shift) x ($3,234 per 1% shift)

Total range repair requirement = $123,215

Calculate Total Installation RRAM Requirement

Finally, the total installation repair requirement is summed to calculate a TOTAL installation RRAM requirement.

Appendix E: System Overview

Database Physical Diagrams

AFM System Database

The AFM Database contains all the information required to manage various aspects of the AFM model. This includes the management of DODIC and constituent details. All process information is stored within various tables. The entity-relationship diagram has been included in the Documentation folder. Figure E-1 shows AFM for ArcGIS system database logical structures.

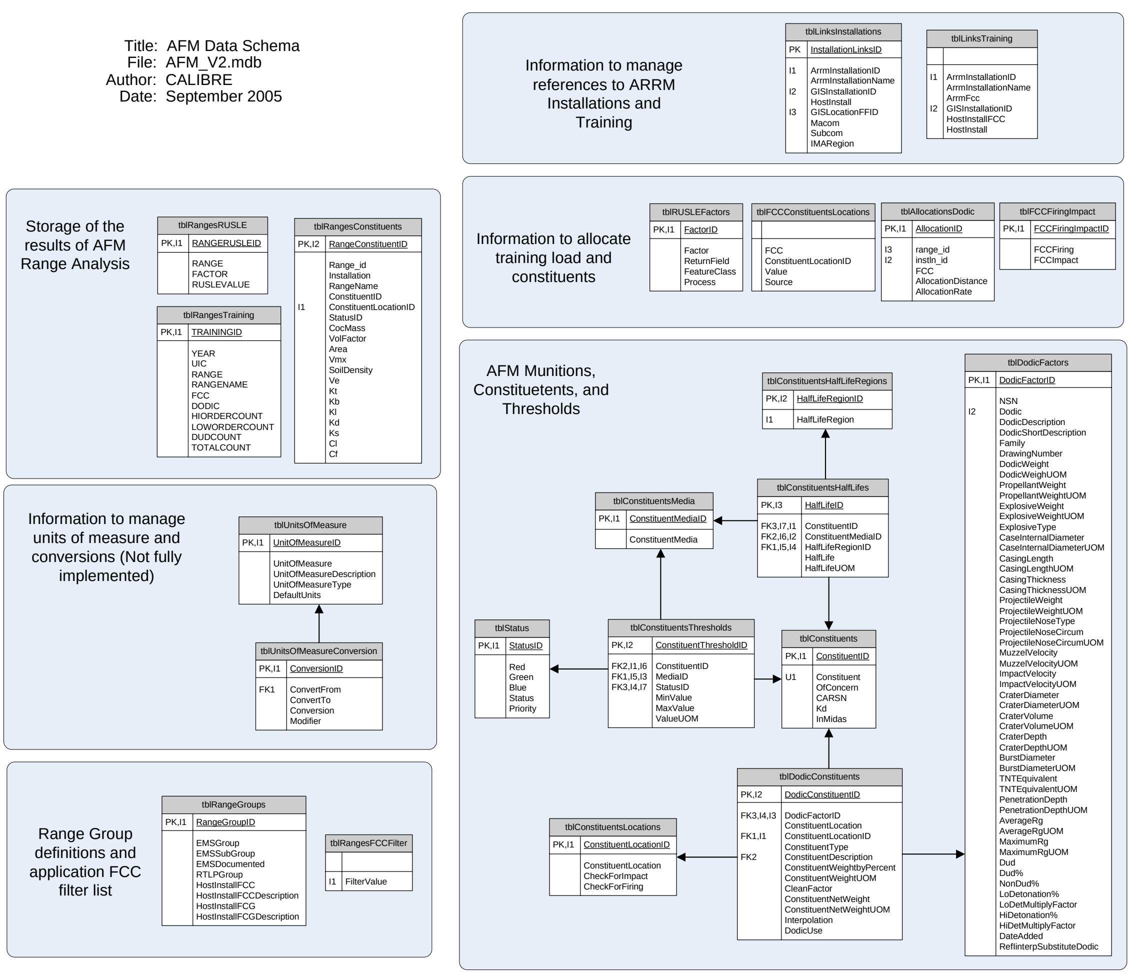

Figure E-1. AFM for ArcGIS system database logical structures.

AFM Geodatabase

This ESRI Personal Geodatabase contains spatial features required for calculations within the model. Within this database, feature classes exist for ecological regions, rainfall and rainfall recharge rates, and soil densities.

ARID Geodatabase

This ESRI Personal Geodatabase contains spatial features of installations, ranges, and usages. USAEC manages all range inventory data in a single geodatabase, the Army Range Inventory Database Geodatabase (ARID-Geo). In the initial inventory, tabular information was stored in the Army Range Inventory Database (ARID). Spatial information was stored in separate shape files. In preparation for the sustainment of the inventory, USAEC migrated the operational range data from ARID and the separately stored spatial data into a single geodatabase that complies with the Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE). The entity-relationship diagram has been included in the Documentation folder.

RUSLE Geodatabase

This ESRI Personal Geodatabase contains spatial features required for RUSLE calculations. Each RUSLE factor is stored as a stand-alone feature class. The information has been obtained from various sources including NRCS, ITAM, and other databases. This database encompasses the contiguous states. Figure E-2 shows the RUSLE geodatabase logic structure.

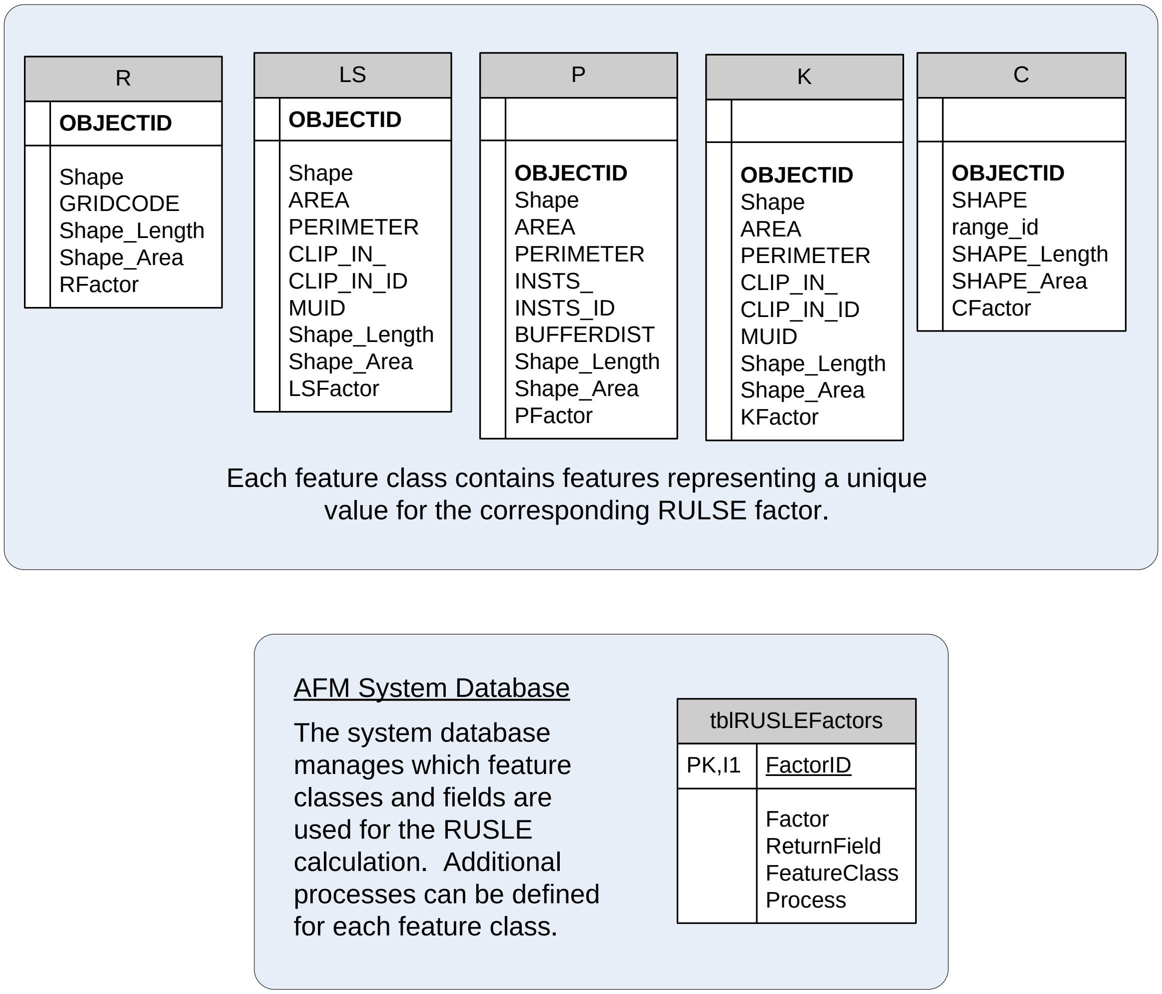

Figure E-2. RUSLE geodatabase logic structure.

ARRM Database

AFM derives the munitions by-type and quantity using an output from the DA Ammunition Requirements Tool (DAART). The DAART information is derived from the STRAC tables found in DA PAM 350-38 and is provided through the ARRM. The STRAC data within DAART provides for ammunition type by weapons system, iterations the weapon system is used, and total amount of munitions expended to perform annual training requirements of the unit. The STRAC tables are based on the main branches of the Army (Infantry, Armor, Combat Support, Finance, etc.). The entity-relationship diagram has been included in the Documentation folder.

Logical Process Flows

The following section describes the major processes within AFM in more detail. Each section constitutes a small subsection of the AFM For ArcGIS application.

Distribute Munitions

Figure E-3 illustrates the logic defined for distributing munitions during execution of the model. The ARRM data source is queried for munitions fired at the installation and EMS/FCC selected. Munitions are distributed among these same FCC ranges based on the range distance from the cantonment area. The quantity of High, Low, and Normal munitions detonations are calculated in a subprocess based upon the quantity of the DODIC fired. This diagram is available in .jpg and .vsd formats in the Documents\Flowcharts folder as Distribute Training Load.jpg/.vsd. Figure E-3 shows the distribute munitions process flow.

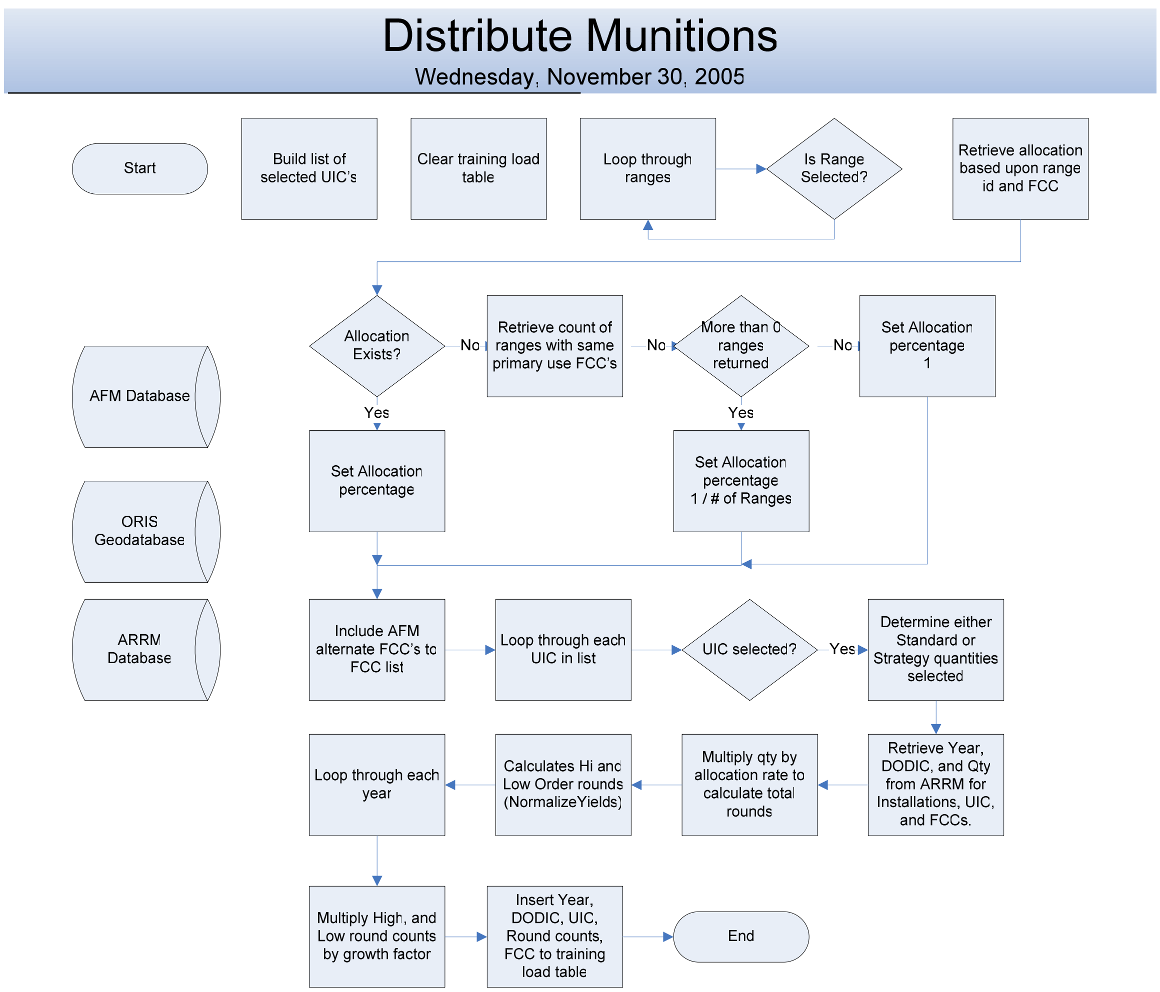

Figure E-3. Distribute munitions process flow.

Calculation of Round Counts

The quantity of High, Low, Normal, and dud munitions detonations are calculated in a subprocess based upon the quantity of the DODIC fired. Figure E-4 shows the calculate count of rounds process flow.

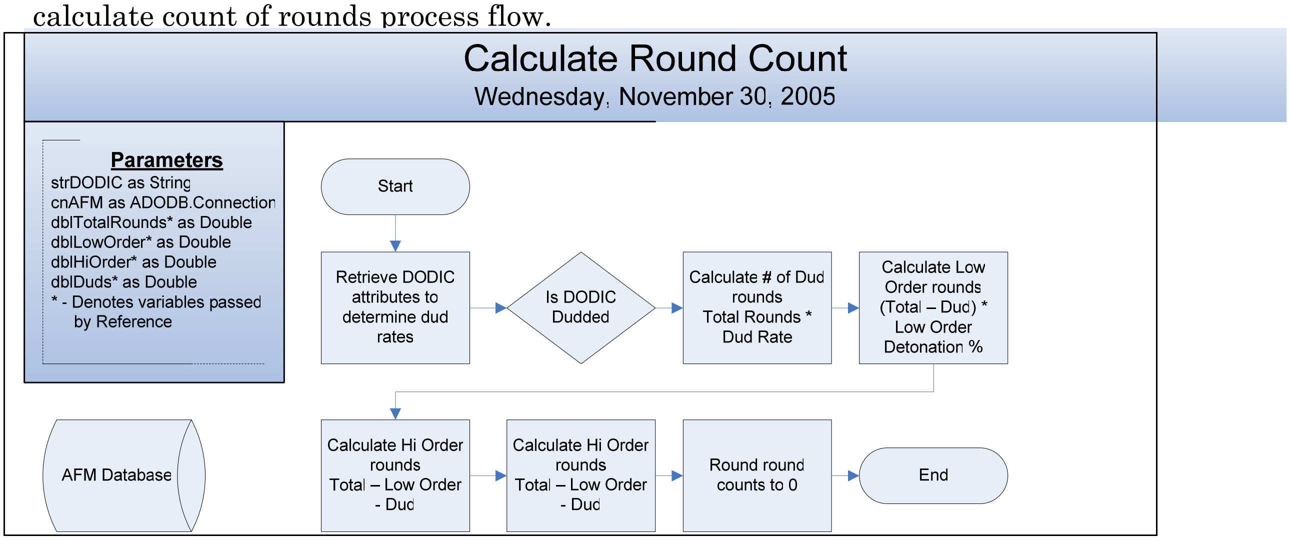

Figure E-4. Calculate count of rounds process flow.

Calculation Range Condition

The following diagram illustrates the logic defined for calculating Range Condition during execution of the model. This process is performed for each range and unit identification code (UIC) selected. The affected area over which the expended munitions are fired is calculated. The volume of soil in the mixing zone is calculated by multiplying the affected area by the soil density identified by the spatial relationship to the soil density feature class within the AFM Geodatabase. This process continues by calculating the Total Loss Rate Constant (Ks). Individual loss rate constants are summed to calculate the Ks. Loss Rate Constants are: Biodegradation Loss Rate Constant (Kb); Leaching Loss Rate Constant (Kl); and Transport Loss Rate Constant (Kt). The Ks is applied to the concentration of CoPC in the affected area to provide year-end concentration of constituents of potential concern (CoPCs). This diagram is available in *.jpg and *.vsd formats in the Documents\Flowcharts folder as CalculateStatus.jpg/.vsd. Figure E-5 shows the calculating range condition process flow.

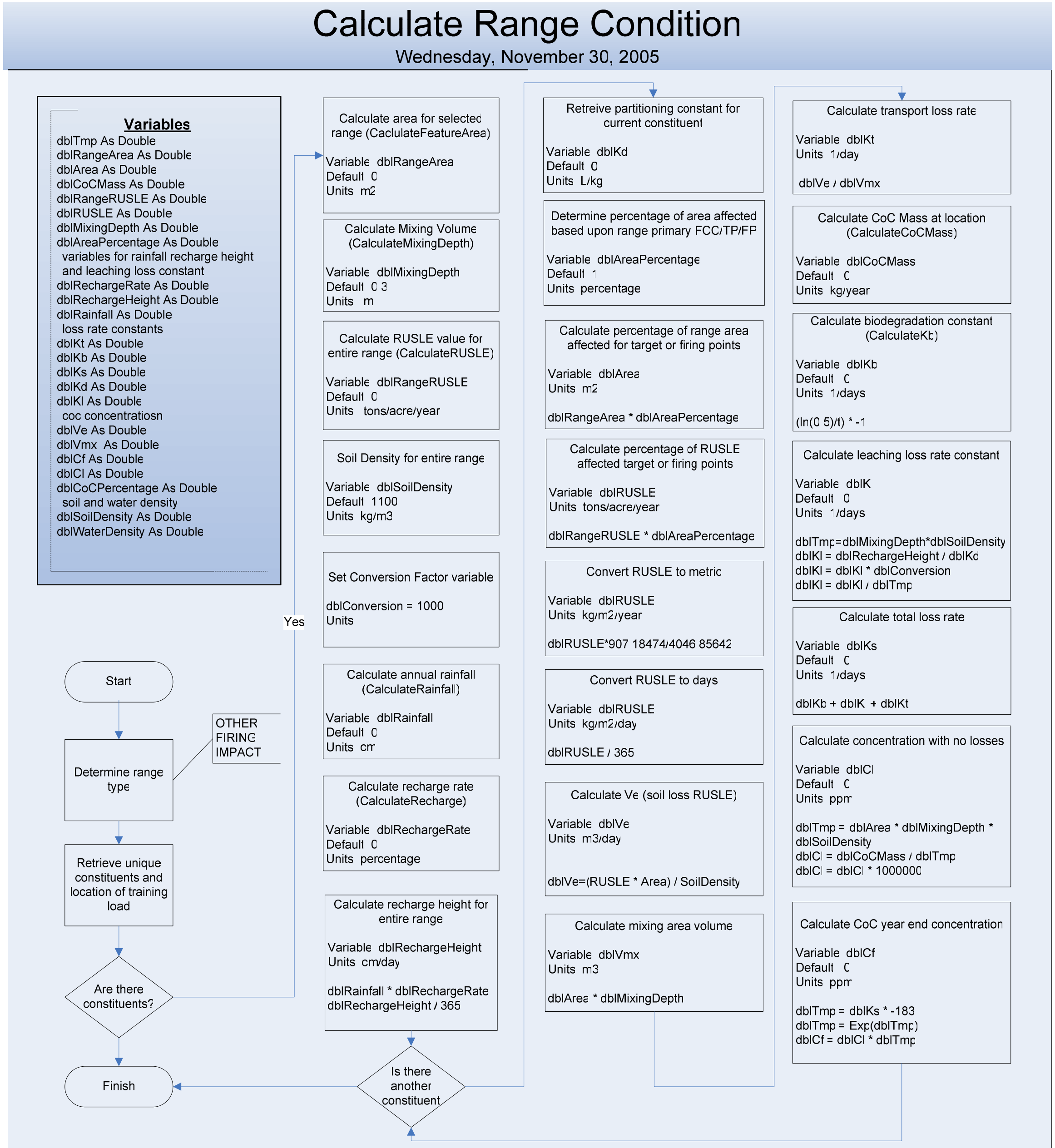

Figure E-5. Calculating range condition process flow.

Calculating CoPC Mass

The residual mass of CoPC is dependent on the type of resulting detonation. Much of the explosive compounds found in projectiles are expended when the round explodes. Factors are applied to account for the remaining constituents high order, low order, and dud-producing rounds. These factors are derived from government studies and data provided by the USAEC.

On direct-fire ranges, the shell cartridges are usually removed at the end of firing. Some are not removed because they are buried, hidden from view, or located downrange. The clean-up factor for this constituent would be 0.001 (1 in every 1,000 cartridges left on the range). Whereas the chemical propellant residues are not removed and receive a 0.999 (most of the chemicals remain in the soil). Figure E-6 shows the calculating CoPC mass process flow.

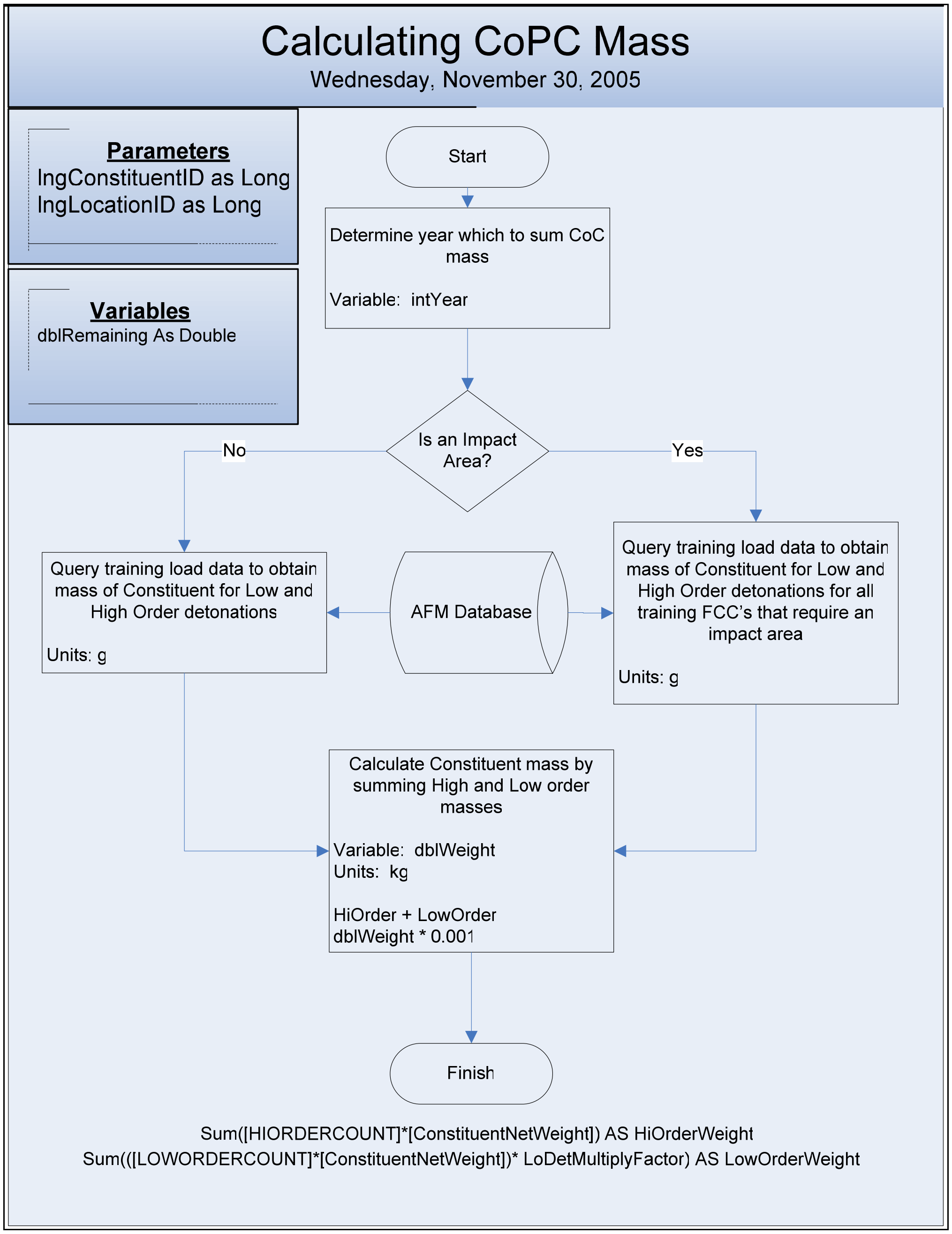

Figure E-6. Calculating CoPC mass process flow.

Calculation of Revised Universal Soil Loss Equation

RUSLE is the primary driver for the calculation of the Transport Loss Rate Constant. A separate geodatabase containing stand-alone RUSLE feature classes has been provided with the AFM Model. The feature classes provided have been derived from national databases. For increased accuracy of the results, more reliable RUSLE data may be substituted. The RUSLE formula provides the number of tons per acre per year eroded because of rill erosion. The RUSLE value is converted to metric units and represented as a 1/days value. Figure E-7 shows the calculating RUSLE for soil loss constant process flow.

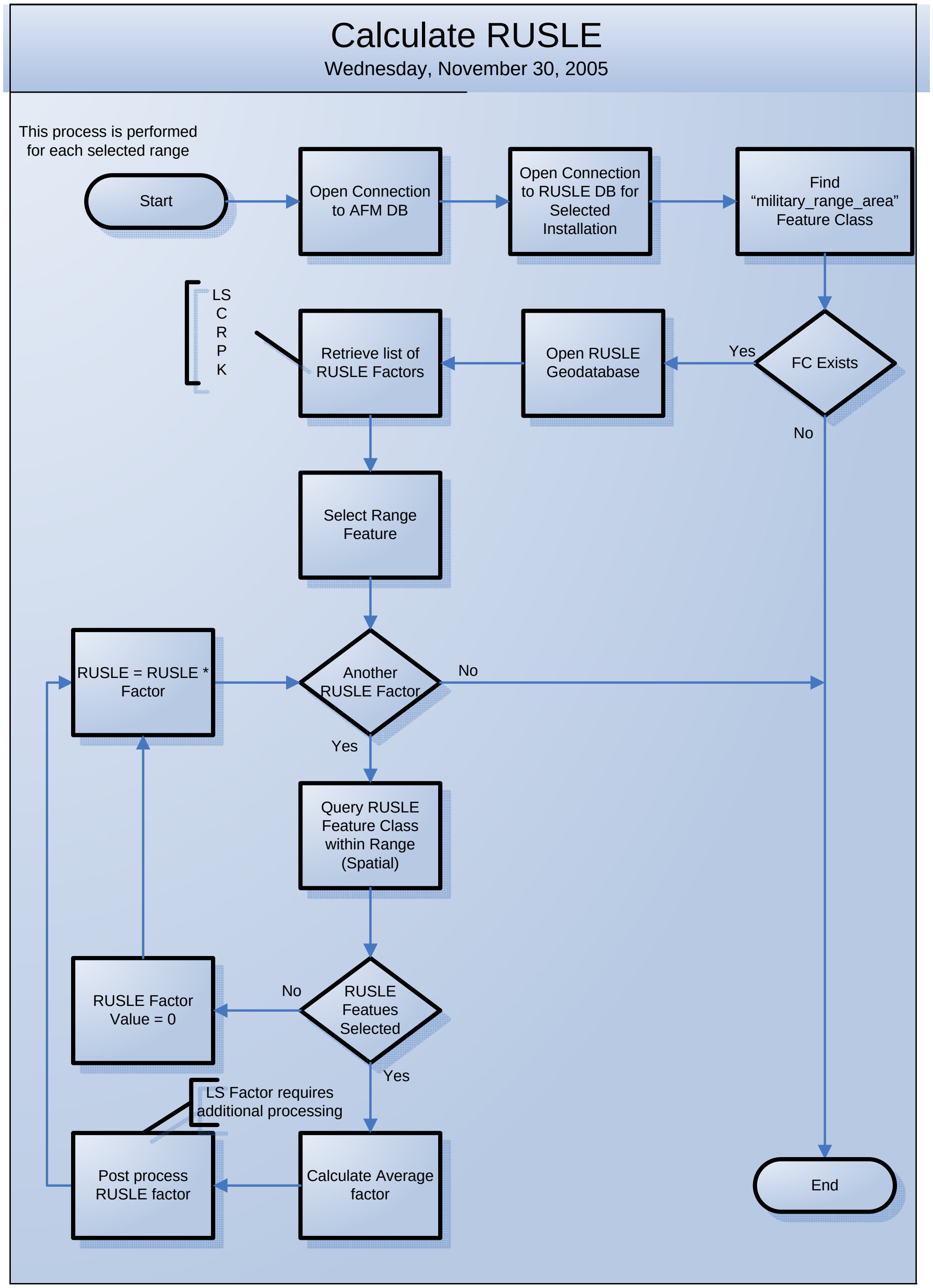

Figure E-7. Calculating RUSLE for soil loss constant process flow.

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14. ABSTRACT

The Army Training and Testing Area Carrying Capacity (ATTACC) program is a methodology used for estimating the impact of military use of maneuver lands on Army installations. The ATTACC for Munitions (AFM) program is an extension of the base ATTACC methodology. AFM is in development to estimate environmental carrying capacity based on munitions constituent load on Army live-fire ranges. The AFM methodology has been developed to predict munitions constituent accumulation and location for expended munitions from live-fire military training activities. The functional principles of the AFM methodology are to: (1) estimate live-fire range status by relating training munitions load, range condition, and range management practices, and (2) provide decision support to installation managers for optimizing range use.

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