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ATC REPORT NO. ATC-8811
USAEC REPORT NO. SFIM-AEC-AT-CR-2005007

SMALL ARMS RANGE TRAINING AREA ENVIRONMENTAL SCREENING-LEVEL ASSESSMENT AT FORT JACKSON, SOUTH CAROLINA

SITE LOCATION:
FORT JACKSON, SOUTH CAROLINA

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

March 2005

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Fort Jackson, South Carolina

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21 Apr 05

MEMORANDUM FOR Commander, U.S. Army Environmental Center, (SFIM-AEC-ATT/ Ms. Kimberly Watts), 5179 Hoadley Road, Bldg E4430, Aberdeen Proving Ground, MD 21010-5401

SUBJECT: Submittal of the Final Small Arms Range Training Area Environmental Screening Level Assessment at Fort Jackson, South Carolina Report for TRMS 9-CO-160-000-504

1. The U.S. Army Aberdeen Test Center (ATC) is submitting the enclosed subject final report to USAEC. Included with this final report submittal is the ATC response to AEC comments on the Draft Small Arms Range Training Area Environmental Screening Level Assessment at Fort Jackson, South Carolina Report (encl).

2. The POC for this action is Mr. Gene L. Fabian. Mr. Fabian can be reached at (410) 278-7421 or by email at gene.fabian@atc.army.mil.

FOR THE COMMANDER:

CHARLES D. VALZ
Director, Survivability/Lethality Directorate

Encl

ATC Response to USAEC Comments on Small Arms Range Training Area Environmental Screening-Level Assessment At Fort Jackson, South Carolina, May 2004

Comment Number	Comment Location	Comment	Response
1	General Comment	Confirm the name of the road that the range is located on. Is it Firetrain or Trainfire? There are several places in the document where both are used.	The correct name is Train Fire. Corrections have been made throughout the document.
2	Cover	The statement concerning other requests for the document should be referred to the Commander, USAEC, ATTN: SFIM-AEC-ATT.	Comment incorporated
3	Page 8. Table 3-2.	Why are we looking at FY2000 data? Should we be looking at the year we monitored data?	FY2000 is the year we began collecting data for the Phase I assessment effort. This is the data we used.
4	Page 9. Figure 3-1.	This figure is confusing. Identify all the lines, i.e. dark blue and black.	The original Figure 3-1 was deleted when a Fort Jackson comment on aquifer description was incorporated.
5	Page 9. Table 3-4.	Background concentrations should be mentioned somewhere in the table or in the write-up.	We don't know what the background levels are for shallow groundwater. No shallow groundwater wells were available on post for sampling. The data presented in this table was collected from wells located on Range 2 in support of the berm modification BMP demonstration. The purpose of the wells was not to characterize the shallow groundwater. Their purpose was to monitor these wells to note any influence in water level or lead level resulting from the range modifications implemented on Range 2. Comment not incorporated.

Comment Number	Comment Location	Comment	Response
6	Page 13. 2nd para.	Because 50ppb is used for the Twin Lakes well, does that mean that the well is subject to a treatment process.	I am not familiar with the treatment or use of the water extracted from this well. Basically, the information we were provided was that lead concentrations in this well were non-detect and the reportable detection limit required by the SC state was 50 ppb. The well was incompliance with state requirements for whatever designated use that was being reported to the state by Fort Jackson.
7	Page 15. Top of the page. Last sentence.	"This is generally intended for a point source discharge but may be able to be adapted to Fort Jackson". This appears to be a legal interpretation; therefore, an assumption should not be made.	The sentence was changed as follows: "This is generally intended for a point source discharge. Its application to the range area is subject to legal and regulatory interpretation of the classification of the types of discharges (point source or non-point source) occurring in range areas. As a result, if mixing zones are being considered as part of a lead management BMP, as a minimum the installation environmental and judge advocate offices should be consulted to assess its applicability (ref 10)."
8	Page 15 Table 3-6.	Correct entries in the table.	The entries are correct.

Comment Number	Comment Location	Comment	Response
9	Page 18 1st full para. Last sentence.	Once again this appears to be an assumption. Reword to say that, "Corrosion is known to occur in environments with…"	The sentence was changed as follows: "An overall estimate of stability as a result of corrosion passivation could not be inferred based on visual observations of the debris. However, corrosion is known to occur in environments with the pH, precipitation, and overall lack of soil nutrient conditions as found at Fort Jackson. These conditions may result in the formation of mobile lead ions."
10	Figures 3-14 and 3-15, page 22.	The depiction of Range 8 on the Range 9 figure does not quite agree with the way it looks on the Range 8 figure. In Figure 3-14, the Range 8 berm extends to the end of the firing lanes, but not to the drainage pipe. In Figure 3-15, it appears to extend past the drainage pipe.	Figure 3-15 has been corrected.
11	Section 3.4, page 27.	In the first paragraph, eleventh line, it should be "These scores are then combined into an overall numeric ranking".	Comment incorporated
12	Section 3.5.1, page 29.	In the third paragraph, first line, there is the phrase "lead particles of lead contaminated soil". There needs to be a better way to express this. Possibly it could be "transport of particles of lead contaminated soil". This phrase also appears in the discussions of the other sub-watersheds.	Comment incorporated

Comment Number	Comment Location	Comment	Response
13	Page 40. Section 4.1 and 4.2.	Should we add another section for storm water(4.3). The results for these three; surface water, groundwater, and storm water are separate.	Stormwater sampling is adequately discussed in section 4.1 with the surface water discussion. Changed the heading to section 4.1 to "Surface Water and Stormwater Sampling".
14	Section 4.3.2, page 41.	The first paragraph should start "Surface water samples were analyzed". Not "samplers".	Typo corrected.
15	Page 43. Section 5.3 1st para.	"Three groundwater samples were taken." Number needs to be verified. With the description provided, I count 5 samples????	Only three samples were collected. The paragraph has been revised for clarity. Comment incorporated.
16	Pages 45 and 46 Table 5-1.	In the column, "Total Lead" multiple data values represent duplicate analysis of samples; however, in the column "Dissolved Lead" only one data value may be entered. Why if 4 values are listed in the "total Lead" column are there not 4 values in the "dissolved lead" column and which sample does the value located in the "dissolved lead" column represent?	These are not duplicate samples. They are duplicate analyses of the same sample. The filtered sample was only analyzed once. The unfiltered sample was analyzed 4 times. They all represent the same grab sample.
17	Section 5.5, page 44.	In the discussion on the lack of agreement between the Hach data and the ICP-MS data for the dissolved phase lead results, the argument presented on the preceding page concerning the different pore sizes of the filters needs to be repeated here.	Comment incorporated.

Comment Number	Comment Location	Comment	Response
18	Page 48. Section 6.1. 2nd para.	Where is Table 11? Also the reference to background lead levels should be included sooner in the document. Suggest putting it in the introduction.	Table 11 was renumbered as Table 5-1. This has been corrected. Information on background levels have been included in section 3.2.3 "Local Surface Water Resources". Comment incorporated.
19	Page 51.	A reference is made to Table 11. Where is this table?	Table 11 was renumbered as Table 5-1. This has been corrected.
20	Page 51. 1st full para. 1st sentence.	How can we assume the ranges at Ft. Jackson are at Steady State?	The sentence assuming steady state conditions has been deleted. There is not enough data available to support that assumption. Comment incorporated.
21	Appendix C, page C-1.	USAEC does not need 40 copies of the document. Provide 10 hard copies and a CD. Also, no need to send this to the DTIC.	Comment incorporated.
22	Page 17, Figure3-5	Change "Firetrain Road" to "Train Fire Road" on this figure	Comment incorporated
23	Page 47, Section 6	The current title of this section is "Conclusion for Fort Jackson Small Arms". It should probably be "Conclusions for Fort Jackson Small Arms Ranges"	Comment incorporated
24	Page 55, Figures 7-3 and 7-4.	Both figures for Range 9 require the same corrections done for Figure 3-14 on page 22.	Comment incorporated

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None.

14. ABSTRACT
This report documents the results of a screening-level assessment of soil erosion and lead mobility from active small arms ranges at Fort Jackson, South Carolina. This assessment was performed to support the development of a general assessment methodology for assessing environmental concerns at active Army small arms training ranges. This report is intended to serve as an example of how the assessment procedures can be applied, the information required to be collected, analyzed, and interpreted, and how decisions on possible range modifications are made. It is part of the Army's overall proactive effort to increase range sustainability and environmental management while maintaining the essential troop training mission of small arms ranges.

15. SUBJECT TERMS
Small arms, small arms range, erosion, lead, lead mobility, assessment, screening-level assessment, best management practices, maintenance

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
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EXECUTIVE SUMMARY

This report documents the results of a screening-level assessment of soil erosion and lead mobility from active small arms ranges at Fort Jackson, South Carolina. This assessment was performed to support the development of a general assessment methodology for assessing environmental concerns at active Army small arms training ranges. This report is intended to serve as an example of how the assessment procedures can be applied, the information required to be collected, analyzed, and interpreted, and how decisions on possible range modifications are made. It is part of the Army's overall proactive effort to increase range sustainability and environmental management while maintaining the essential troop training mission of small arms ranges. This project was conducted for the U.S. Army Environmental Center under the Advanced Range Design Program, DTC Project No. 9-CO-160-000-504.

The bulk of the data used to support this assessment was collected between June 2000 and February 2002. Additional groundwater data collected between March 2002 and November 2003 on Range 2 in support of a best management practice implementation demonstration was also included to support the assessment of range activities on shallow groundwater.

The screening-level assessment methodology utilized a watershed-based approach to assess the cumulative impacts of multiple ranges within an environmentally defined area. This approach allows the identification of areas where management practices will provide the maximum benefits to address potential erosion or lead mobility issues. Fourteen active small arms ranges that impacted three subwatersheds at Fort Jackson were included in the assessment. The assessment was conducted in two phases. The first phase consisted of existing data and range use information to support the development of conceptual site models of the erosion and lead mobility characteristics within each subwatershed. The second phase consisted of targeted surface water, stormwater, and groundwater sampling to confirm the lead mobility characteristics identified in the conceptual site models.

In the three subwatersheds (Mack Creek, Rowell Creek, and Bynum Creek subwatersheds) in the small arms range impact area, the primary lead transport mechanism appeared to be that associated with stormwater runoff from the range areas. Lead transport was predominantly in the suspended solids in the runoff water. These suspended solids naturally settle within a relatively short distance of entering the creeks that flow out of the range impact areas. Range use effects on surface water resources are not detectable at the overall training area boundary or installation boundary.

From an overall range impact area perspective, current management practices appear to adequately control erosion and lead mobility in surface water at Fort Jackson. However, some additional management methods have been identified that may provide additional benefits to surface water quality immediately adjacent to the range area and to the overall maintenance and sustainability of the small arms ranges. These management methods primarily consist of berm grading and vegetation management recommendations that expand on previously successful efforts conducted by Fort Jackson to control soil erosion and stormwater runoff suspended solids concentrations from the range areas. They can easily be incorporated into existing maintenance practices and may result in long term range maintenance cost savings.

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1. Introduction

The U.S. Army Aberdeen Test Center's (ATC) Military Environmental Technology Demonstration Center (METDC) is developing and field demonstrating a screening-level environmental assessment methodology for assessing the environmental concerns from Army small arms ranges. This project is being conducted for the U.S. Army Environmental Center (USAEC) under the Advanced Range Design Program, DTC Project No. 9-CO-160-000-504. It is part of the Army's overall proactive effort to increase range sustainability and environmental management while maintaining the essential troop training mission of small arms ranges. The small arms training ranges at Fort Jackson, South Carolina were selected based on previous lead transport data collected by the South Carolina Department of Health and Environmental Control (DHEC) as the site to develop and demonstrate the range assessment methods.

The range area assessment procedures are ultimately to be included as part of a Small Arms Range Best Management Practices (BMP) Manual under development by the USAEC. The range BMP manual is intended to serve as a complete guide for installations or range managers to:

- Screen small arms range areas for potential environmental concerns
- Determine if concerns exist and if they can be addressed through management actions or modest range modifications
- Provide guidance on the type of management response actions or range modifications that can be made to reduce or eliminate environmental concerns
- Provide guidance on potential funding sources for various types of range work
- Determine if more in depth environmental investigation beyond the scope of the manual is needed

The development of the assessment methods and final report on the assessment of the small arms range training complex at Ft Jackson is intended to serve as an example of assessment procedures and how they can be applied, what information is collected, reviewed, analyzed, and interpreted, and how decisions on possible range modifications or response actions are made.

A watershed-based assessment and range management approach was developed and applied to the small arms range training area at Fort Jackson. A watershed is the line of separation between 2 contiguous drainage valleys and represents a defined area and true boundary. In general, surface waters, stormwater runoff, and shallow groundwater movement are grouped or confined to a well defined watershed or subwatershed. Within the watershed, most influences or potential pollution sources can be identified, their contributions to any pollution estimated, and they can then be managed. In contrast, individual firing range boundaries are lines on a map that have no meaning from the functional environmental perspective. In addition, the watershed management perspective appears to be in agreement with current and future regulatory guidance for non-point source watershed assessment and management.

The primary issues of concern at small arms ranges are lead residues and soil erosion, and the active mechanisms such as surface water runoff or groundwater flow that may currently be transporting these "pollutants" to off range areas or to potential receptors. Assessing a range or range complex on the watershed scale will focus and prioritize the limited resources available. Locations can be identified to maximize benefits by performing any modifications or management efforts in strategic locations where they can address the greatest number of problems.

1.1 Site Background

Fort Jackson is located in central South Carolina, occupying approximately 52,000 acres adjacent to, and east of, Columbia, South Carolina. This area is located in the upper Atlantic Coastal Plane geologic province of South Carolina. This area is characterized by low elevation, rolling, sandy hills. The installation is predominantly covered with pine forests except in the low lying areas and floodplains surrounding streams where more deciduous trees and marsh vegetation occur.

Fort Jackson is the U.S. Army's premier basic training facility where approximately 40,000 soldiers complete basic training annually. Approximately 2,700 buildings are present at Fort Jackson, the majority of which occupy a 3-mile by 3-mile area in the southeastern quadrant of the Fort, an area known as the cantonment area. The remaining areas of the Fort are mainly training areas and ranges (ref 14).

Fort Jackson was established in 1917 as an infantry training center, originally built on 1,200 acres donated by the City of Columbia. After World War I, Fort Jackson was demobilized as a full-time training site, and the post was state-controlled as a training area for troops of the South Carolina National Guard. The installation was returned to Federal control in 1940 for U.S. Army infantry training for World War II (WWII). During WWII, the fort was expanded to approximately its present size. Following WWII, the Fort was used to station various U.S. Army Divisions. The Fort has been an active U.S. Army Basic Training Center since 1973 (ref 14).

1.2 Small Arms Firing Range Area

A training complex that consists of 14 active small arms firing ranges was assessed for this project. Ranges 1 through 13 are located consecutively along Train Fire Road. Range 20, located approximately 1 mile from this range complex, was determined to be within the same subwatershed boundary as Ranges 1 through 4, and as such was included in the range complex assessment (fig. 1-1).

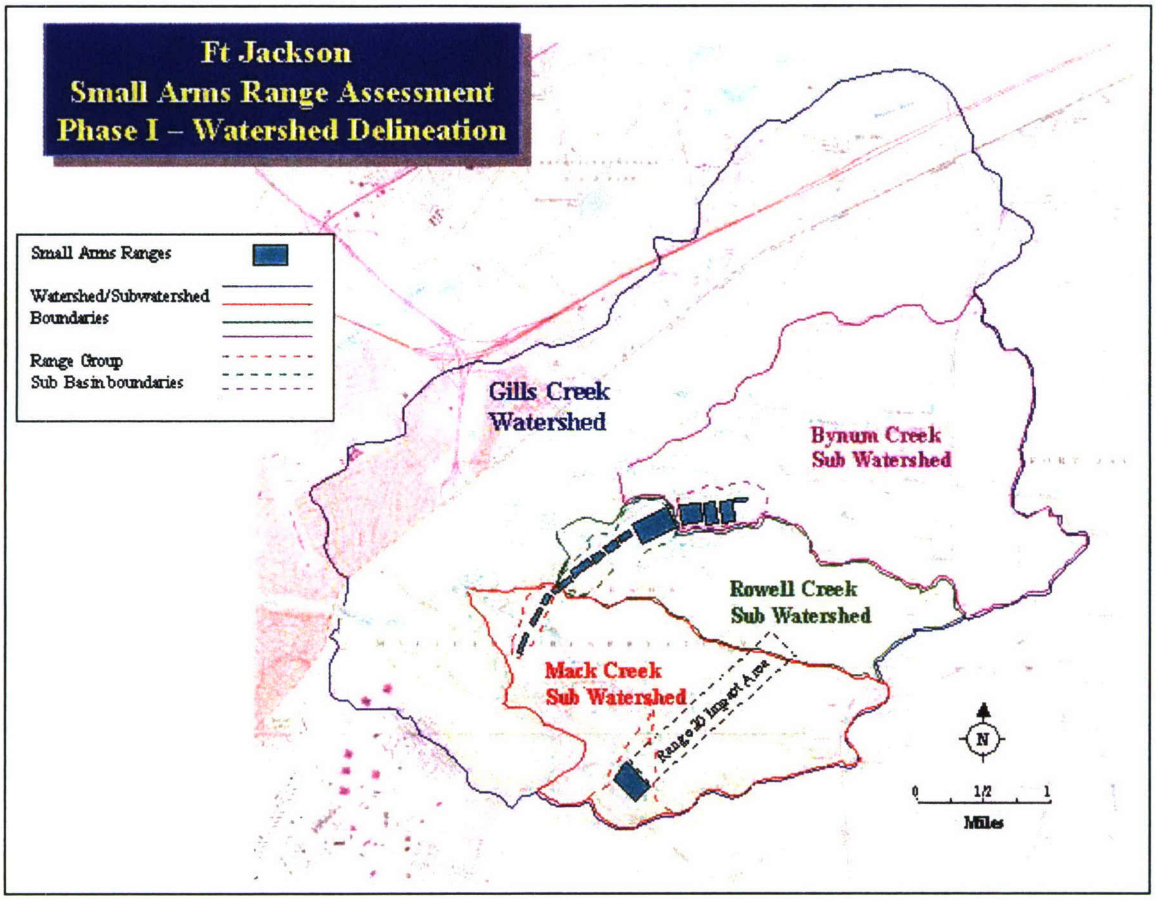


Figure 1-1. Small Arms Ranges and Delineated Watersheds Map
(modified from ref 12 and 13).

2. Range Area Environmental Screening Level Assessment - Phased Approach

A screening-level environmental assessment of the small arms range training area was performed using a phased approach. The phases of the assessment and a partial listing of the types of information and data generated for each phase are shown below.

Phase I - Preliminary Site Assessment

- Watershed delineation for range areas/complex.
- Site background and range information collection.
- Site inspections.
- Range Evaluation Software Tool (REST) analysis of ranges.
- Conceptual Site Model Development.

Phase II - Field Sampling

- Field sampling based on conceptual site model or for confirmatory purposes.
- Analysis (total lead and dissolved lead) of field sampling results.
- Identify and prioritize environmental concerns.

Phase III - Response Implementation

- Determine and implement appropriate response/mitigation efforts.
- Evaluate/monitor performance of mitigation efforts.

The objective of the assessment was to identify any potential environmental concerns at the range area with respect to lead residues, soil erosion, and the active mechanisms such as surface water runoff or groundwater flow that may currently be transporting these "pollutants" off range areas, or potentially impacting receptors. Information such as watershed and subwatershed delineation in the range areas, site inspections, reviewing existing environmental reports and data, and reviews of Federal, State and local regulatory requirements and current classifications and definitions were collected or developed. The assessment combined all relatively available information to form an understanding of the local environmental conditions (local groundwater, surface water, soils, etc.), to determine what regulatory requirements may apply based on local and site specific conditions, and to identify how the range area functions within and potentially impacts the local environment. Limited field sampling was then performed and the results were combined with the analysis of the site background information to produce the overall assessment of the range area. This assessment was performed to support range maintenance and management decisions that would minimize lead migration and the potential environmental impact resulting from training range use. This assessment was not conducted to support cleanup decisions or activities and should not be used in that manner in the future.

For this report, only phases I and II of the screening-level assessment were completed. Information from these phases was used to make recommendations (a portion of the first part of Phase III) for areas that appear to need pollution prevention response or mitigation efforts. This report on Fort Jackson's small arms range area ends with a listing of the recommendations of response actions.

3. Phase I - Preliminary Site Assessment

Phase I of the screening level site assessment consisted of a preliminary assessment that delineated the local watersheds and subwatersheds the ranges are within and potentially impacting, and collected as much readily available site background and local environmental information as possible. This information was compiled to produce the conceptual site model that concluded phase I. The site model simply and clearly states the environmental conditions at the range area as they are understood. The general components of phase I are listed below.

Phase I - Preliminary Site Assessment

- Watershed delineation for range areas/complex.
- Site background and range information collection.
- Site inspections.
- REST analysis of ranges.
- Conceptual Site Model Development.

3.1 Watershed Delineation

A watershed-based approach was used for the range area assessment. The watersheds and subwatersheds that Ranges 1 through 13 and 20 are found within were delineated using 1:24,000 scale, USGS Quadrangle 7.5 minute series, topographic maps for the Fort Jackson area (ref 12 and 13). The range locations were overlain on the USGS maps and the watersheds were manually delineated by analysis of the elevation contours. The Gills creek watershed up to Fort Jackson's property boundary, and the Mack, Rowell, and Bynum Creek subwatersheds that flow into Gills creek were delineated. Ranges 1 through 13, and 20 are all located within one of these three subwatersheds. Figure 1-1 shows the small arms ranges and delineated watersheds.

The size of each watershed and subwatershed was calculated using a dot matrix area calculator. This calculator is a scaled series of dots and squares where each dot or square represents an amount of land area based on the scale of the map with which it is being used. By laying the grid over the watershed map and counting the number of dots or squares contained within the watershed boundary, the number of dots and their associated land area were added up to produce the total land area within each watershed. The calculated land area of each watershed is listed in Table 3-1.

TABLE 3-1. WATERSHED LAND AREA INFORMATION

Watershed	Land Area, (square miles)	Percent of Total Watershed Area
Gills Creek	19.0	100.0
Mack Creek	3.1	16.3
Rowell Creek	2.1	11.1
Bynum Creek	4.5	23.7
Other areas	9.3	48.9

3.2 Site Background Information

A site background information collection effort was performed for the range area to obtain information that included:

- Range use information.
- Local groundwater resources.
- Local surface water resources.
- Range soils.
- Range and Training Land Delineation.

3.2.1 Range Use Information

Small arms ranges 1-13 and 20 are used primarily for soldier basic training using the M16A2 rifle and M855 5.56-mm ball round. Minor amounts of training are performed on Range 6 with 9-mm pistol and shotgun. The ranges, the type of training on the range, and the amount of rounds fired on each range for the fiscal year 2000 are listed in Table 3-2. Comprehensive firing data was not available for range use prior to the year 2000.

Many ranges have a single impact berm to catch fired rounds. These are either constructed berms created by pushing up local soils or hauling in soil from a borrow pit on the installation to form the berm, or using natural hillsides as impact berms. In most cases the rounds impact in fairly concentrated areas behind the targets due to the fixed location of the targets. Bullet debris dispersion is typically concentrated at the impact point on the berm with some physical dispersion of bullet debris and soil in front of and behind the berm as a result of the impact on the berm face. Some rounds overshoot the berm and fall within the impact area. These rounds are dispersed along the flight path behind the targets. The extent of this dispersion is dependent upon the topography of the range. Range 20 does not have a man-made or natural berm behind it. On range 20, individual berms are placed in front of the targets to protect the target mechanisms. The rounds fly freely into a large, densely forested impact area. On range 20, the rounds are widely dispersed on the range and into the impact area due to the varying topography of the range.

TABLE 3-2. FIRING RANGE TYPE AND FY 2000 FIRING DATA (REF 24)

Range	Description	Current Type of Rounds Fired	FY2000 Number of Rounds Fired
1	Zero range	M16 - 5.56-mm	410,000
2	Zero range	M16 - 5.56-mm	440,000
3	Zero range	M16 - 5.56-mm	5,000
4	Zero range	M16 - 5.56-mm	430,000
5	Zero range	M16 - 5.56-mm	494,000
6	Pistol, shotgun	N/A[1]	N/A[1]
7	NBC, night fire	M16 - 5.56-mm	242,000
8	NBC, night fire	M16 - 5.56-mm	331,000
9	M16 Prequalification	M16 - 5.56-mm	3,185,100
10	Qualification	M16 - 5.56-mm	319,000
11	KD range	M16 - 5.56-mm	N/A[1]
12	Misses and hits	M16 - 5.56-mm	1,657,300
13	National Guard zero range	N/A[1]	N/A[1]
20	Qualification	M16 - 5.56-mm	1,798,700
Total rounds fired			**9,312,100**

1. Data not available.

3.2.2 Local Groundwater Resources

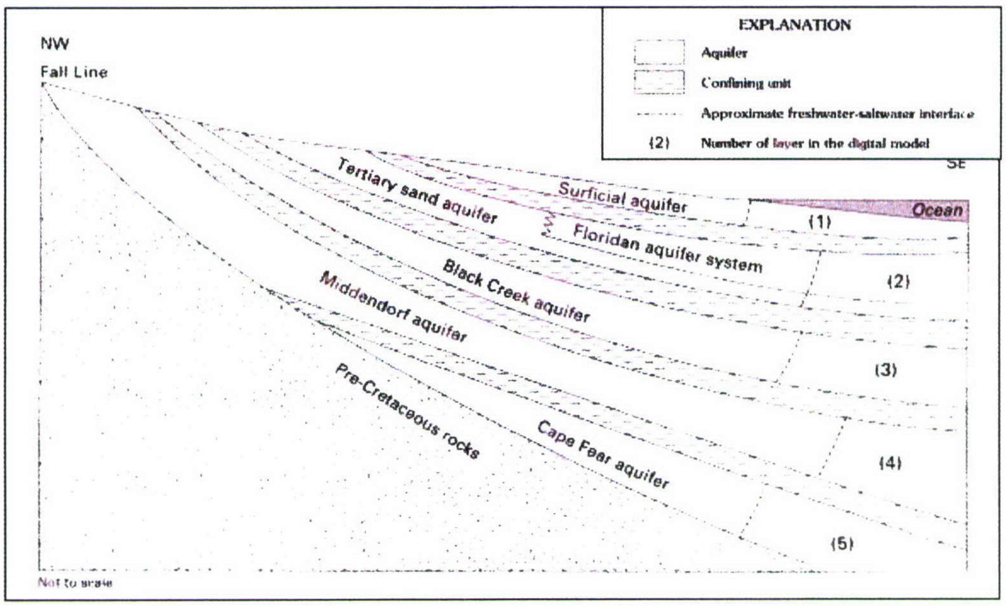
Assessment of the groundwater in the small arms range area was limited to a study and analysis of existing data and reports to collect and analyze information that included:

- Delineation of local groundwater/ aquifers.
- Hydrogeological assessment of identified aquifers.
- Inferring the behavior or movement of the various components of the groundwater flow regime based on existing information or application of generalized principles.
- Classification and regulatory requirements impacting local groundwater.
- Data from groundwater sampling in the range area.
- Local use of groundwater.

Groundwater is generally plentiful at Fort Jackson. The Tuscaloosa Formation, of Upper Cretaceous age, underlies Fort Jackson and is the primary source of groundwater in the area. Small quantities of groundwater may be available in alluvial deposits along major streams.

The Tuscaloosa Formation is at the surface over most of Fort Jackson. This formation lies unconformably on a peneplained surface of older, crystalline rocks. The formation consists of interbedded, generally unconsolidated, fine to coarse sand and clay, causing groundwater to occur under both unconfined and confined (i.e. artesian) conditions. Groundwater occurs under water table conditions in the upper part of the zone of saturation. At a depth of about 99 – 251 feet, permeable sand zones are frequently overlain by less permeable clay zones, and the groundwater exists under artesian conditions (ref 14 and 24).

The regional aquifer functions as an unconfined, surficial aquifer in the region before dipping below other aquifers and confining units trending east toward the coast/ocean. A generalized cutaway profile of the aquifer system in the South Carolina Coastal Plain (Figure 3-1) shows the Middendorf aquifer outcropping at the fall line (ref 2). The USGS has produced groundwater equipotential contours for the Middendorf aquifer. Based on these equipotential lines, groundwater flow paths were inferred. The flow lines for the deep, regional scale movement of groundwater in the Middendorf aquifer are shown in Figure 3-2. These flow lines show that deep, regional groundwater movement arcs in a south to southeasterly direction across Fort Jackson towards two major discharge points, the Congaree River to the south and southwest, and the Wateree River to the east (ref 2 and 9).



Diagrammatic geohydrologic section across the South Carolina Coastal Plain.

Figure 3-1. Profile of Geohydrologic System in South Carolina (ref 2).

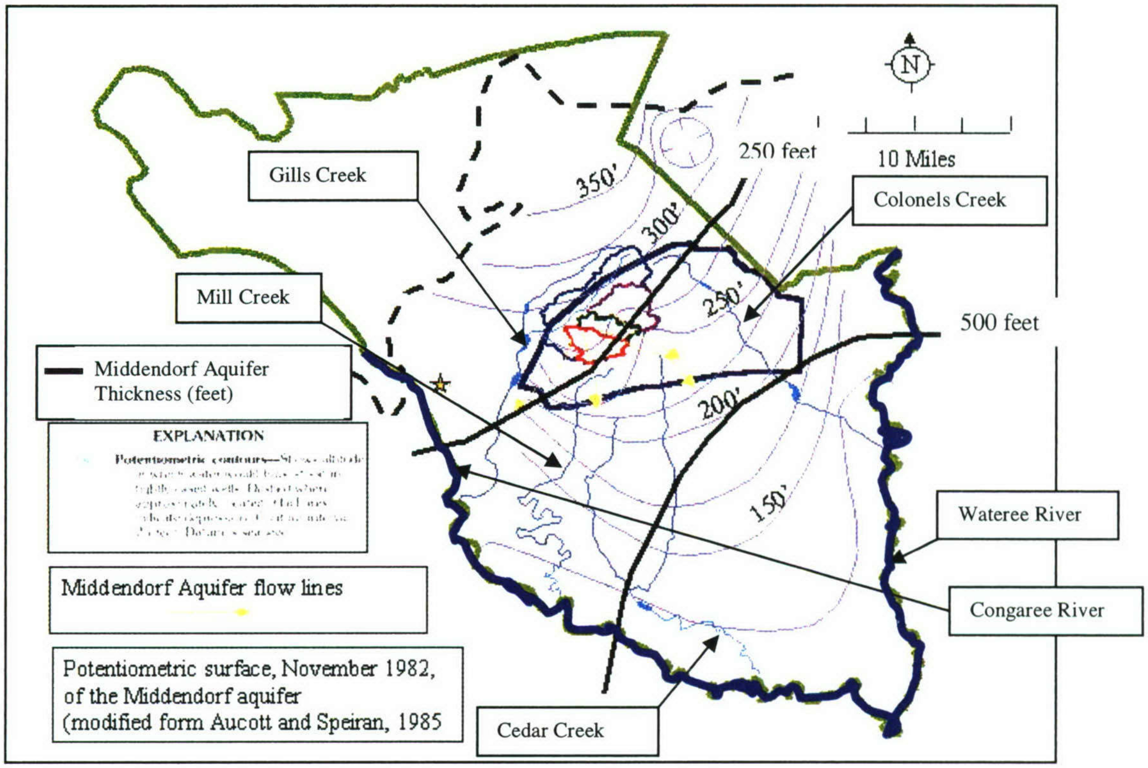
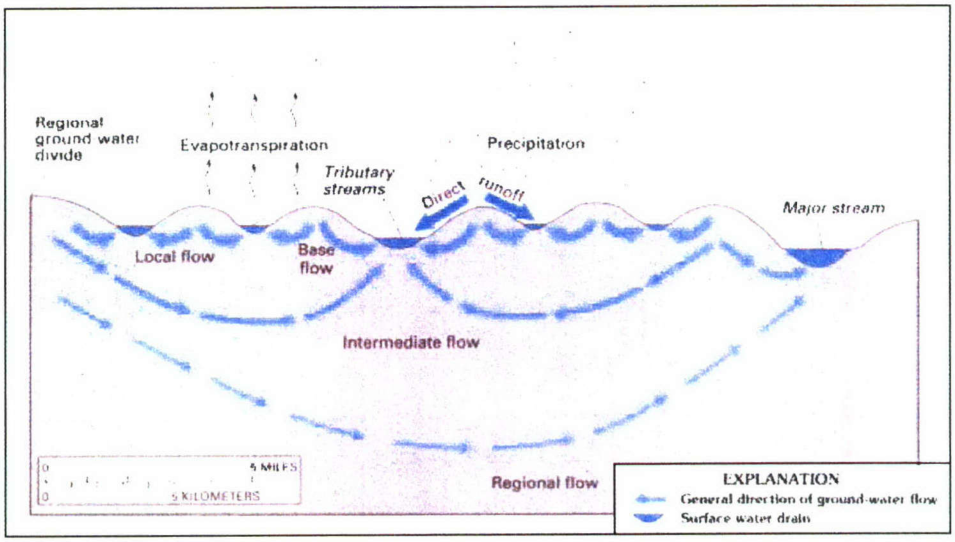


Figure 3-2. Regional Groundwater Flow Directions within the Middendorf Aquifer (ref 2 and 23).

Using a generalized understanding of groundwater movement, the various components of the groundwater flow regime at Fort Jackson were inferred. Shallow groundwater is assumed to discharge as base flow into the network of small creeks (Mack, Rowell, Bynum) that run through the range area. The idealized behavior of the components of local, shallow groundwater is shown in Figure 3-3 (ref 3).

In March 2002, three shallow groundwater monitoring wells were installed by ARM Environmental Services, Inc (under contract to ATC) in the surficial part of the aquifer on or near small arms Range 2 on Train Fire Road as part of a range technology demonstration project related to the range area assessment effort. All wells are between ten and fifteen feet in depth below grade with ten foot well screen sections installed at the bottom of the well. Two, four-inch diameter wells were installed using hollow stem auger. One, two-inch diameter well was installed using a geoprobe direct push method. Well locations at Range 2 are shown in Figure 3-4. Well installation information is summarized in Table 3-3.



Relation among local, intermediate, and regional patterns of groundwater flow and surface water drainage (modified from Toth, 1963).

Figure 3-3. Generalized Depiction of Groundwater Components and Behavior (ref 3).

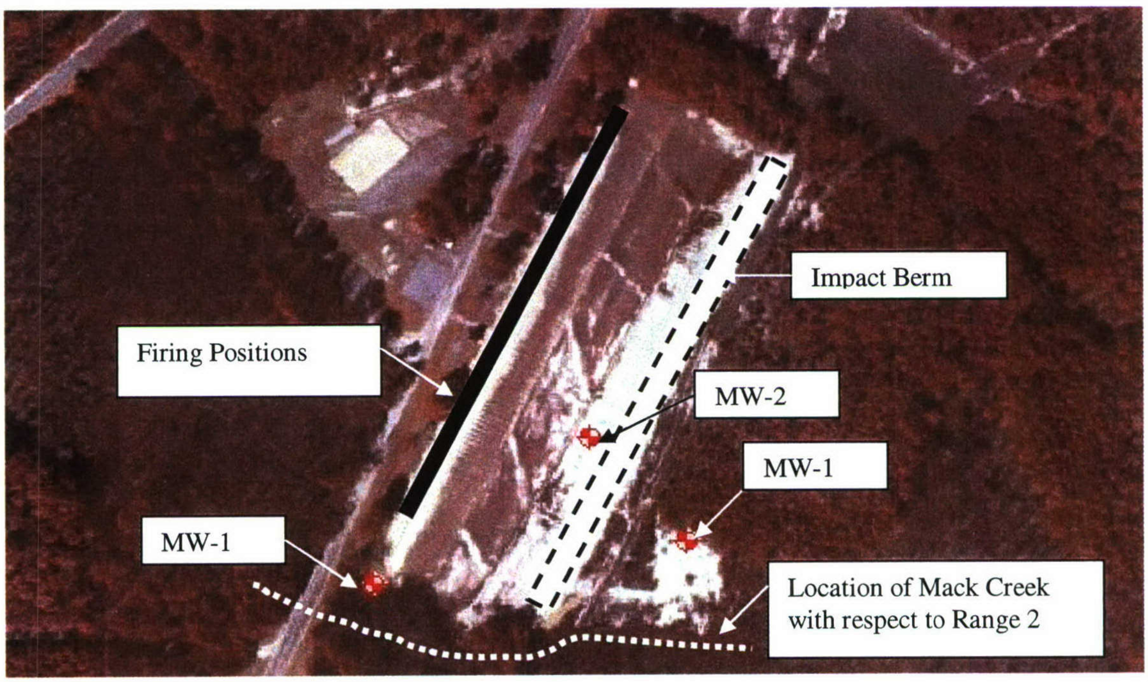


Figure 3-4. Shallow Groundwater Monitoring Well Locations at Range 2.

TABLE 3-3. RANGE 2 WELL INSTALLATION SUMMARY

Well Number	Diameter (inch)	Total Depth (feet below grade)	Screen Depth (feet below grade)	Screen Interval (feet)
MW-1	2	13.4	3.4 – 13.4	10
MW-2	4	14.9	4.9 – 14.9	10
MW-3	4	13.9	3.9 – 13.9	10

Soil core sections retrieved during the well installations showed a substantial clay confining unit exists immediately below the ground surface and extends to roughly ten feet below ground surface at wells locations MW-2 and MW-3. Core sections for MW-1 showed a soil profile that is much more sand in nature. The core section data suggests that at the location of MW-1 there is direct communication between the ground surface and groundwater, but at MW-2 and MW-3 there is a localized confining condition that prevents direct communication between the ground surface and groundwater. As of January 2004, these wells have been sampled for lead contaminants on six occasions. In addition, monthly water levels have been recorded for these wells. The results of these samplings and water level measurements are shown in Tables 3-4 and 3-5.

TABLE 3-4. RANGE 2 SHALLOW GROUNDWATER LEAD CONCENTRATION DATA

Date	MW-1		MW-2		MW-3	
	Total Lead (ppb)	Dissolved Lead (ppb)	Total Lead (ppb)	Dissolved Lead (ppb)	Total Lead (ppb)	Dissolved Lead (ppb)
Mar 02	Not Analyzed[1]	ND	Not Analyzed[1]	ND	Not Analyzed[1]	ND
Aug 02	930	23	28	ND	14	14
Nov 02	3,200	2,600	7.5	5.9	ND	30
Mar 03	6,300	660	10	6	ND	ND
May 03	4,000	2,000	13	ND	ND	ND
Aug 03	3,200	2,900	5.9	ND	ND	4.9

ND = Non-detect (Below Analytical Limits)

1. The first samples collected after the initial well development in Mar 02 were analyzed for dissolved lead only.

TABLE 3-5. RANGE 2 GROUNDWATER LEVEL MEASUREMENTS

Date	Groundwater Monitoring Well Water Level					
	MW-1		MW-2		MW-3	
	feet bgs	feet above MSL[2]	feet bgs	feet above MSL[2]	feet bgs	feet above MSL[2]
Mar 02	6.06	56.18	6.10	55.49	4.55	51.64
Jul 02	6.67	55.57	6.99	54.60	5.30	50.89
Aug 02	7.35	54.89	7.50	54.09	5.56	50.63
Sep 02	7.24	55.00	7.50	54.09	5.20	50.99
Oct 02	5.35	56.89	7.44	54.15	6.60	49.59
Nov 02	4.64	57.60	6.20	55.39	4.35	51.84
Dec 02	4.46	57.78	6.20	55.39	4.81	51.38
Jan 03	5.08	57.16	5.58	56.01	4.25	51.94
Feb 03	4.88	57.36	5.95	55.64	4.58	51.61
Mar 03	2.95	59.29	4.50	57.09	3.92	52.27
Apr 03	N/C[1]	N/C[1]	N/C[1]	N/C[1]	N/C[1]	N/C[1]
May 03	4.51	57.73	4.25	57.34	4.1	52.09
Jun 03	5.55	56.69	4.32	57.27	4.56	51.63
Jul 03	4.55	57.69	4.04	57.55	3.96	52.23
Aug 03	4.75	57.49	4.29	57.30	4.45	51.74
Sep 03	5.63	56.61	4.50	57.09	4.53	51.66
Oct 03	5.72	56.52	4.32	57.27	3.72	52.47
Nov 03	5.90	56.34	4.79	56.80	4.41	51.78

1. Water levels were not measured in April 2003.
2. Water level values above MSL are calculated based on the surveyed height of the well head casing above MSL.

bgs = below ground surface
MSL = Mean Sea Level

Groundwater in the Fort Jackson area is suitable for human consumption. Water quality is considered excellent. Total dissolved solids are generally less than 50 milligrams per liter. Water standards are occasionally exceeded by slight concentrations of iron and manganese. Fort Jackson is not located within a recharge area for a sole-source aquifer (ref 24).

Unless otherwise stated all aquifers in South Carolina are classified as Class GB, suitable for drinking water, and are subject to the Underground Source of Drinking Water (USDW) standards (ref 10). South Carolina Maximum Contaminant Level (MCL) for lead in groundwater is 50.0 parts per billion (ppb) (ref 20 and 21) if a treatment process is included to comply with the drinking water standard. Otherwise, the MCL for Class GB untreated groundwater is 15.0 ppb.

The State of South Carolina has sampled the Twin Lakes water supply well on Fort Jackson for lead content three times over a 10-year period (May 1987 through May 1997) as part of its statewide ambient groundwater monitoring program. The Twin Lakes well is approximately 3 miles due south of the small arms range complex on Train Fire Road and 2 miles southwest of Range 20 and other adjacent ranges. The well is down gradient of a portion of the small arms ranges complex on Train Fire Road in the regional groundwater flow regime. All sampling results for lead content from the Twin Lakes well have been below the State MCL of 50.0 ppb (ref 20).

South Carolina recognizes the concept of "mixing zones" within aquifers/groundwater flow regimes where contamination has occurred and allows exceptions to Standards for Class GB aquifers where the mixing zone is solely within the boundaries of the applicant's property (ref 10). All shallow groundwater impacted by range use is assumed to fall within the installation boundary and is located with the range areas. South Carolina defines a public water system to be any public or privately owned waterworks which provides drinking water for human consumption, except those serving a single private residence or dwelling (ref 10). This is a more strict definition of a public water system than that listed by the Environmental Protection Agency (EPA) under the Safe Drinking Water Act. This effectively extends State regulatory authority to more wells, including the supply wells in the range area.

Fort Jackson does not use groundwater as a major drinking water source. It receives potable water from the City of Columbia. There are however a number of small supply wells throughout the installation that service range areas and remote locations. Two of these wells are located in or near the small arms range areas. One is located at and serves Range 20. Its depth is 174 feet below ground surface. The other is the Algiers well located across Train Fire Road near Range 8. This well supplies drinking water for Ranges 1 through 9. Its depth is 105 feet below ground surface (ref 24). Both of these wells are believed to be screened within the surficial Middendorf aquifer and the water from neither of these wells are treated prior to use. The water produced by these wells fall under the requirements for Class GB untreated water and has a 15.0 ppb lead MCL. These wells are routinely sampled by Fort Jackson, but records of the analysis results could not be located for inclusion in this report.

3.2.3 Local Surface Water Resources

The relevant surface water resources for this assessment were identified during the range area watershed delineation effort. These resources include Gills, Mack, Rowell and Bynum creeks. These are the surface water resources that may be directly or indirectly affected by stormwater runoff, and are likely the discharge point for shallow groundwater base flow from the small arms range area. This assumption is based on the proximity of the creeks to the ranges and the accepted interpretation that shallow groundwater movement generally mimics topography. The impact the range area is having (if any) on Gills creek is particularly important in that this creek flows off the installation.

Gills Creek is classified by the State of South Carolina as a freshwater resource (ref 21). This is the lowest relative ranking for a surface water resource and subsequently has the lowest usage, water quality, and protection requirements (ref 10). The upstream tributaries of Gills Creek, Mack, Rowell, and Bynum Creeks, are also classified as freshwater resources (ref 21). The State of South Carolina currently uses a 50 ppb lead concentration as a comparison or standard for any ambient or stormwater-influenced surface water classified as a freshwater resource (ref 22).

South Carolina recognizes the concept of "mixing zones" within a surface water where a discharge occurs. "A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented (except as defined within a Zone of initial dilution) and public health and welfare are not endangered. The Zone of initial dilution is the minimal area of a mixing zone immediately surrounding the outfall where water quality criteria are not met, provided there is no acute toxicity to drifting organisms and public health and welfare are not endangered (ref 10)." This is generally intended for a point source discharge. Its application to the range area is subject to legal and regulatory interpretation of the classification of the types of discharges (point source or non-point source) occurring in range areas. As a result, if mixing zones are being considered as part of a lead management BMP, as a minimum the installation environmental and judge advocate offices should be consulted to assess its applicability (ref 10).

Under an EPA national watershed analysis program Gills Creek has been monitored at two locations several miles downstream of Fort Jackson. Metals are not listed as a concern based on the results from this sampling (ref 33). Background levels for lead in surface water at Fort Jackson have not been defined. However, the City of Columbia, South Carolina, which draws most of its drinking water from surface water resources in the region, reported a lead level of 3.0 ppb in the year 2000 public water supply annual water quality report (ref 26). This lead concentration remains in the finished water after treatment. This assumed background reference value indicates the natural presence of low levels of lead in local surface waters.

In November of 1993 the South Carolina DHEC performed a site inspection and issued a Notice of Violation (NOV) for excessive soil erosion throughout the training area at Fort Jackson. This included the small arms training ranges. The small arms range areas represented the training areas that experienced some of the highest amounts of soil erosion and land degradation as a result of routine training activities. As a result of the NOV, Fort Jackson entered into a Memorandum of Agreement (MOA) with the Natural Resources Conservation Service (NRCS) in 1994 for support in rehabilitating and controlling soil erosion throughout the training area. Under the MOA, Ft Jackson and the NRCS have developed and are implementing range land rehabilitation, range land management, and stormwater management projects to control soil erosion on and around the small arms ranges (ref 24).

During routine sampling by the DHEC for the Gills Creek Non-point Source Watershed Project, DHEC noticed increased surface water turbidity in Rowell Creek at Dixie Road. A sample was taken and found to contain 1,100 ppb total lead concentration. As a result, between November 1994 and April 1995, additional stormwater grab samples were collected by South Carolina DHEC in Gills, Mack, Rowell, and Bynum Creeks (ref 28). The results from this sampling effort are shown in Table 3-6. During this period the State MCL for surface water lead concentration was not exceeded in the Gills Creek samples, however, elevated lead levels were found in stormwater samples collected near the ranges in the Mack, Rowell and Bynum Creek tributaries.

TABLE 3-6. SOUTH CAROLINA DHEC RANGE AREA STORMWATER SAMPLING RESULTS (REF 28).

Date	Total Lead Concentration (ppb)			
	Gills Creek	Mack Creek	Rowell Creek	Bynum Creek
21 Nov 1994	--[1]	--[1]	1,100	--[1]
23 Jan 1995	< 50	--[1]	70	--[1]
8 Mar 1995	--[1]	360	--[1]	260
24 Apr 1995	< 50	--[1]	2,200	--[1]

1. These locations were not sampled on these dates.

3.2.4 Range Soils

Soils at Fort Jackson are in general very high in sand content and naturally low in fertility. The Richland County Soil survey typically lists soil types at Fort Jackson ranging from sands to loamy sands (Table 3-7) (ref 23). The high sand content of local soils promotes leaching of minerals, reduced water retention, and a susceptibility to soil erosion. Once disturbed and when the vegetative cover is lost, soils easily erode and recovery or stabilization are slow to occur through natural processes.

TABLE 3-7. SOIL TYPES ON THE SMALL ARMS RANGES (REF 23)

Name	pH	Sand, %	Silt, %	Clay, %
Ailey Loam Sand	5.2	83	10	7
Lakeland Sand	5.1	92	6	2
Pelion Loamy Sand	5.0	85	8	7
Vaucluse Loamy Sand	5.0	83	10	7

3.2.5 Range and Training Land Delineation

The EPA's Military Munitions Rule defines a range as designated land and water areas set aside, managed, and used to develop, test, and evaluate military explosives, munitions, or weapon systems, or to train personnel in their use and handling. Ranges include firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas and buffer zones with restricted access and exclusionary areas (ref 27).

Based on information supplied by Fort Jackson, the boundary considered to be "off the range" with respect to firing range safety is Train Fire Road immediately in front of Ranges 1 through 13 (ref 24). Past this point, access to Dixie Road and other areas of the installation is only limited as needed dependent upon the type of training being conducted in adjacent maneuver areas and force protection condition level. Train Fire Road and its proximity to the small arms range area is shown in Figure 3-5. The training areas surrounding the constructed ranges and defined impact areas are primarily used for maneuver training. In the past they have also been used as firing ranges and potentially may be used as such in the future. The installation boundary is considered the boundary for all training areas. This includes the currently constructed firing ranges. The installation boundary is considered the boundary at which point contaminants are considered to have migrated off site.

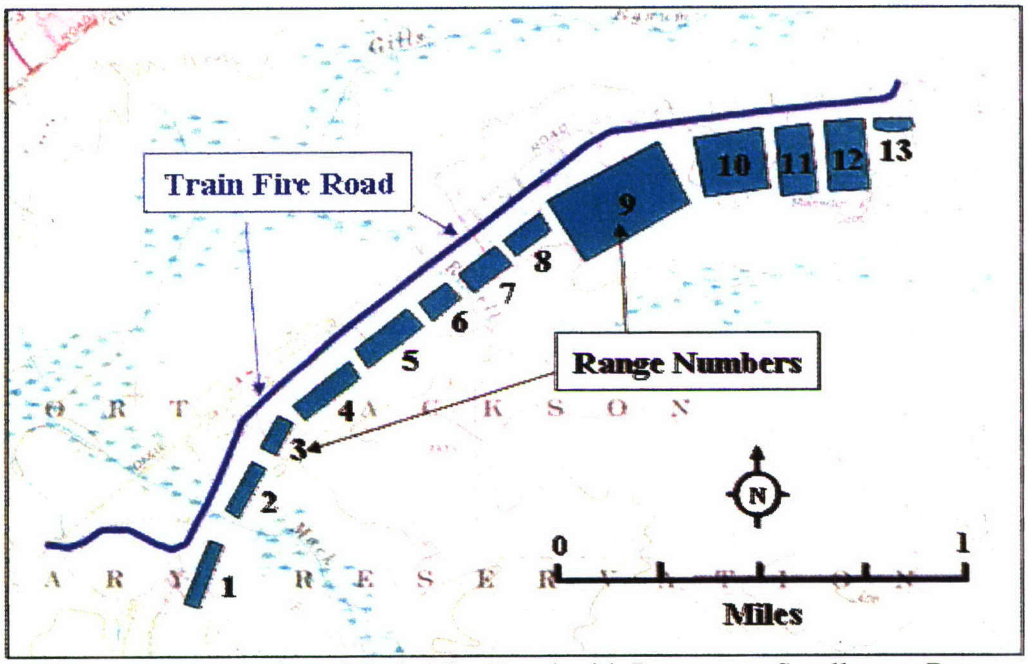


Figure 3-5. Proximity of Train Fire Road with Respect to Small arms Range

3.3 Site Inspections

Site inspections of all ranges were conducted for general familiarization with the range complex and specifically to:

- Review general range features.
- Draw conceptual maps of the layout of each range.
- Assess the general state of erosion and vegetation on each range.
- Look for and qualitatively gauge and assess the evidence of transport of eroded soils away from individual ranges. Signs of erosion and transport included, visible trails of soil/sediment from the eroding area, and mud films or scum lines on vegetation or rocks in runoff water drainage paths.
- Delineate the surface runoff/drainage patterns on each range and throughout the range complex for each subwatershed. This included the natural and man-made stormwater drainage features/structures.

In general, the ranges are maintained with very short grass on the range between the firing line and the target line. The berm (and usually the drainage path in front of each berm) on each range was found to have no vegetation and showed evidence of significant erosion and sediment transport. Berm slopes typically ranged between 35 and 45 degrees from the horizontal with significant rilling and erosion. These rills and erosion were found to occur in areas outside of the primary bullet impact points, indicating an inherent instability of the berm soils at these slopes. Bullet debris was found in the bullet pockets, dispersed on the berm face, and dispersed on the backside of the berm. This initial dispersion of bullet debris on and behind the berm is typical of the berm consists of soil particles as suspended solids in stormwater. This transport continues until the stormwater reaches areas where flow slows enough to allow settling of the solids or it flows through vegetated areas where the solids are filtered out. In several cases, the solids appeared to remain suspended in the stormwater and enter the creeks that drain the subwatershed in which the range lies. Visible trails of eroded soil are evident in these flow paths.

Corrosion of the bullet debris was observed on both surface and subsurface debris. A white lead oxide corrosion product was observed on the surface of lead fragments and a green copper oxide corrosion product was observed on the surface of the copper jacket fragments. In addition, highly oxidized copper fragments were found to have a rust colored buildup on the fragments. This indicates that the copper may be undergoing an electrochemical reaction with iron or other minerals in the soil. An overall estimate of stability as a result of corrosion passivation could not be inferred based on visual observations of the debris. However, corrosion is known to occur in environments with the pH, precipitation, and overall lack of soil nutrient conditions as found at Fort Jackson. These conditions may result in the formation of mobile lead ions.

One of the main outputs of the site inspections is a conceptual site diagram for each individual range that shows the basic layout and features of the ranges as well as the surface water runoff drainage patterns on and around the range. The conceptual site plan for each of the 14 ranges (small arms Ranges 1 through 13, and 20) surveyed is shown below (fig. 3-6 through 3-19).

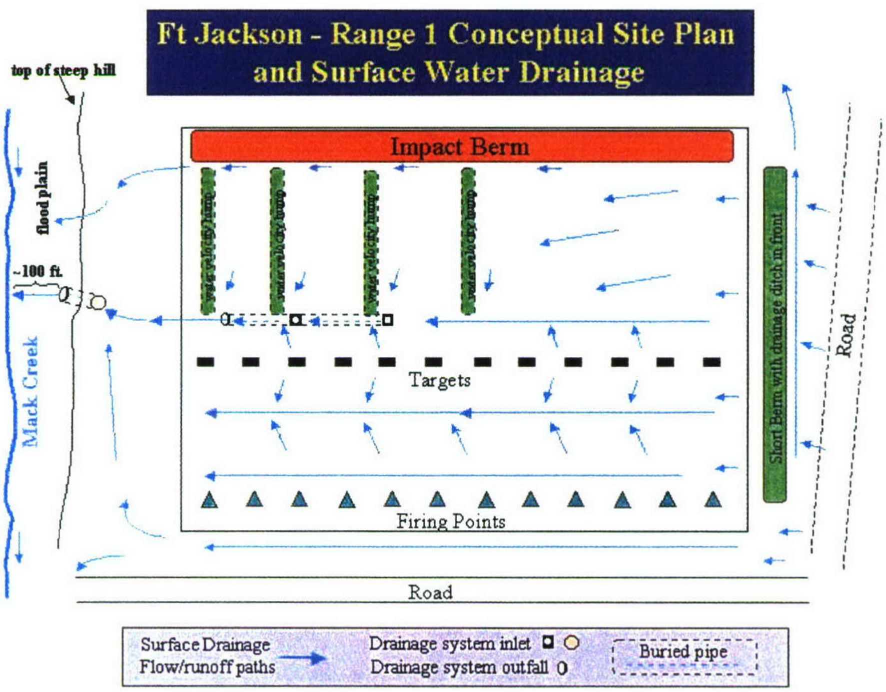


Figure 3-6. Range 1 - 25-Meter Zero Range.

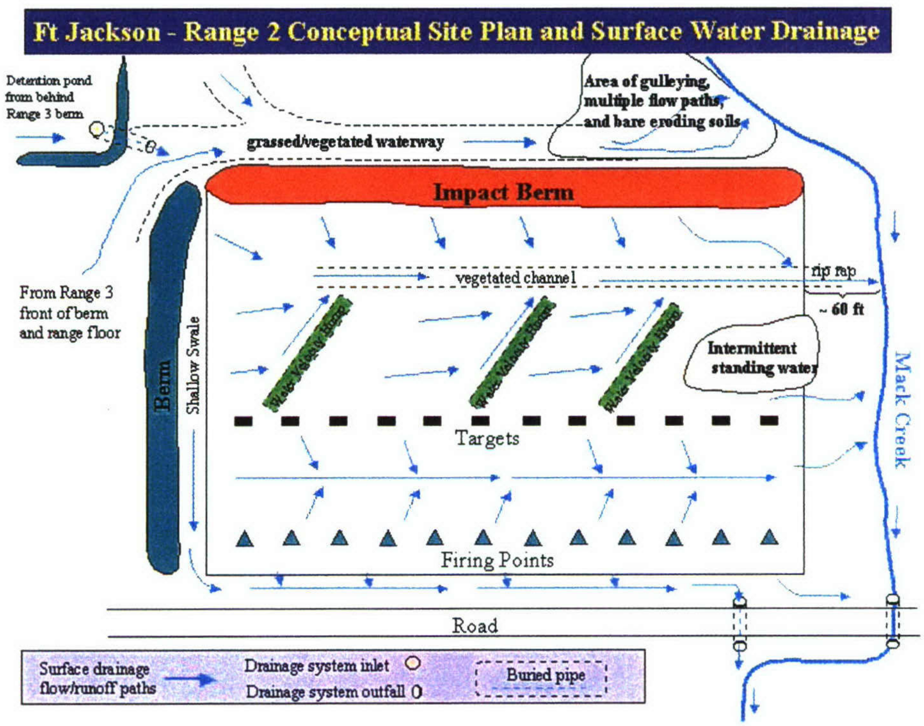


Figure 3-7. Range 2 - 25- Meter Zero Range.

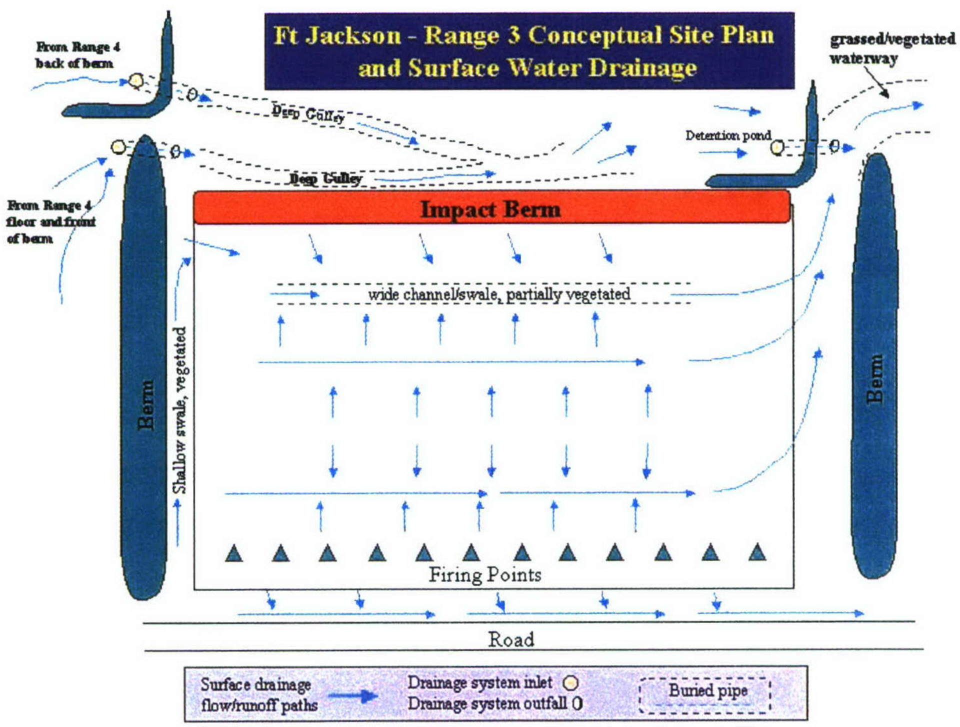


Figure 3-8. Range 3 - 25- Meter Zero Range.

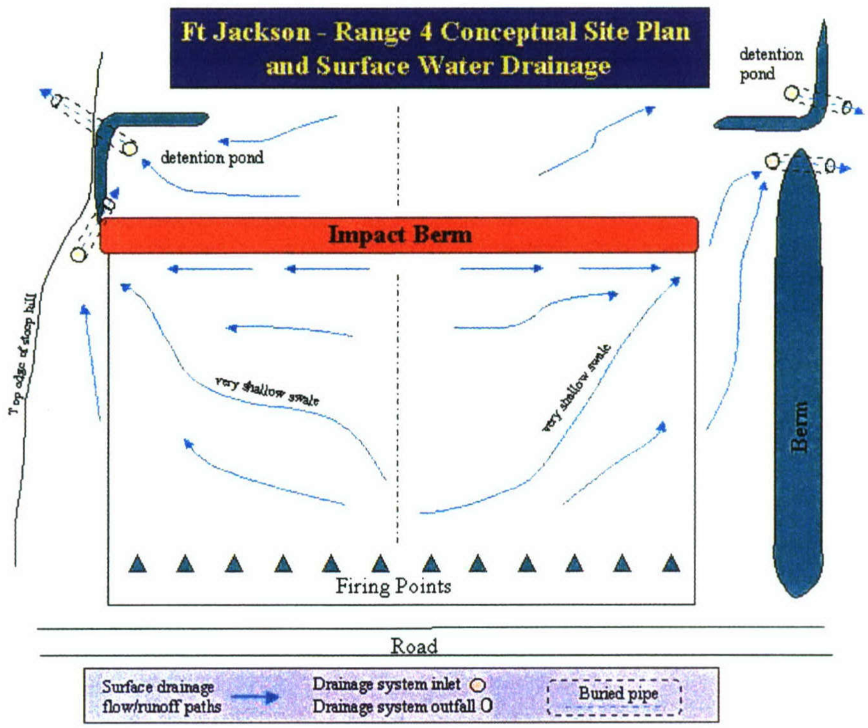


Figure 3-9. Range 4 - 25- Meter Zero Range.

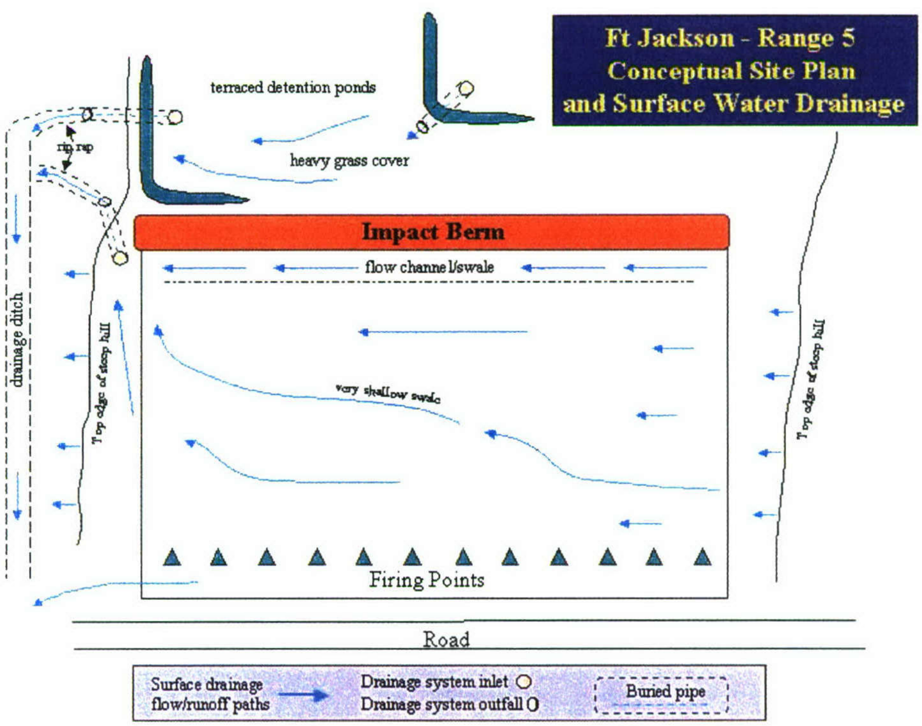


Figure 3-10. Range 5 - 25- Meter Zero Range.

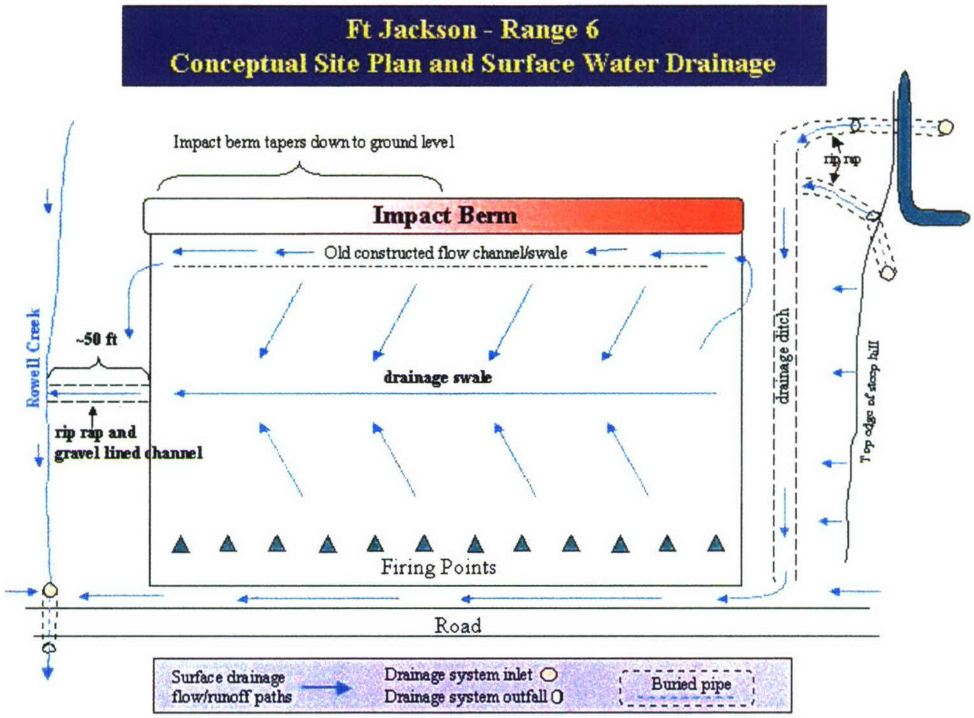


Figure 3-11. Range 6 - Multiple Use.

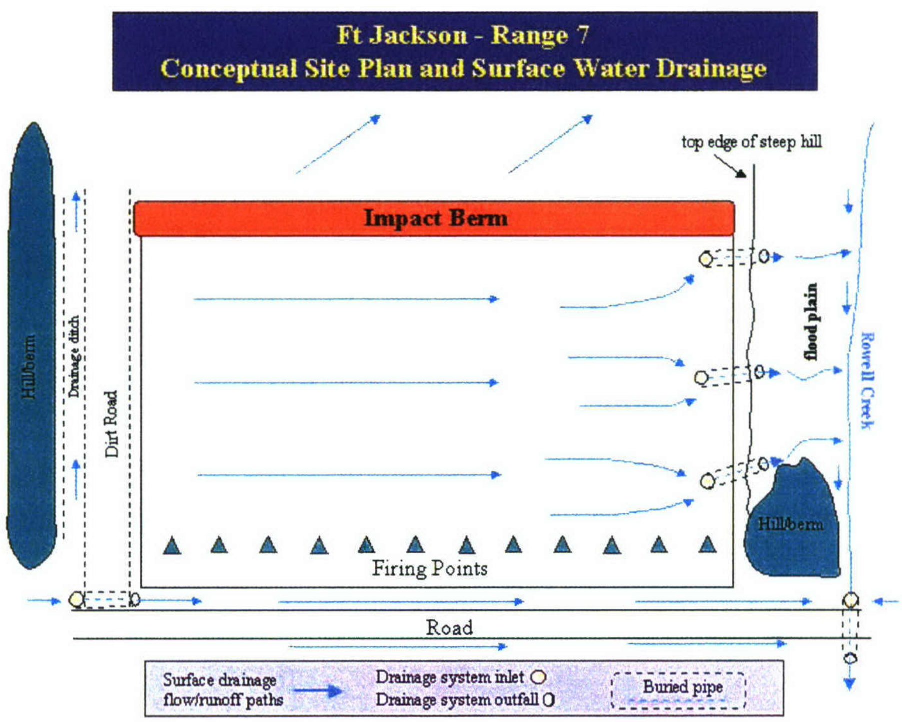


Figure 3-12. Range 7 – NBC, Night Fire Training.

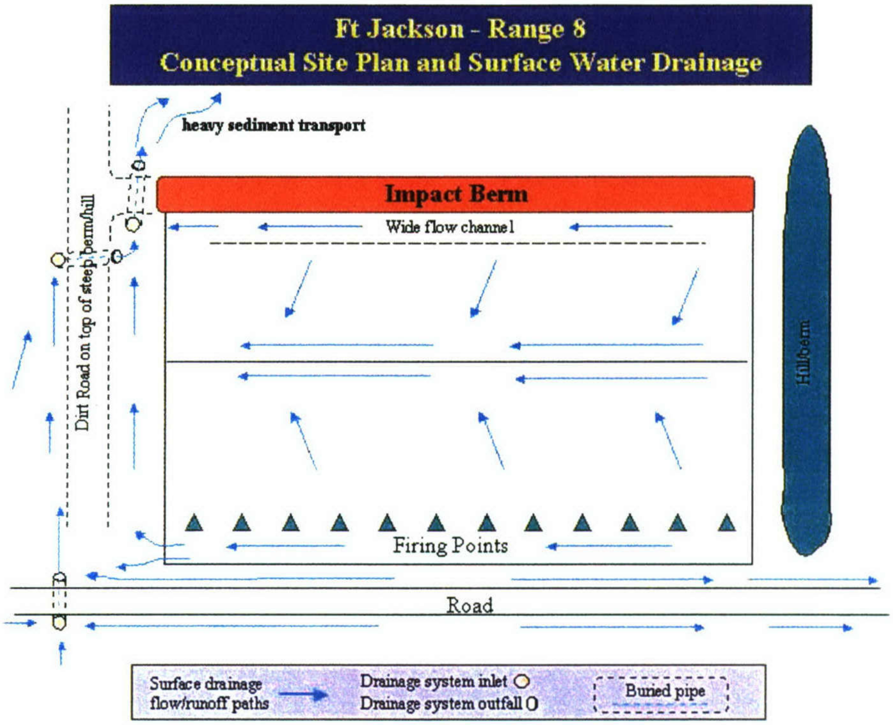


Figure 3-13. Range 8 – NBC, Night Fire Training.

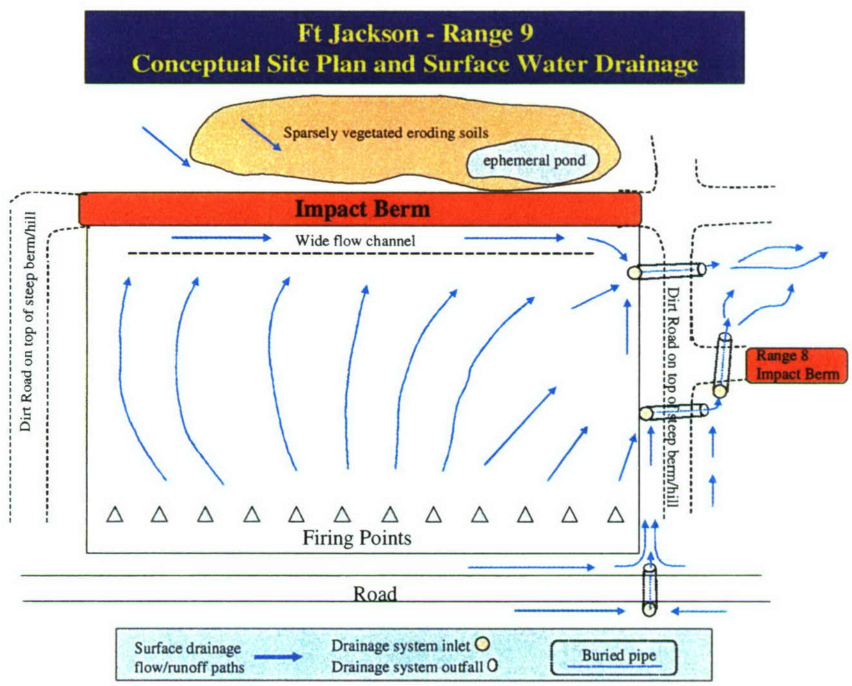


Figure 3-14. Range 9 - 300-Meter Prequalification Range.

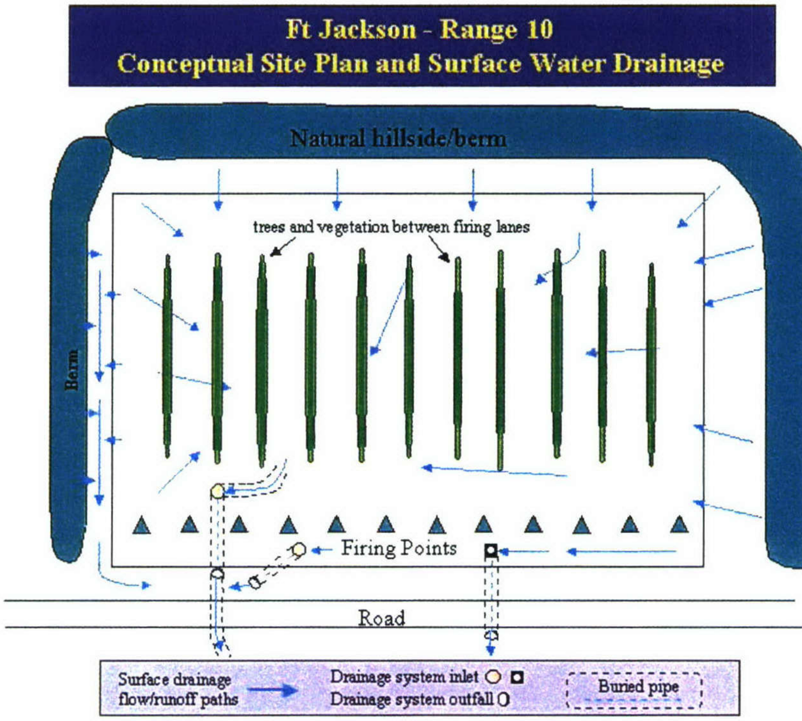


Figure 3-15. Range 10 - Qualification Range.

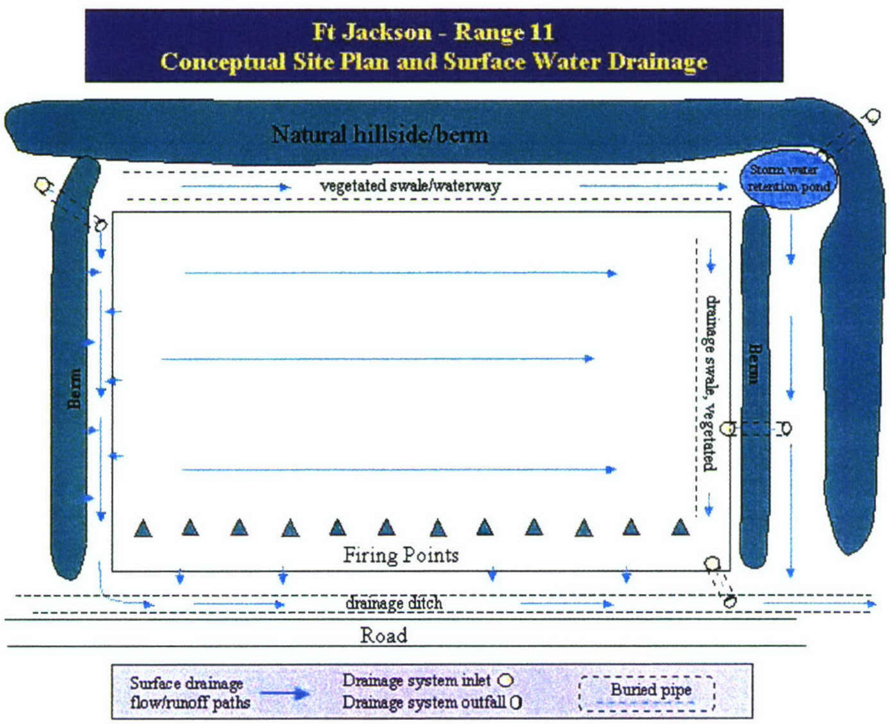


Figure 3-16. Range 11 - Known Distance Range.

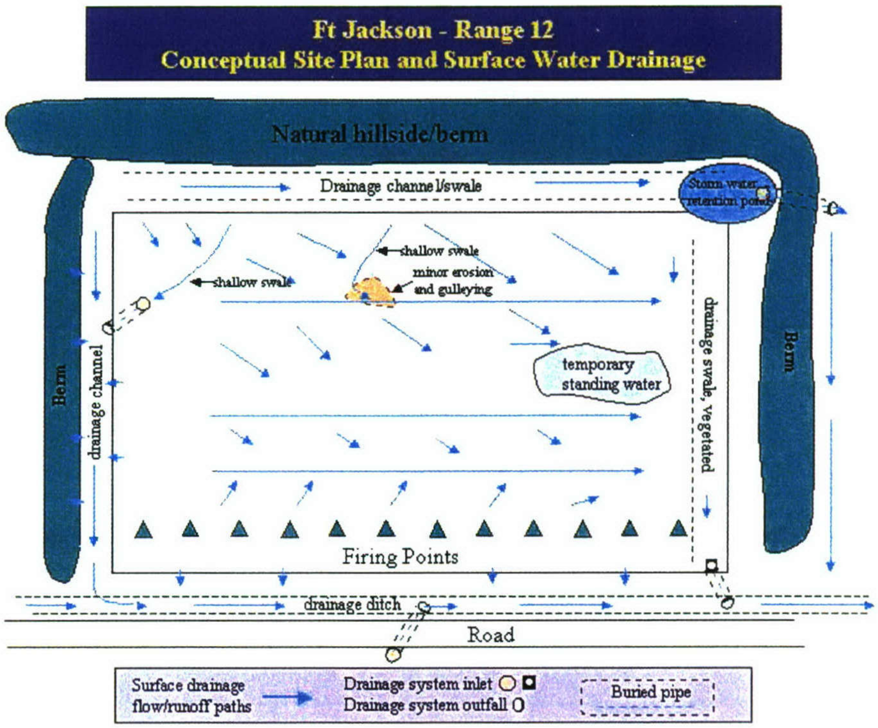


Figure 3-17. Range 12 - Misses and Hits.

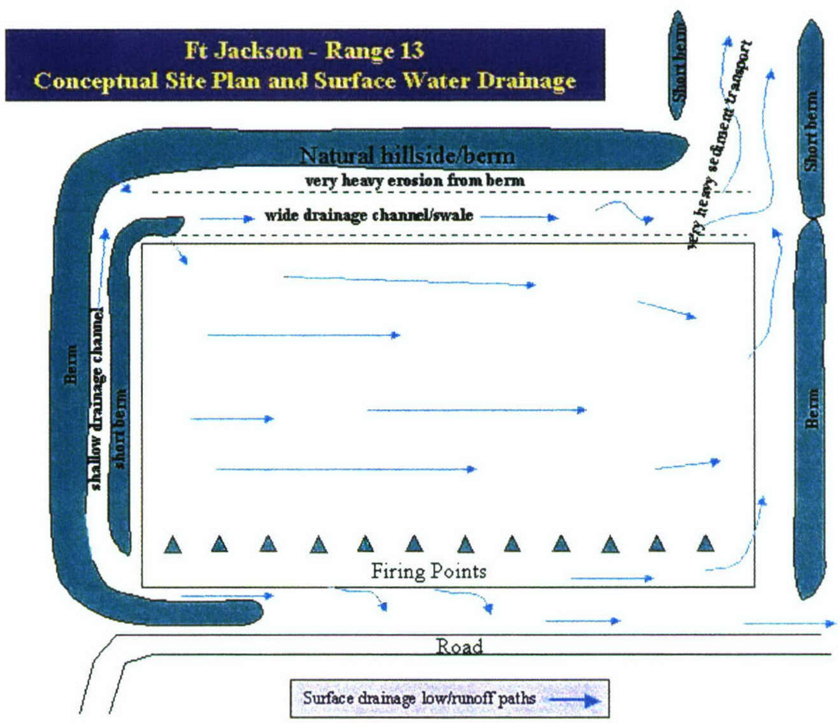


Figure 3-18. Range 13 - Zero Range.

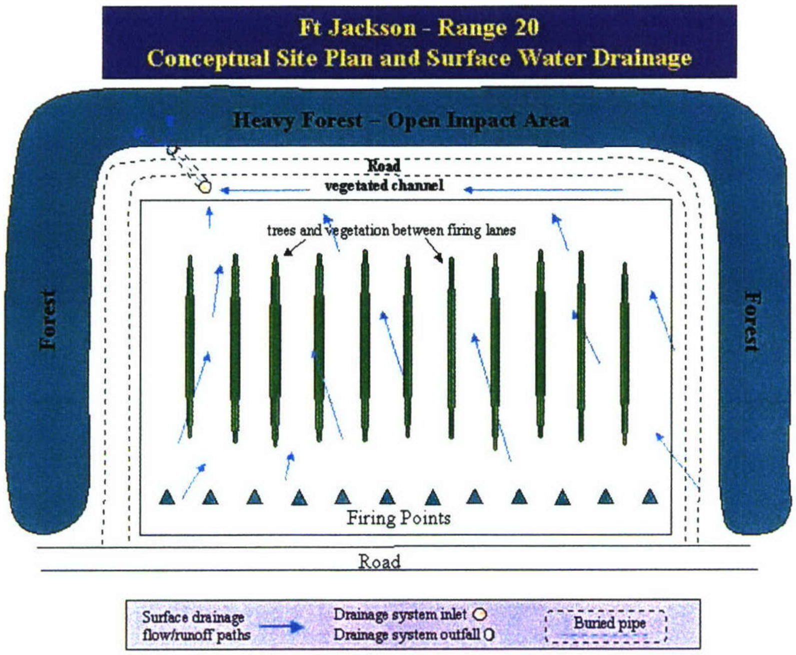


Figure 3-19. Range 20 - 300-Meter Qualification Range.

The manual site inspections also allowed for a delineation of the overall stormwater drainage pathways in the range area. For each subwatershed the stormwater drainage patterns were mapped out for each group of ranges. The runoff water drainage patterns immediately around the ranges in each subwatershed are shown in Figures 3-20 through 3-22. The contour intervals on these figures are 10 meter intervals.

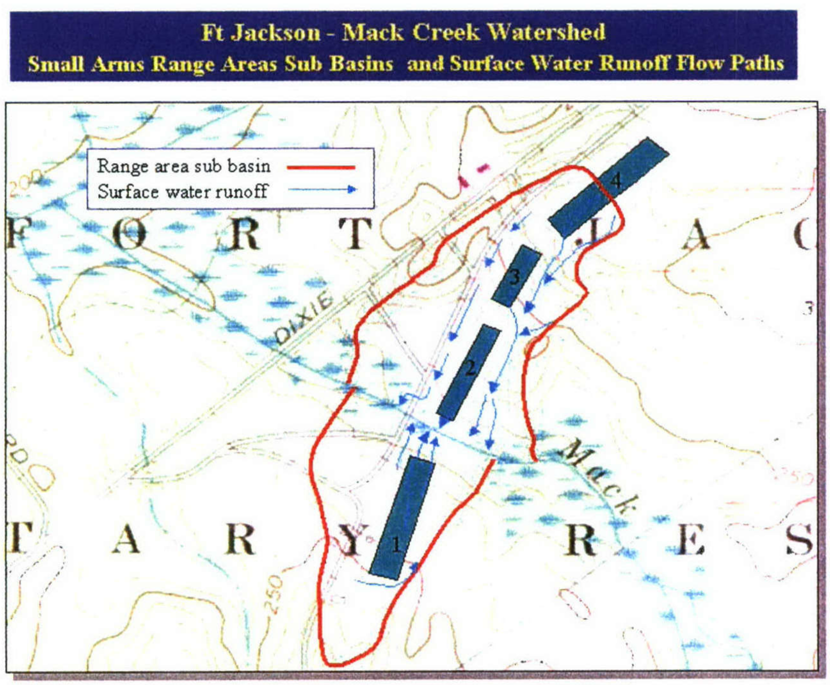


Figure 3-20. Range Runoff Pattern within Mack Creek Subwatershed.

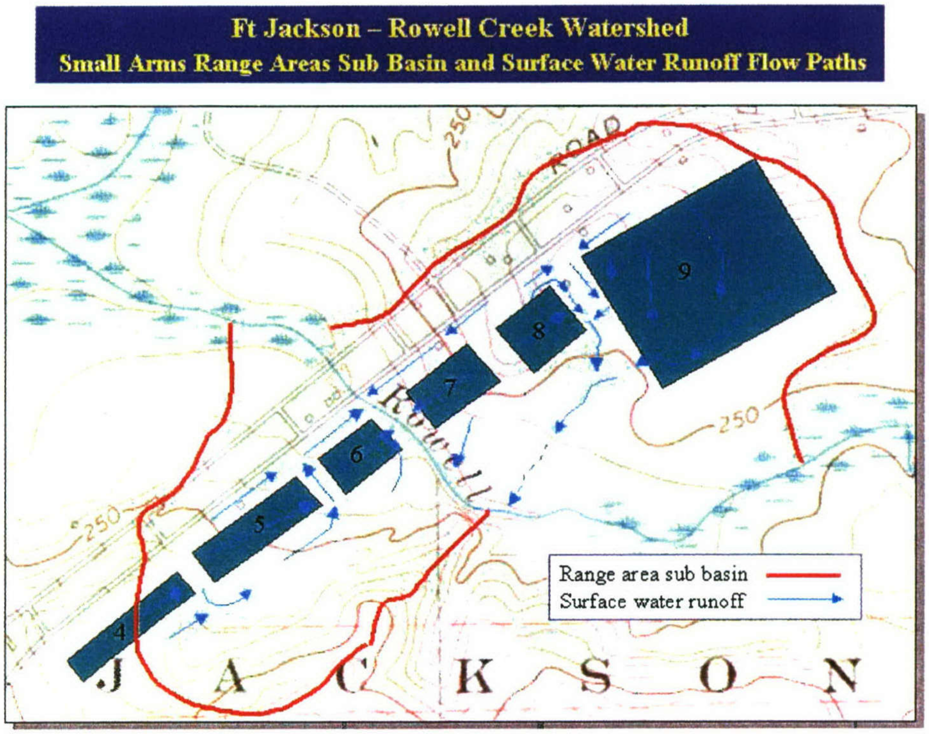


Figure 3-21. Range Runoff Pattern within Rowell Creek Subwatershed

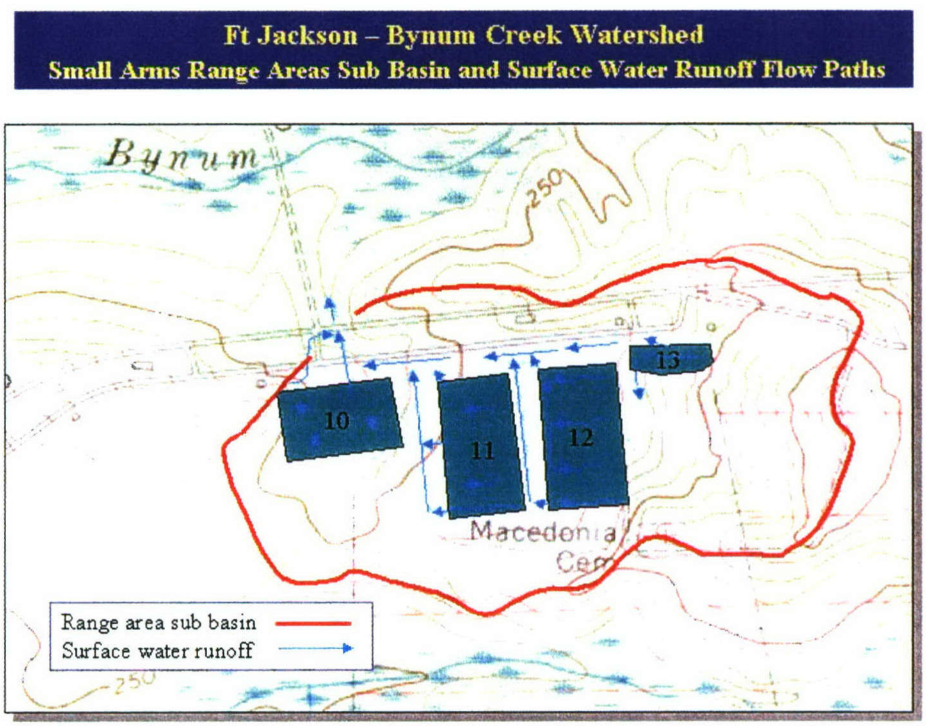


Figure 3-22. Range Runoff Pattern within Bynum Creek Subwatershed

3.4 Range Evaluation Software Tool Analysis

The REST analysis was performed for each small arms range. The REST is a Windows-based software application created by the USAEC to be used as a tool to help range personnel assess the potential for lead transport from small arms ranges. It requires site-specific data such as the type and number of rounds fired, soil types, and estimated depth to groundwater as input data. This information is collected and then entered into the program to estimate the potential of metals contaminant migration in range areas through a specific pathway, aerial, surface water, or groundwater transport. The REST generates a four-level ranking of the range's overall potential for lead migration. The REST generates a numeric score to five parameters that contribute to the overall ranking. These parameters are 1) ammunition mass, 2) corrosion, 3) aerial transport, 4) surface water transport, and 5) groundwater transport. Each parameter is assigned a numeric score. These scores are then combined into an overall numeric ranking and color code for the range. High overall scores (red color code) indicate possible mobility lead concerns and the need for further investigation. Conversely, low overall rankings (green color code) indicate a range has very little or no lead mobility concerns, and investigation or mitigation is unnecessary (ref 11). The relation between the potential for transport and numeric rank and color code is shown in Table 3.8.

TABLE 3-8. RANKING OF REST OUTPUT SCORES (REF 11)

Potential for Transport	Numeric Range	Color Code
High	8 – 10	Red
Medium	6 – 7	Orange
Low	4 – 5	Blue
Very Low	1 - 3	Green

The scoring system and color code used by REST represents a qualitative assessment of lead transport that is intended to help range managers evaluate the need for maintenance operations to mitigate lead migration from the range area. The REST does have limitations. Every small arms range is unique and these unique characteristics must be evaluated collectively. The REST helps users know what to look for, but it is not able to process all of the variables and form a complete picture of lead migration potential. The REST is only meant to be a low cost screening to initially assess a range for potential lead migration. Environmental sampling and analysis may need to be conducted to validate the REST analysis.

A summary of the REST analysis output of the small arms ranges at Ft Jackson is listed in Table 3-9. The overall potential for metals migration as calculated by the REST is medium to very low. The REST guidance encourages further investigation for any parameter with a score of 5 or greater. The REST input data is shown in Appendix A.

While this REST analysis seems to indicate that the overall potential for lead migration is low, it must be interpreted with caution since only firing data for the year 2000 was available as input data for the model. Typically, the program input consists of several years' of firing data to account for the fact that the number of rounds fired on a range can vary greatly depending on factors such as the training need and whether or not the range is down for regular maintenance or renovation. Since this analysis does not include historical data on the number/type of rounds fired, this introduces a great deal of uncertainty to the REST calculations in this report for lead mass loading at the range. Since the total number of rounds firing at Fort Jackson is expected to increase roughly ten percent each year (ref 24), range managers should verify the analysis on a periodic basis to assess the potential for lead transport.

TABLE 3-9. REST ANALYSIS SUMMARY

Range Number	Ammunition Mass	Corrosion	Aerial Transport	Surface Water Transport	Ground-water Transport	Numerical Overall Rating	Color Coded Overall Rating
1	3.0	3.0	2.0	7.0	10.0	3.7	Blue
2	3.0	4.0	3.3	10.0	10.0	5.5	Orange
3	1.0	4.0	3.3	10.0	10.0	3.2	Blue
4a	2.0	4.0	3.3	10.0	10.0	4.3	Blue
4b	2.0	4.0	2.3	9.0	9.0	4.1	Blue
5	2.0	4.0	3.3	10.0	10.0	4.3	Blue
6[a]	-	-	-	-	-	-	-
7	2.0	4.0	3.3	10.0	10.0	4.3	Blue
8	2.0	4.0	3.3	10.0	10.0	4.3	Blue
9	3.0	4.0	4.3	10.0	10.0	5.5	Orange
10	1.0	4.0	2.3	10.0	10.0	3.1	Blue
11[a]	-	-	-	-	-	-	-
12	3.0	4.0	1.3	9.0	9.0	5.1	Orange
13[a]	-	-	-	-	-	-	-
20	1.0	3.0	1.0	2.0	6.0	1.0	Green

a. Ammunition loading data was not available for ranges 6, 11, and 13.

3.5 Conceptual Site Model

A conceptual site model was developed as a brief and succinct description of the environmental conditions at the range area, as they are understood, combined with an assessment of those conditions and the potential for environmental impact. The three subwatersheds in which the small arms ranges are located comprise 51.1% of the Gills Creek watershed. The remaining portions of the Gills Creek watershed consists of maneuver training areas (5.6 square miles), on post, and off post land (3.7 square miles) through which an interstate highway (I-77) crosses. The off post area is used primarily for commercial and residential purposes (developed urban areas). Each subwatershed conceptual site model is presented below. The subwatershed information is summarized in Table 3-10.

3.5.1 Mack Creek Subwatershed

The Mack Creek subwatershed drains an area of 3.1 square miles and comprises 16.3% of the Gills Creek watershed. Small arms fire from ranges 20, 1, 2, 3, and half of 4 impact within this watershed. Approximately 2.9 million rounds of 5.56-mm rounds are fired into this area annually. These rounds are typically fired into berms on ranges 1, 2, 3, and 4. However, dispersion of bullet fragments behind the berm does occur after the rounds impact the berms. In addition, rounds are frequently fired over the berms into the impact area. Rounds fired on range 20 will impact either on the range or in the impact area dependent upon the elevation of the target with respect to the firing position. These firing and dispersion patterns yield a broad area of dispersion of bullet fragments within the subwatershed.

The REST analysis of corrosion with in these range areas predicted low to very low potential for corrosion of the bullet debris. However, during site inspections both surface and subsurface bullet debris was observed to have a build up of corrosion products indicating an aggressive corrosion environment. This may result in the formation of lead ions that may bond to soil particles or be mobilized in water that either infiltrates into the soil or runs off the range.

Aerial transport of lead contaminated soil is not believed to be a factor at Fort Jackson. The impact area and areas surrounding the ranges are heavily forested, thus providing natural wind breaks. No evidence of wind blown sediment transport was observed during site inspections. This corresponds to the REST predictions of low to very low potential for aerial transport.

The REST analysis predicted a transport to groundwater potential of medium to high for the area within this subwatershed. Soil cores taken during the installation of shallow (10 to 15 foot depths) monitoring wells on range 2 showed the presence of clay confining units in two of the wells (MW-2 and MW-3). The third well (MW-1) encountered no interstitial clay layers. The entire soil profile was sand. The lead levels monitored in MW-2 and MW-3 reflected the impact of the clay confining units. As seen in Table 3, lead levels are elevated in both the total and dissolved phase in MW-1 while lead levels in MW-2 and MW-3 remained below the South Carolina MCL. These variations in soil conditions are typical to Fort Jackson. Considering the fact that lead is widely dispersed in the impact area, then areas of varying shallow groundwater impact can be expected to be found throughout the ranges.

TABLE 3-10. PHASE I - RANGE AREA, WATERSHEDS, AND FIRING DATA

Subwatershed	Land Area, (Miles^2)	% of Total Watershed Area[a]	Ranges	REST Score	Rounds Fired, FY2000	Lead Mass, (kg)	Stormwater Control Structures[b]	Comments
Mack Creek	**3.1**	**16.3**			**2,868,700**	**5,949.7**		
			1	3.7	410,000	850.3	No	
			2	5.5	440,000	912.6	No	Mack Creek is within 20 to 30 feet of backside of impact berm, bullet fragments in creek bed.
			3	3.2	5,000	10.4	Partial	Heavy gullying in drainage immediately behind berm.
			4 - S. half	4.3	215,000	445.9	Yes	
			20	1.0	1,798,700	3,730.5	No	Water supply well on site
Rowell Creek	**2.1**	**11.1**			**4,467,100**	**9,264.8**		
			4 - N. half	4.1	215,000	445.9	Yes	
			5	4.3	494,000	1,024.6	Yes	
			6	-	-[c]	-[c]	No	
			7	4.3	242,000	501.9	No	
			8	4.3	331,000	686.5	No	Berm completely un-vegetated, heavy soil erosion and sediment transport off range, water supply well for Ranges 1 through 9 near range.
			9	5.5	3,185,100	6,605.9	No	Largest range, heaviest training use, large un-vegetated berm, heavy sediment transport off range.

TABLE 3-10. PHASE I - RANGE AREA, WATERSHEDS, AND FIRING DATA (CONT'D)

Subwatershed	Land Area, (Miles^2)	% of Total Watershed Area[a]	Ranges	REST Score	Rounds Fired, FY2000	Lead Mass, (kg)	Stormwater Control Structures[b]	Comments
Bynum Creek	**4.5**	**23.7**			**1,976,300**	**4,098.8**		
			10	3.1	319,000	661.6	No	
			11	-[c]	-[c]	-[c]	Yes	
			12	5.1	1,657,300	3,437.2	Yes	
			13	-[c]	-[c]	-[c]	No	Heavy soil erosion and sediment transport but disperses over flat area, range ownership in transition.
Other Areas	**9.3**	**49.0**	**N/A**[d]	**N/A**	**N/A**	**N/A**	**N/A**	
On Installation	5.6	29.5	N/A	N/A	N/A	N/A	N/A	
Off Installation	3.7	19.5	N/A	N/A	N/A	N/A	N/A	Mostly developed, urban areas.

a. Gills Creek Watershed Area = 19.0 mi^2.
b. Stormwater control structures are defined as water detention or retention ponds that intercept runoff from impact berms.
c. Range usage data was not available.
d. N/A = Not Applicable.

The primary transport mechanism for lead from the ranges appears to be surface water transport, specifically, stormwater runoff. The REST analysis ranked the surface water transport potential for range 20 as very low due to its distance from Mack Creek and the heavy forest and vegetation between where the rounds are dispersed and Mack Creek. Ranges 1, 2, 3, and 4 were ranked as medium to high by REST. Site inspections supported this ranking. The hilly nature of the small arms range area and the use of steep sloped berms constructed from local soils combined with the high sand content of local soils creates conditions that are naturally susceptible to soil erosion. The berm (and usually the drainage path in front of each berm) on each range has no vegetation with evidence of significant erosion and sediment transport. Berm slopes (35 and 45 degrees) have significant rilling and erosion. These rills and erosion occur in areas outside of the primary bullet impact points indicating an inherent instability of the berm soils at these slopes. Transport away from the berm appears to consist of soil particles as suspended solids in stormwater. This transport continues until the stormwater reaches areas where flow slows enough to allow settling of the solids or through vegetated areas where the solids are filtered out. Visible trails of eroded soil are evident in these flow paths. Within the Mack Creek subwatershed, the solids appeared to remain suspended in the stormwater and enter the creek.

3.5.2 Rowell Creek Subwatershed

The Rowell Creek subwatershed drains an area of 2.1 square miles and comprises 11.1% of the Gills Creek watershed. Small arms fire from ranges 5, 6, 7, 8, 9, and half of 4 impact within this watershed. Approximately 4.5 million rounds of 5.56-mm rounds are fired into this area annually. The majority of these rounds (3.2 million) are fired on range 9. These rounds are fired into berms. However, dispersion of bullet fragments behind the berm does occur after the rounds impact the berms. In addition, rounds are frequently fired over the berms into the impact area. These firing and dispersion patterns yield a broad area of dispersion of bullet fragments within the subwatershed.

The REST analysis in these range areas predicted a low potential for corrosion of the bullet debris. However, during site inspections both surface and subsurface bullet debris was observed to have a build up of corrosion products indicating an aggressive corrosion environment. This may result in the formation of lead ions or compounds that may bond to soil particles or be mobilized in water that either infiltrates into the soil or runs off the ranges.

Aerial transport of lead contaminated soil is not believed to be a factor at Fort Jackson. The impact area and areas surrounding the ranges are heavily forested, thus providing natural wind breaks. No evidence of wind blown sediment transport was observed during site inspections. This corresponds to the REST predictions of low to very low potential for aerial transport.

The REST analysis predicted a transport to groundwater potential of high for the area within this subwatershed. A potable water well located on range 8, which is believed to be screened within the Middendorf aquifer, was not believed to have been previously sampled for lead. Based on a generalized understanding of Fort Jackson's groundwater flow and the shallow well information presented for the Mack Creek subwatershed, lead infiltration is believed to be a shallow groundwater phenomenon only, with the discharge of the shallow groundwater providing the base flow for the creek in the Rowell Creek subwatershed.

The primary transport mechanism for lead from the ranges in this watershed appears to be surface water transport, specifically, stormwater runoff. The REST analysis ranked the surface water transport potential for the ranges in the Rowell Creek subwatershed as high. Site inspections supported this ranking. The hilly nature of the small arms range area and the use of steep sloped berms constructed from local soils combined with the high sand content of local soils creates conditions that are naturally susceptible to soil erosion. The berm (and usually the drainage path in front of each berm) on each range has no vegetation and show evidence of significant erosion and sediment transport. Berm slopes (35 and 45 degrees) have significant rilling and erosion. These rills and erosion even occur in areas outside of the primary bullet impact points indicating an inherent instability of the berm soils at these slopes. Transport away from the berm appears to consist of soil particles suspended in stormwater. This transport continues until the stormwater reaches areas where its flow slows enough to allow settling of the solids or it flows through vegetated areas where the solids are filtered out. Visible trails of eroded soil are evident in these flow paths. Within the Rowell Creek subwatershed, the solids appeared to remain suspended in the stormwater and enter the creek.

3.5.3 Bynum Creek Subwatershed

The Bynum Creek subwatershed drains an area of 4.5 square miles and comprises 23.7% of the Gills Creek watershed. Small arms fire from ranges 10, 11, 12, and 13 impact within this watershed. Approximately 2 million rounds of 5.56-mm rounds are fired into this area annually. The majority of these rounds (1.7 million) are fired on range 12. These rounds are fired into a natural hillside. Due to the design of these ranges, there is a broad area of dispersion of bullet fragments on the hillside.

The REST analysis of corrosion with in these range areas predicted a low potential for corrosion of the bullet debris. However, during site inspections both surface and subsurface bullet debris was observed to have a build up of corrosion products indicating an aggressive corrosion environment. This may result in the formation of lead species that may bond to soil particles or be mobilized in water that either infiltrates into the soil or runs off the ranges.

Aerial transport of lead contaminated soil is not believed to be significant. The impact area and areas surrounding the ranges are heavily forested, thus providing natural wind breaks. No evidence of wind blown sediment transport was observed during site inspections. This corresponds to the REST predictions of very low potential for aerial transport.

The REST analysis predicted a transport to groundwater potential of high for the area within this subwatershed. Based on the information previously presented, lead infiltration is believed to be a shallow groundwater phenomenon only, with the discharge of the shallow groundwater providing the base flow for the creek in the Bynum Creek subwatershed.

The primary transport mechanism for lead from the ranges appear to be surface water transport, specifically, stormwater runoff. The REST analysis ranked the surface water transport potential for the ranges in the Bynum Creek subwatershed as high. Site inspections supported this ranking. The hilly nature of the small arms range area combined with the high sand content of local soils creates conditions that are naturally susceptible to soil erosion. The hillsides on each range have little vegetation and show evidence of significant erosion and sediment transport. Transport away from the hillsides appears to consist of soil particles as suspended solids in stormwater. This transport continues until the stormwater reaches areas where its flow slows enough to allow settling of the solids or it flows through vegetated areas where the solids are filtered out. Visible trails of eroded soil are evident in these flow paths. Within the Bynum Creek subwatershed, the solids appeared to remain suspended in the stormwater and enter the creek.

3.6 Gills Creek Watershed Overview

Stormwater runoff transport of eroded soils and lead residues is occurring and likely poses the most significant environmental concern at the small arms ranges on Fort Jackson. There is visual evidence of significant soil erosion and sediment transport from the impact berms on many ranges, particularly Ranges 8 and 9 in the Rowell Creek subwatershed. All three subwatershed creeks discharge into Gills Creek, which eventually flows off the installation. Much of Gills Creek's flow path is flat and marshy. A marshy area with slow water movement and a great deal of vegetation is a low energy area conducive to the settling out of any sediments suspended in the water. Gills Creek also discharges into Boyden Arbor pond prior to leaving the installation. This is another low energy area that should further reduce sediment loads by settling. Gills Creek and Boyden Arbor pond are likely acting as significant barriers or filters for suspended sediment loads that may be washing off the small arms range area. It is unlikely that significant off installation transport of range pollutants will occur through this surface water pathway during moderate rainfall events. Historical data collected by the South Carolina DHEC (Table 3-6) supports this conclusion.

Shallow groundwater under the range areas has likely been impacted. This is assumed due to the high sand content and acidic pH of local soils. These site conditions represent a harsh environment that may be conducive to dissolving and transporting lead from bullet fragments into the shallow base flow that discharges into the three subwatershed creeks. This is supported by the few rounds of shallow groundwater sampling performed at the wells on Range 2 that showed high lead concentrations in the shallow groundwater immediately at range impact area.

Deeper, regional groundwater flow in the surficial aquifer under Fort Jackson flows further into the installation in a southeast-southerly direction, opposite the direction of surface water drainage in the small arms range area. Three rounds of sampling at the Twin Lakes water supply wells by the State of South Carolina have not shown lead levels at or above the State MCL of 50.0 ppb. Two potable water supply wells for the ranges are found in close proximity to the ranges and may represent a pathway for troops (human receptors) to be exposed to lead concentrations in the drinking the water, however, lead was not detected in samples collected in these wells.

Table 3-10 shows watershed, firing range, and site inspection data collected for the preliminary assessment. A review of this data suggests the Rowell Creek subwatershed has the highest potential for being impacted by small arms range operations, and the potential for the highest concentrations or volumes of pollutant transport. This is due to:

- Rowell Creek is the smallest subwatershed, having the least amount of land area and containing the least amount of water.
- Rowell Creek subwatershed has the most number of ranges. The ranges represent a greater relative percent of the area of its subwatershed than do the ranges in the other two subwatersheds.
- Rowell Creek subwatershed has the single biggest range (Range 9), with the single biggest input of lead.
- Rowell Creek subwatershed as a whole has the largest annual input of lead from firing.
- Rowell Creek subwatershed has two ranges (Ranges 8 and 9) with by far the largest erosion and sediment transport problem based on visual observations.

Of the two remaining subwatersheds, Mack and Bynum Creeks, the data from the conceptual site model suggests a vague ranking of the subwatersheds as far as the next highest potential for off range pollution transport concerns, and which subwatershed shows the least. The Mack creek subwatershed may be considered to have a slightly higher potential for pollution transport and concentration concerns. The Mack creek subwatershed has more ranges, a greater annual input of lead mass, less stormwater management control structures, and a smaller land area than Bynum Creek. This at least suggests that the ranges may be having a larger impact on the Mack Creek subwatershed than on the Bynum Creek subwatershed.

4. Phase II - Field Sampling

Field sampling for Phase II of the range assessment was performed to validate the results of the Phase I preliminary assessment. The selection of sampling locations and the media to be sampled were influenced by the data collected, site specific conditions, and preliminary findings generated by Phase I and listed in the conceptual site model. The field sampling locations for Phase II were influenced by three main factors. These were:

- The Rowell Creek Subwatershed is believed to have the highest potential for being impacted by range activities.

- Two key locations for screening pollution transport concentrations are the constructed range boundary at Train Fire Road, and the "off installation or property" point where Gills Creek leaves the Fort Jackson property boundary. All three subwatersheds have a high potential for transport through stormwater runoff/surface waters. Transport off the installation is believed to be unlikely as a result of settling of suspended solids prior to reaching the installation boundary.

- Groundwater is used at the ranges for potable water supply.

The types of sampling performed for Phase II of the assessment were determined by two main factors. These were:

- Stormwater runoff from the ranges and the impact on the creeks appears to be the primary issue. This required sampling of surface waters under ambient conditions to establish a baseline. Sampling of stormwater runoff and/or surface waters when stormwater runoff is discharging into the creeks is required to gauge the impact of the runoff on surface water quality.

- Two potable water wells that supply the ranges are located in close proximity to the ranges and may be pathways for exposing human receptors to lead levels above regulatory standards. This required sampling of these wells.

The field sampling that was performed for Phase II of the assessment was designed to answer a number of basic questions about transport of range-generated pollutants. These are:

- Is off-installation transport of range pollutants occurring through the suspected pathway (stormwater runoff/surface water)?

- What concentrations of pollutants and to what extent are pollutants being transported away from the constructed ranges?

- Are the concentrations of pollutants being transported a cause for concern when assessed against State water quality criteria?

- What is being impacted (environmental or human receptors) by the transported pollutants?

- Is further investigation beyond a screening-level effort needed?

Phase II field sampling consisted of surface water sampling throughout the watersheds during ambient and stormwater-influenced conditions, and groundwater samples collected from range 20 and the Algiers (range 8) water supply wells (ref 31). Figure 4-1 shows the locations of the planned surface and ground water sampling points distributed throughout the watersheds. Table 4-1 lists sampling locations, types of samples collected and the parameters measured or analyzed.

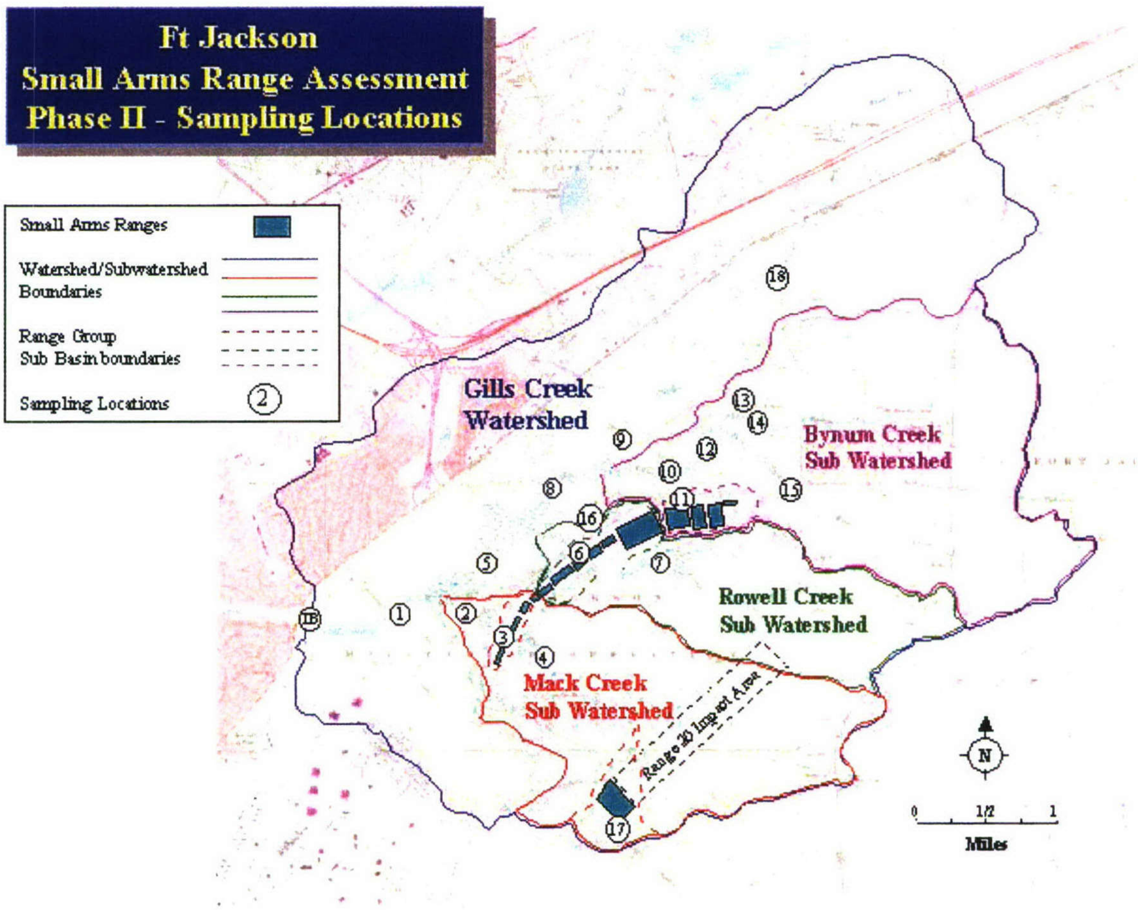


Figure 4-1. Phase II Field Sampling Locations.

TABLE 4-1. SUMMARY OF PHASE II SAMPLING LOCATIONS AND PARAMETERS

Site No.[1]	Location	Sample Type	Analysis to be Performed	Analysis Rationale	Comments
IB	Installation Boundary	Surface Water	WQP, D/TL, TSS	Surface water quality leaving installation	Stormwater grab samples.
1	Gills Creek	Surface Water Stormwater	WQP, D/TL, TSS	Surface water quality from entire range area	Stormwater grab samples.
2	Mack Creek	Surface Water	WQP, D/TL, TSS	Sampling to support mixing zone approach	
3	Mack Creek	Surface Water Stormwater	WQP, D/TL, TSS	Ambient water chemistry, impact on water quality from stormwater runoff	Stormwater grab samples.
4	Mack Creek	Surface Water	WQP, D/TL, TSS	Ambient water chemistry up gradient of ranges	
5	Gills Creek	Surface Water	WQP, D/TL, TSS	Impact on water chemistry from upstream ranges/runoff	
6	Rowell Creek	Surface water Stormwater	WQP, D/TL, TSS	Ambient water chemistry, impact on water quality from stormwater runoff	Stormwater grab samples.
7	Rowel Creek	Surface Water	WQP, D/TL, TSS	Ambient water chemistry up gradient of ranges	
8	Gills Creek	Surface Water Sediment	WQP, D/TL, TSS	Impact on water chemistry from upstream ranges/runoff	
9	Gills Creek	Surface water	WQP, D/TL, TSS	Ambient water quality/chemistry up gradient of all ranges	
10	Bynum Creek	Surface Water	WQP, D/TL, TSS	Ambient water quality of subwatershed down gradient of all ranges	
11	Bynum Creek	Surface Water Stormwater	WQP, D/TL, TSS	Ambient water chemistry, impact on water quality from stormwater runoff	Stormwater grab samples.
16	Range 1 through 9 Water Supply	Drinking Water (Groundwater)	WQP, D/TL	Lead content of on-site groundwater used as a source of drinking water	Sampling of tap in accordance with Safe Drinking Water Act.
17	Range 20 Water Supply	Drinking Water (Groundwater)	WQP, D/TL	Lead content of on-site groundwater used as a source of drinking water	Sampling of tap in accordance with Safe Drinking Water Act.
18	Gills Creek	Surface water	WQP, D/TL	Ambient water quality/chemistry up gradient of all ranges	

D/TL = Dissolved and/or total lead content.
TSS = Total suspended solids; gravimetric laboratory analysis method.
WQP = Water quality parameters (pH, temperature, turbidity, dissolved oxygen, conductivity).
1. Sample site numbers 12 through 15 were not sampled either due to no water being present (intermittent streams) at the time of sampling or restricted access at the time of sampling.

4.1 Surface Water and Stormwater Sampling

Surface water locations were chosen to assess the impact of the range activities on the individual subwatersheds, and then the impact of each subwatershed on the Gills Creek watershed by using the common upstream and down stream sampling pairs placed above and below a critical discharge point. Sampling was originally planned to collect ambient surface water samples during each season over a 1-year period, for a total of four complete sampling rounds. Stormwater grab samples collected at various times from the same locations as the ambient samples would then be used to attempt to gage the impact of stormwater runoff from the range areas on stream water quality with respect to lead and total suspended solids content.

Three ambient surface water sampling events were conducted. These were performed in June 2001 (summer), November 2001 (fall), and January 2002 (winter). During these samplings, not all originally selected sampling points were accessible either due to training/firing on the ranges or thick vegetation that prevented access to these areas. Originally planned sampling locations that were either inaccessible or eliminated after an initial attempt to sample are listed below.

- Site 4 Mack Creek - inaccessible after first sampling due to range firing/training
- Site 5 Gills Creek – inaccessible after first sampling
- Site 7 Rowell Creek – eliminated after first sampling as not truly up gradient of ranges influence
- Site 8 Gills Creek – inaccessible due to heavy marsh vegetation
- Site 12 Bynum Creek – inaccessible due to heavy marsh vegetation
- Site 13, 14, 15 – alternates to site 12 that were never sampled

Stormwater grab samples were collected randomly throughout this period.

All surface water samples were collected using a polyethylene dipper. Samples were transferred to 500- and 1000-mL polyethylene bottles for total and dissolved lead, and total suspended solids analyses. General water quality parameters of temperature, pH, conductivity, turbidity, and dissolved oxygen were measured at sampling locations at the time of ambient water sampling. This was accomplished using a Horiba U-10 multimeter.

4.2 Groundwater Sampling

Samples were taken from the supply wells at Range 20 and the Algiers well near Range 8. The proximity of these wells to the range areas and the fact that they are used for drinking water made them possible exposure pathways for ingestion of lead to human receptors. As such, they were sampled for lead content.

Samples were collected by opening the water tap at each well, similar to the first flush sampling method prescribed in the Safe Drinking Water Act for household water taps. Samples were collected directly into 500-mL polyethylene sample bottles. General water quality parameters of temperature, pH, conductivity, turbidity, and dissolved oxygen were measured by filling a bucket with water to an adequate depth to submerge the water quality meter probes. The collection of the sample in the bucket for measuring water quality parameters results in the aeration of the water which affects the dissolved oxygen content. As a result, the dissolved oxygen measurements were not representative of the groundwater conditions. Water quality parameters were measured using a Horiba U-10 multi-meter.

4.3 Phase II Sample Analysis Methods and Equipment

All surface and groundwater samples were analyzed for lead content using either a HACH field portable lead-specific colorimeter or through traditional laboratory method ICP-MS using EPA Method 6020 (ref 17). The method reporting limit was 1.0 part per billion for total and dissolved lead concentrations.

4.3.1 Lead Analysis

A HACH lead-specific Pocket Colorimeter™ that utilizes the LeadTrak® Fast Column Extraction Method was used to determine total and dissolved lead content of all samples. This field portable instrument has a detection range of 0 to 150 micrograms per liter (ppb), and a method error limit of ±2.0 micrograms per liter (ppb) (ref 18 and 19). Samples analyzed for dissolved lead content using the HACH colorimeter were filtered using a Whatman 934-AH glass microfiber filter with 1.5 micron pore size filter.

As a quality control check of the field-portable method a number of water samples were also analyzed by performing EPA Method 6020 through ICP-MS. Lead analysis was performed using a Perkin-Elmer ICP-MS, Elan 5000 to perform Method 6020 (ref 25). This method is valid to below the single part per billion detection range. The machine was calibrated to the 1.0 to 50.0 ppb range (ref 25). Samples analyzed for dissolved lead content using Method 6020 were filtered using a 0.45 micron pore size filter.

4.3.2 TSS Analysis

Surface water samples were analyzed for total suspended solids (TSS) content in accordance with procedures listed in EPA Standing Operating Procedure (SOP) No. 462 - Analysis of Total Suspended Solids. This SOP states that TSS samples be analyzed using EPA Method 160.2, a laboratory gravimetric method (ref 7). Under this method, a 1.5 micron pore mesh size filter is dried and weighed. A specific volume of sample water is passed through the filter. The filter is then re-dried and reweighed. The difference in dry filter weight before and after passing the water through the filter provides the mass of TSS removed.

One liter of sample water was analyzed for TSS. A Whatman 934-AH glass microfiber filter with 1.5 micron filter pore size or its equivalent was used for filtering during all TSS analyses.

5. Phase II Field Sampling Data/Results

Analytical results from all rounds of ambient surface water, stormwater and groundwater sampling are listed in Tables 5-1 and 5-2. Results from the HACH colorimeter analysis of samples are shown in Table 5-1. Results from the analysis quality control exercise that reanalyzed split samples using ICP-MS performing EPA Method 6020 are shown in Table 5-2.

5.1 Ambient Surface Water Sampling Results

Twenty-five (25) ambient surface water samples were collected and analyzed with the HACH colorimeter. All surface water results are shown in Table 5-1. Duplicate analyses were performed on many samples for a total of 41 analyses performed on 25 samples for total lead concentration. No total lead concentrations were detected in the ambient surface water samples above the 50.0 ppb standard that South Carolina currently uses for ambient or stormwater influenced surface water classified as freshwater.

A total of 40 analyses were performed on the 25 ambient surface water samples for dissolved lead concentrations. HACH analysis shows all samples were non-detect (below method detection limit) to 8.0 ppb for dissolved lead concentration. These dissolved lead analyses may be suspect based on the comparison of the HACH colorimeter results with ICP-MS derived dissolved lead concentration results (See Section 5.5). A review of the ICP-MS analyzed sample results (Table 5-2) also showed dissolved lead analyses results to be low with results ranging from non-detect to 11.1 ppb.

During the June 2001 sampling, sporadic rain showers best described as short-term cloudbursts occurred several times during the sampling trip. This opens the possibility that there may have been some contribution to lead concentrations from the influence of stormwater runoff from the range areas during this sampling event, although it was not noted whether runoff was occurring in the range areas or if stream flows had increased.

5.2 Stormwater Grab Sampling Results

Eight (8) stormwater grab samples were collected and analyzed with the HACH colorimeter. All stormwater sampling results are shown in Table 5-1. Duplicate analyses were performed on all samples for a total of 16 analyses performed on the 8 samples for total lead concentration. No total lead concentrations were detected in the stormwater samples above the 50.0 ppb standard that South Carolina currently uses for ambient or stormwater influenced surface water classified as freshwater. All HACH colorimeter analyses performed for dissolved lead produced results of non-detect to 5.0 ppb concentration. These dissolved lead analyses may be suspect based on the comparison of the HACH colorimeter results with ICP-MS derived dissolved lead concentration results (See Section 5.5). A review of the ICP-MS analyzed sample results (Table 5-2) also showed dissolved lead analyses results to be low with results ranging from non-detect to 5.4 ppb.

5.3 Groundwater Sampling Results

Three groundwater samples were taken from the two water supply wells in the range area. One sample was taken from the water supply well on Range 20. Two samples were taken from the Algiers well and water supply network for Ranges 1 through 9 on Train Fire Road. One of these samples was taken from a tap at the Algiers well near Range 8 and the other was taken from a tap at the end of the water supply network at Range 1.

Results of lead analysis performed with the HACH Colorimeter shows that all samples are in the 0 to 9.0 ppb total lead concentration range. Dissolved lead analysis of these samples showed all samples to be between 0.0 and 2.0 ppb lead concentration. However, the dissolved lead analyses may be suspect based on the comparison of the HACH Colorimeter results with ICP-MS derived dissolved lead concentration results (See Section 5.5). No total lead concentrations were detected in the groundwater samples above the 15.0 ppb MCL that South Carolina uses for Class GB untreated groundwater. These results are shown in Table 5-1.

5.4 TSS Analysis Results

The analysis of TSS in all surface water samples (ambient or stormwater grab samples) was performed to investigate the hypothesis that lead concentrations in water correlate with TSS concentrations. While re-drying many filters after processing water samples, the filters had a tendency to stick to the crucible and lose filter material and mass. As such the weight of many filters after filtering TSS was less that the initial dry weight of the filter. This negates the TSS mass data generated. As such, the data is not presented in this report.

5.5 HACH Colorimeter and ICP-MS Lead Analysis QC Comparison Results

A total of 17 ambient surface water and stormwater grab samples were analyzed with both the HACH colorimeter and by performing EPA Method 6020 using a Perkin-Elmer Elan 5000 ICP-MS. The most directly comparable results are the total lead concentrations produced through each method. Dissolved lead concentrations are not directly comparable due to the fact that filters of different pore sizes were used to process samples for dissolved lead analysis. Filtering for the HACH analysis was done with a 1.5 micron filter appropriate for TSS analysis. Filtering for the ICP-MS analysis was performed with the 0.45 micron pores size filter as prescribed in the lab method.

The total lead concentrations were compared by calculating the relative percent difference (RPD) between the HACH and the ICP-MS derived values. The RPD is a measure of the precision of two replicate samples. RPD is calculated as follows (ref 32):

$$RPD = \left[\frac{(|X_1 - X_2|)}{\left(\frac{X_1 + X_2}{2} \right)} \right] \times 100$$

In this equation X_1 is the average HACH derived concentration and X_2 is the ICP-MS derived value.

Results from analyses for total and dissolved lead concentrations show similar, low-level lead concentrations. Although there are no established data quality standards for comparison of the HACH field analytical method and ICP-MS, an assumed data quality parameter of < 30% RPD was used to assess the lead concentration comparison results. The RPD results are listed in Table 5-2. The RPD of the results of the two analysis methods for total lead concentration generally indicated good precision in the total lead analyses with 5 of the 13 data sets developed showing differences in results (> 30% RPD). Two (2) of these out of specification data sets were very close to the data quality parameter limit. The total lead concentration values for the samples are in good agreement between the two analytical methods. However, this agreement of lead concentration values was not observed in the dissolved phase lead concentration comparison. In this comparison, only 2 of the 10 data sets met the data quality limit. The discrepancy in the results of the two analytical methods may be due to several reasons. For example, improper sample preparation may have affected the HACH analyses or heterogeneities in the sample may have skewed results. Additionally, the difference in filter pore sized used to prepare the samples for the HACH and ICP-MS analyses (1.5 micron vs. 0.45 micron, respectively) may account for the discrepancies. Based on this comparison, ATC believes the data presented in Table 5-1 for total lead to be representative of site conditions, but the dissolved lead may be suspect and the ICP-MS data in Table 5-2 should be used in the site assessment when possible. ATC recommends any future sample analysis be conducted by ICP-MS in accordance EPA SW846 Method 6020.

TABLE 5-1. AMBIENT SURFACE WATER, STORMWATER GRAB SAMPLE, AND GROUNDWATER SAMPLE HACH LEAD ANALYSIS RESULTS

Sample Date	Sample Location	Sample Type	pH	Conductivity, mS/cm	Turbidity, NTU	Dissolved Oxygen, mg/L	Temperature, °C	Total Lead, ppb	Dissolved Lead, ppb
6/1/01	Site 1 - Gills Creek	Ambient Surface	-	-	-	-	-	5	5
6/1/01	Range 1 Water Tap	Groundwater	-	-	-	-	-	4, 9, 2, 3	1
6/1/01	Range 20 Well Tap	Groundwater	-	-	-	-	-	0, 2	2
6/2/01	Algiers Well Tap	Groundwater	-	-	-	-	-	4	2
6/2/01	Site 9 -Gills Creek	Ambient Surface	-	-	-	-	-	2	2
6/2/01	Installation Boundary - Outfall	Ambient Surface	-	-	-	-	-	3, 5, 5	3, 3, 3
6/2/01	Site 1- Gills Creek	Ambient Surface	-	-	-	-	-	5	5
6/2/01	Site 5 - Gills Creek	Ambient Surface	-	-	-	-	-	3	2
6/2/01	Site 7 - Rowell Creek	Ambient Surface	-	-	-	-	-	12	6
6/2/01	Site 4 - Mack Creek	Ambient Surface	-	-	-	-	-	4	3
6/2/01	Site 10 - Bynum Creek	Ambient Surface	-	-	-	-	-	3, 2	2
6/2/01	Site 11- Bynum Creek	Ambient Surface	-	-	-	-	-	23	8
6/2/01	Site 6 - Rowell Creek	Ambient Surface	-	-	-	-	-	33	7
6/2/01	Site 3 - Mack Creek	Ambient Surface	-	-	-	-	-	6	3
6/2/01	Site 2 - Mack Creek	Ambient Surface	-	-	-	-	-	7	3
11/5/01	Site 3 - Mack Creek	Ambient Surface	4.8	0.005	1.0	11.1	12.9	4, 3	4, 4
11/5/01	Site 1- Gills Creek	Ambient Surface	5.1	0.01	12.0	10.9	11.5	3, 4	2, 2
11/5/01	Installation Boundary - Outfall	Ambient Surface	5.0	0.11	1.0	9.5	15.5	3, 3	4, 3
11/6/01	Site 18 - Gills Creek	Ambient Surface	5.9	0.018	1.0	8.5	12.2	1, 2	2, 2
11/6/01	Site 10 - Bynum Creek	Ambient Surface	5.0	0.007	1.5	5.6	9.2	3, 3	2, 3
11/6/01	Site 9 -Gills Creek	Ambient Surface	6.0	0.017	0.0	9.5	11.2	2, 2	1, 2
11/6/01	Site 6 - Rowell Creek	Ambient Surface	4.9	0.005	5.0	10.3	9.2	18, 15	3, 3
1/22/02	Site 2 - Mack Creek	Ambient Surface	4.7	0.01	10.0	11.2	8.7	6, 5	4, 4
1/22/02	Site 3 - Mack Creek	Ambient Surface	4.4	0.01	10.0	11.6	8.8	6, 6	2, 2
6/28/01	Site 3, No. 2- Mack Creek	Stormwater Grab		-	-	-	-	8, 12	5, 3
6/28/01	Site 3, No. 3 - Mack Creek	Stormwater Grab		-	-	-	-	9, 10	4, 2

TABLE 5-1. (CONT'D)

Sample Date	Sample Location	Sample Type	pH	Conductivity, mS/cm	Turbidity, NTU	Dissolved Oxygen, mg/L	Temperature, °C	Total Lead, ppb	Dissolved Lead, ppb
6/28/01	Site 3, No. 4 - Mack Creek	Stormwater Grab	-	-	-	-	-	16, 17	3, 5
6/28/01	Site 3, No. 5 - Mack Creek	Stormwater Grab	-	-	-	-	-	15, 16	4, 3
6/28/01	Installation Boundary - Outfall	Stormwater Grab	-	-	-	-	-	5, 4	2, 4
6/28/01	Site 1- Gills Creek	Stormwater Grab	-	-	-	-	-	4, 4	5, 3
10/6/01	Site 3 - Mack Creek	Stormwater Grab	-	-	-	-	-	4, 4	2, 3
1/21/02	Site 6 - Rowell Creek	Ambient Surface	-	-	-	-	-	10, 10	5, 5
1/21/02	Site 9 -Gills Creek	Ambient Surface	-	-	-	-	-	2, 2	1, 1
1/22/02	Site 2 - Mack Creek	Ambient Surface	-	-	-	-	-	2, 3	3, 3
1/22/02	Site 3	Ambient Surface	-	-	-	-	-	5, 5	3, 3
2/6/02	Site 3	Stormwater Grab	-	-	-	-	-	4, 5	2, 1

Multiple data values represent duplicate analysis of samples.
(-) Data not collected.

TABLE 5-2. COMPARISON OF SAMPLES ANALYZED BY ICP-MS AND THE HACH COLORIMETER

Sample Location	Sample Type	ATC Chemistry Lab ID	Total Lead			Dissolved Lead		
			ICP-MS, ppb	HACH[1], ppb	RPD, %	ICP-MS, ppb	HACH, ppb	RPD, %
Boundary at Outfall	Ambient Surface Water	1020500142	1.3	3, 3	79.1	<1.0[4]	4, 3	-[3]
Gills Creek at Boyden Arbor Rd	Ambient Surface Water	1020500138	3.7	3, 4	5.6	1.1	2, 2	58.1
Site 3 - Mack Creek	Ambient Surface Water	1020500140	2.9	4, 3	18.8	<1.0[4]	4, 4	-[3]
Boundary at Outfall	Ambient Surface Water	1020500144	1.7	NA[2]	-[3]	<1.0[4]	NA[2]	-[3]
Site 6 - Rowell Creek	Ambient Surface Water	1020500148	22.9	18, 15	32.5	10.7	3, 3	112.4
Site 6 - Rowell Creek	Ambient Surface Water	1020500149	NA[2]	NA[2]	-[3]	11.1	NA[2]	-[3]
Site 9 - Gills Creek	Ambient Surface Water	1020500150	<1.0[4]	2, 2	-[3]	1.0	1, 2	40.0
Site 18 - Gills Creek	Ambient Surface Water	1020500146	<1.0[4]	1, 2	-[3]	<1.0[4]	2, 2	-[3]
Site 6 - Rowell Creek	Ambient Surface Water	1020500153	12.2	10, 10	19.8	9.5	5, 5	62.1
Site 9 - Gills Creek	Ambient Surface Water	1020500154	1.6	2, 2	22.2	1.6	1, 1	46.2
Site 18 - Gills Creek	Ambient Surface Water	1020500152	1.2	3	85.7	<1.0[4]	NA[2]	-[3]
Site 2 - Mack Creek	Ambient Surface Water	1020500156	7.5	6, 5	30.1	3.5	4, 4	13.3
Site 3 - Mack Creek	Ambient Surface Water	1020500157	5.4	6, 6	10.5	2.9	2, 2	36.7
Bynum Creek Site	Ambient Surface Water	1020500155	2.0	5, 5	85.7	1.4	3, 2	56.4
Site 1 - Gills Creek	Stormwater Grab	1020500135	11.3	4, 4	95.4	5.4	5, 3	29.8
Outfall at Boundary	Stormwater Grab	1020500136	5.6	5, 4	21.8	<1.0[4]	2, 4	-[3]
Site 3, No. 3 - Mack Creek	Stormwater Grab	1020500137	3.1	4, 4	25.4	1.1	2, 3	77.8

1. Multiple data values represent duplicate analysis of samples.
2. NA = Not analyzed.
3. RPD cannot be calculated either due to one or more samples was not analyzed or analysis results were below the method detection limit.
4. Below method detection limit.

6. Conclusions for Fort Jackson Small Arms Ranges

The analytical results for ambient surface water, stormwater, and groundwater help validate the conceptual site models for the Mack, Bynum, and Rowell Creek subwatersheds as well as the Gills Creek watershed overview (Section 3.5). A discussion of each transport pathway follows.

6.1 Surface Water Transport

Analytical results from the three rounds of ambient surface water sampling suggest the range areas are contributing to low-level lead concentrations in ambient surface waters adjacent to the range areas. The ambient surface water sample results (HACH or ICP-MS methods) show total and dissolved lead levels well below the 50.0 ppb South Carolina standard for surface waters classified as freshwater.

Data from initial site inspections and the information collected on the characteristics and use of the range area initially inferred that the Rowell creek subwatershed would likely be the most impacted by range activity due to the following factors: 1) the relatively small size of the subwatershed; 2) the largest number of ranges in the subwatershed; 3) data that suggests the highest relative soil erosion and transport problem; 4) lack of stormwater management structures, and; 5) the amount of rounds fired on the ranges. The results of the surface water sampling under ambient flow conditions support this inference. Table 5-1 shows the results of all surface water sampling under normal flow conditions. Rowell Creek consistently showed the relative highest concentrations of lead when compared to the Mack and Bynum Creek subwatersheds.

The surface water in the Fort Jackson area has been suggested to have elevated levels of lead and other metals over what may typically be found in surface waters (ref 20 and 24). This elevated level has not been defined for lead. The City of Columbia, South Carolina, which draws most of its drinking water from surface water resources in the region, reported a lead level of 3.0 ppb in the year 2000 public water supply annual water quality report (ref 26). This lead concentration remains in the finished water after treatment. This assumed background reference value indicates that lead levels in local surface waters are naturally elevated and may account for a portion of the lead detected in ambient surface waters during sampling. The lead levels in Columbia's treated water are similar to what was detected in Fort Jackson's ambient surface water downstream of the small arms range areas and in some cases immediately adjacent to the range area.

All four creeks (Gills, Mack, Rowell, and Bynum) are classified as freshwater resources. This classification means they are suitable for primary and secondary contact and as a drinking water source only after treatment. A review of the water quality parameters taken during sampling shows the surface waters in each creek could be considered low quality based on the pH values alone. To attempt to treat these waters for use as a drinking source would require substantial buffering to raise the pH levels to the neutral values (~ pH 7.0) that are typically required of water supply systems. Any buffering might act as a metals precipitation treatment process that could remove these low-level lead concentrations. The sum of all these factors is that these waters are naturally low quality, they would be required to undergo treatment for use as a drinking water source based on their classification, and any required treatment should be able to address the low-level lead concentrations.

6.2 Stormwater Runoff Transport

Stormwater grab sampling data from 28 June 2001 suggest that stormwater discharge to the creeks is increasing lead concentrations in each creek. It is possible that any increases in lead concentrations from stormwater sampling could also be from creek sediments that contain lead residues that are being re-suspended with the increased flow volumes and turbulence that result from runoff waters discharging into the creek. The creek stormwater sample results (HACH or ICP-MS methods) show total and dissolved lead levels well below the 50.0 ppb South Carolina standard for surface waters classified as freshwater.

Previous stormwater sampling performed by the South Carolina DHEC showed lead concentrations elevated well above the 50.0 ppb level (Table 3-6). At the time these samples were taken, the small arms range areas represented the training areas that experienced some of the highest amounts of soil erosion and land degradation at Fort Jackson as a result of routine training activities. Since these samples were taken, Fort Jackson has embarked on substantial land reclamation and stormwater management projects to control erosion from the small arms ranges. The limited sampling conducted under this assessment indicates that the actions taken by Fort Jackson have resulted in a substantial reduction in lead mobility from the small arms areas.

Based on a review of sampling data and site conditions, increases in lead or TSS content in the stormwater will be attenuated prior to reaching the installation boundary where Gills Creek flows under Interstate 77. Stormwater grab sampling data at the installation boundary from 28 June 2001 show lead concentrations in the 4-5 ppb range similar to sampling results under ambient flow conditions at this location. In addition, between the small arms range area and the installation boundary, each subwatershed creek flows through marshy areas before discharging into Gills Creek. Gills Creek itself is characterized as a heavily vegetated, marshy area. Gills Creek must also flow through Boyden Arbor pond prior to flowing off the installation. These two environments (marsh and pond) act as natural filters to slow down and trap sediments by a decrease in water velocity and a subsequent decrease in the water's ability to carry sediment loads, as well as by the large amount of organic matter in the marshes that may bind or adsorb metals in runoff waters. There are substantial, natural filtering mechanisms in place at Ft Jackson that are mitigating lead and TSS concentrations in stormwater runoff flowing from the small arms range area in the Gills Creek watershed. These filtering mechanisms and the distance to the installation boundary appear to act cumulatively to attenuate range pollutants below regulatory limits. The distance between the range area and installation boundary may be able to be considered a surface water discharge "mixing zone" similar to what might be delineated for a point source discharge. South Carolina code recognizes the concept of mixing zones in surface waters for point source discharges (ref 10). Although the discharges from the small arms ranges and impact areas are non-point stormwater discharges, this concept may be able to be applied to the surface waters leaving the range areas at Ft Jackson. Immediately adjacent to the ranges there is an increase in pollutants from range area discharges, but given the adequate "mixing zone" contained completely within Ft Jackson there is attenuation of these pollutants prior to the surface waters leaving the installation boundary.

Stormwater data to investigate the assumption that the water quality of Rowell Creek would be most impacted by range activities, including the most impacted by stormwater runoff, was not collected. However, it is still suggested that this is likely the case based on the previously described site factors and relative subwatershed characteristics.

6.3 Groundwater Transport

Shallow groundwater immediately beneath and hydraulically down gradient of Ranges 1 through 13 and 20 is likely impacted by range activity in some areas of the small arms ranges. This conclusion is based primarily on an evaluation of the typical site conditions as well as supported by shallow groundwater sampling performed at Range 2. The areas where rounds impact consists of very sandy soil (typically >80 percent sand content) with acidic pH ranges of 4.5 to 6.5. Groundwater samples collected from a shallow well in this area showed very high lead concentrations (Table 3-4). Other areas of the small arms ranges consist of sandy surface soils with interstitial clay layers that act as a confining unit limiting infiltration of lead into the groundwater. Samples collected from shallow wells installed in these areas showed very low lead concentrations (< 50.0 ppb) indicating that the clay layers provide some protection from lead migration to the deep aquifers. In addition there is indirect support through the sampling under ambient flow conditions of the three creeks. Mack, Rowell, and Bynum creeks are believed to serve as the base flow discharge points for shallow groundwater for all of the ranges.

The definition of shallow groundwater is based on a generalized and accepted understanding of idealized groundwater flow and the various components that comprise groundwater (base flow, interflow, groundwater recharge, etc.). Where confining clay layers do not exist, precipitation that percolates through range soils and impact berms is likely gaining a dissolved lead fraction that is then contributed as a part of total base flow recharge to the three creeks. The stream base flow that may be affected by the ranges represents only a portion of the total flow into each creek and, as such, there is likely a significant dilution effect of clean water mixing with water containing increased dissolved lead fractions from the range areas. The net results of the base flow discharge and dilution may be the low lead concentrations seen in ambient surface water sampling results.

Impacts on groundwater are primarily believed to be limited to the shallow base flow discharging to the creeks. This is based on the sandy, permeable soils and hilly topography in the range area that likely allows water to generally percolate quickly towards the creek discharge points. The assumption that shallow base flow is the main groundwater component that will likely be affected by percolating precipitation is supported by the fact that during sampling conducted in November 2001, the drainage channel that serves all the ranges in the Bynum Creek subwatershed went dry. Fort Jackson had been experiencing a drought for much of the year prior to the sampling and as a result there was little to no base flow recharge flowing into this channel. Sampling of the Twin Lakes well by the State of South Carolina has never shown a lead concentration at or above the State MCL. From hydraulic equipotential lines published by the USGS (ref 2) for the aquifer underneath Fort Jackson, groundwater flow lines have been inferred that show deep groundwater at the small arms range area moves further into the installation and towards the Twin Lakes well. Additionally, the South Carolina Code states that if groundwater contamination is contained solely within a property owner's boundary and the contamination would be impractical to clean up, then the state can grant a waiver. Combining all this information suggests that even if regional aquifers at Fort Jackson were being impacted, the impact would be contained within the boundaries of the installation and Fort Jackson could seek a waiver. In addition, sampling results (Table 5-1) from the two wells adjacent to Range 8 and Range 20 yielded lead concentrations below the State MCL. This data suggests that deep regional groundwater is not being impacted by the small arms range activity. Any lead concentrations introduced to "groundwater" may be restricted to the shallow base flow, or are quickly being diluted out in the deep groundwater flow regime.

The ranges at Fort Jackson have operated for many years, some ranges for decades. If there is an impact, as appears to be the case with local, shallow groundwater, there is no reason to believe that the impact will increase or decrease significantly in a short period of time. Groundwater impacts are also likely localized and quickly dilute out in the groundwater flow regime or in the creeks in the range area into which the shallow groundwater base flow discharges.

6.4 Air Transport

Air transport of lead dusts is not considered to be a factor of concern at Fort Jackson. The phenomena does occur but the distances that dusts can be transported from the range are likely minimal. As noted in the Army Sampling and Analysis Plan (ASAP) (ref 11), previous studies indicated that the maximum travel distance of lead dusts from mine tailings piles was 300 meters over open, flat terrain. Most ranges at Fort Jackson are surrounded by forest and/or soil berms that likely serve as effective barriers or filters to the air transport of dusts. No sensitive areas or receptors (such as housing areas) were identified to be within 300 meters of any of the small arms firing ranges. This leaves the only issue from air transport of lead dusts to be a possible industrial hygiene issue for range maintenance personnel. Additionally, the short distance movement of lead dusts will likely be accounted for in the stormwater runoff. Any dusts that land on the ground surface or surfaces of plants may be washed away and transported in stormwater runoff. Monitoring stormwater runoff for lead and TSS concentrations would likely also include any fraction of lead fines originally transported short distances by wind action.

7. Recommendations for Fort Jackson Small Arms Ranges 1 through 13, and Range 20 Training Area

7.1 General Recommendations

- Fort Jackson should continue and expand on previously successful efforts at revegetating barren range areas with native grass species. This should continue in response to the previous Notice of Violation issued by the State of South Carolina for excessive soil erosion in the training area, and would be consistent with the proactive range sustainment policies currently in effect at Fort Jackson. Future efforts should include a focus on revegetating as thoroughly as possible all small arms ranges, in particular the impact berms, range floors, and surface water drainage pathways immediately on and around Ranges 1 through 13.

- The impact berms on most of these ranges typically lack significant vegetation on all berm faces. This is due in part to the current range maintenance procedure of completely regrading or smoothing the berm faces approximately once a year. A result of this practice is the destruction of any vegetation that has been established on the berm, and in at least one recent instance, vegetation that was the direct result of several years worth of reclamation efforts was wiped out by wholesale regrading of the berm face. Range personnel should discontinue the practice of wholesale regrading of impact berm faces on an annual basis for the reasons discussed above. Filling bullet pockets back in with soil, although more time consuming and labor intensive, is a preferable range maintenance practice than complete berm regrading.

- Improve the coordination of range maintenance activities between the Range Manager and the Chief of the Basic Rifle Marksmanship (BRM) Headquarters with the troop training and range maintenance missions, and the ITAM Coordinator and Environmental office with the land management and compliance missions on the ranges. Activities on the ranges from all of these organizations should be complimentary and not work counter to each other as in the instance noted above.

- Discontinue the routine mowing of grasses on all range floors behind the target line. If this is undesirable mow grasses to a minimum height of 4 inches and only frequently enough to prevent vegetation from interfering with training or transitioning to woody shrubs and small trees. Vegetation is the most effective soil stabilization and stormwater management practice available. These are the two primary issues that need to be and can be addressed at any small arms ranges through relatively simple management efforts.

- Consider re-evaluation of the flow directions in the constructed stormwater management system in the range areas. In at least one instance, the system directs runoff water from the comparatively clean firing position end of the range down to the impact berm. This needlessly increases the chances of transporting eroded soils and lead residues into a nearby creeks by increasing the volume of water that flows through the range areas with the highest lead concentrations. One goal of stormwater management should be to minimize the volume of water that flows through the areas with the highest lead concentrations.

7.2 Specific Recommendations

Range 1: Consider eliminating several firing lanes on the end of the range adjacent to Mack Creek, and revegetate the lanes and impact berm with tall grasses or transition to a combination of grasses, shrubs and small trees. This will create a larger riparian zone between the range and creek, and would improve the quality of runoff water from the range. Vegetation in this area or zone influences soil erosion in several ways: (1) foliage and leaf residues intercept rainfall and dissipate energy, (2) root systems physically bind or restrain soil particles, (3) residues increase surface roughness and slow velocity of runoff, (4) roots and residues increase infiltration by maintaining soil porosity and permeability, and (5) plants deplete soil moisture through transpiration, giving the ground a "*sponge effect*" to allow it to absorb water (ref 29).

Range 2: Consider eliminating up to five firing lanes from the end of the range immediately adjacent to Mack Creek. Due to a fairly steep surface gradient and the clay layer underneath the range that prevents percolation or infiltration of precipitation, stormwater runoff volumes are a particular issue on this range. This runoff drains directly into Mack Creek. Eliminating firing lanes would allow for an increase in the width of the vegetated buffer zone (riparian zone) between the range and the creek, and allow more room to let water plane out as sheet flow into an increased buffer zone. This would also allow more room to refurbish and increase the size of the sediment pond previously constructed for stormwater management, if so desired, although improving the riparian zone should provide adequate filtration of sediments suspended in the runoff.

Range 3: Consider lining the large gulley immediately behind the impact berm with marble or limestone rip rap, possibly with a geotextile fabric underneath the rip rap. Rip rap has been placed underneath the outfall pipe of a stormwater detention pond that empties into this gully, and piled in at least one location within the gulley to break the energy of flowing stormwater runoff. Visual inspection shows that the stormwater has simply flown around the rip rap placed within the gully by gouging out a new path around the pile of rip rap. It may be more effective to make a thorough, but flat lining of the bottom of the gulley with rip rap similar to a natural cobble lined streambed. The stormwater will have to flow over and somewhat through this uneven surface. This will help break the energy and erosive power of the water. If further measures are necessary to slow the runoff flow, then incorporate check dams into this design. Using marble or limestone is presumed to have an additional benefit of providing an amount of chemical buffering to the water and may help reduce dissolve lead concentrations that may be within the runoff waters. This technique has been used for acid mine drainage buffering and is recommended by EPA Region 2 for small arms ranges (ref 30). Although recommended by the EPA, at this point in time there is no definitive performance or design guidance for applying this method of chemical buffering to small arms ranges.

Ranges 4, 5, 6, 7: No specific recommendations beyond the general recommendations previously listed in section 7.1.

Range 8: There is a fairly steep surface gradient to the wide channel in front of the impact berm on Range 8. A silt fence previously installed across this channel was observed to have been knocked down, presumably overwhelmed by runoff water volumes and sediment loads. Consider installing a series of rip rap check dams (or similarly functioning technology) across this channel to break the energy of the runoff and help trap sediments.

It is also recommended that stormwater flow patterns on the range near the road and firing positions be examined for possible alteration. A portion of the water from this area is eventually directed to the left side of the range and back to the drainage area behind the impact berm (Figure 7-1). Consider altering the flow of water in this area so that it moves towards the drainage ditch adjacent to the road and then alter the entire flow of this drainage ditch so that it moves towards the right side of Range 8 (towards Range 7 and Rowell Creek). This will reduce the volume of runoff water that flows into the impact berm area and its drainage area. This recommended alteration is shown in Figure 7-2.

Range 9: This range has the single biggest impact on its respective watershed due to its size, the amount of use, volume of lead input, the substantial soil erosion and transport that are visually evident, and the nature of stormwater drainage patterns on the range. Currently all water running off the surface of Range 9 eventually flows towards and past the toe of the impact berm before flowing under a side safety berm through a drainage pipe (Figure 7-3). Site inspections of the drainage area reveal the amount of eroded soils being transported through this pipe are substantial. A possible way to prevent all the surface water draining off the range from contacting eroded soils and lead residues at the toe of the impact berm would be to install a shallow interceptor berm and trench in front of the impact berm. All runoff water would still discharge through the one central pipe on the side of the range but without all the water contacting and likely picking up and transporting a sediment and lead load from the soils at the toe of the impact berm. This recommended alteration is shown in Figure 7-4. At the toe of the impact berm, consider installing a series of water bars across the drainage path to slow down runoff waters and trap sediment loads.

It is also recommended that stormwater flow paths on the range near Train Fire Road and the firing positions be examined for possible alteration. A great deal of water from areas across Train Fire Road from Range 9 and water from near the firing positions on Range 9 is eventually directed back to the drainage area behind Range 8's impact berm (Figure 7-3). Consider altering the flow of water in this area so that it stays within the drainage ditch adjacent to Train Fire Road and flows past Ranges 8 and 7 towards Rowell creek. This will reduce the volume of runoff water that flows into the impact berm area and its drainage area. This recommended alteration is shown in Figure 7-4.

There is an area of seasonal standing water behind the impact berm on Range 9. This pond appears to have been formed by the construction of the berms serving as roads in this area (Figure 7-3). The berms have cutoff the natural surface drainage patterns trapping runoff water. This area is a direct impact zone for Range 9. A large amount of bullets and fragments are clearly visible on the ground surface as a result of rounds being fired over the berm. The pond in this area creates conditions very conducive to the dissolution of lead from bullet fragments. The water in this pond was not sampled but it may have an elevated lead concentration based on the site conditions. There was also evidence that the water is being used by wildlife. Combining the lead dissolution and wildlife use issues, it is recommended that alterations be performed in this area that will allow surface water in the area to drain and eliminate the seasonal pond. This recommended alteration is shown in Figure 7-4.

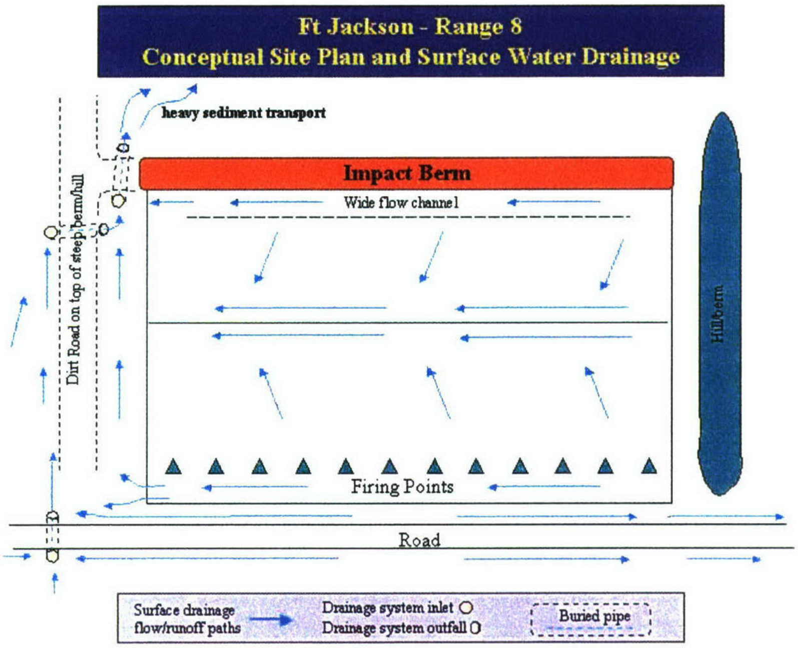


Figure 7-1. Range 8, Existing Drainage.

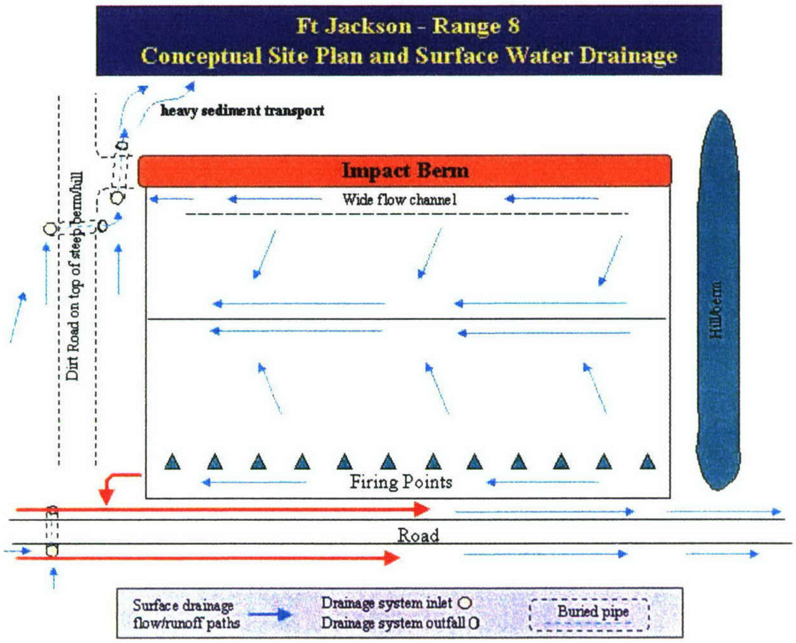


Figure 7-2. Recommended Changes to Range 8 Drainage.

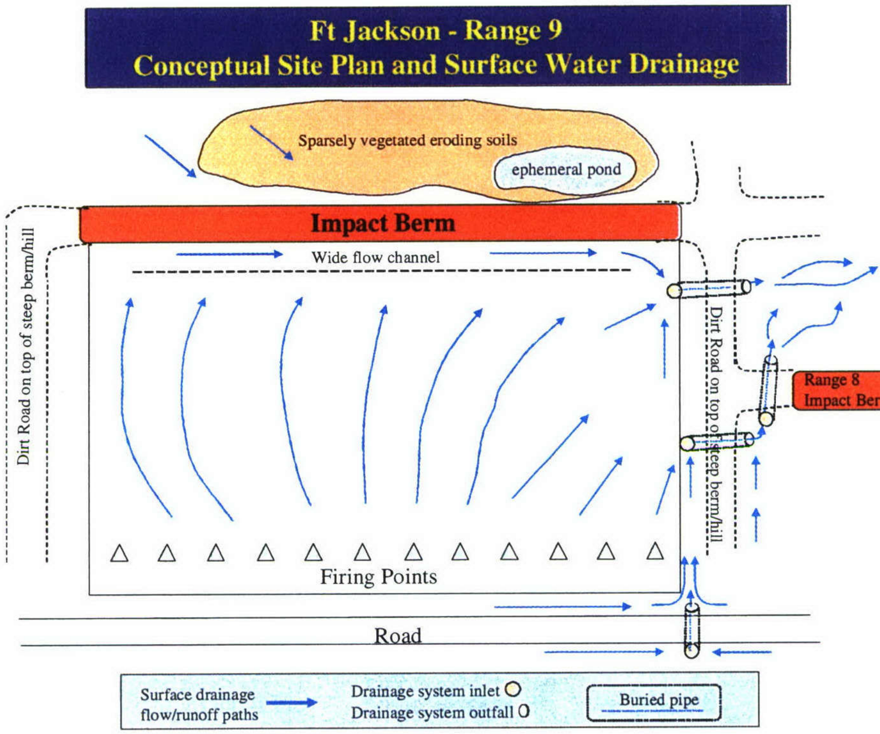


Figure 7-3. Range 9, Existing Drainage.

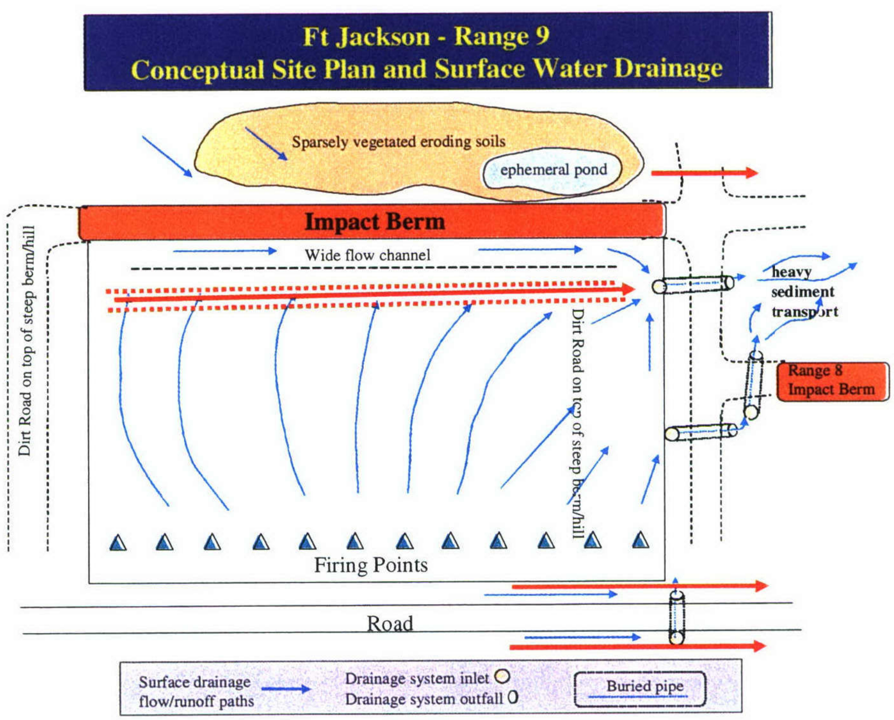


Figure 7-4. Recommended Changes to Range 9 Drainage.

Ranges 8 and 9: The stormwater runoff from both of these ranges currently flows to the same general area behind the impact berms on Ranges 7 and 8, eventually discharging into Rowell Creek behind Range 7. A distinct drainage channel was noted in the wooded area behind Range 8. In an effort to improve stormwater runoff quality by reducing sediment transport, it is recommended that the drainage area behind Range 8 be examined for possible installation of a stormwater detention pond (or other management structures/efforts) to help manage the runoff waters from Ranges 8 and 9. This area is shown in Figure 7-5.

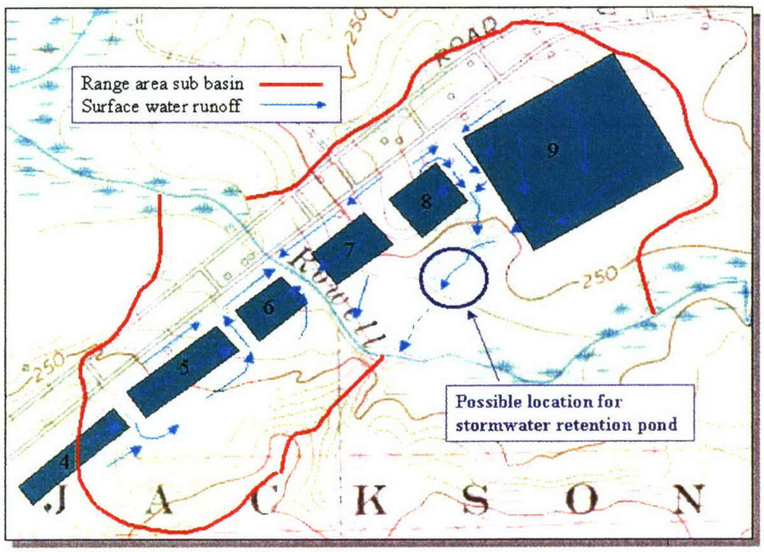


Figure 7-5. Recommended Locations for Stormwater Runoff Management Efforts for Ranges 8 and 9.

Ranges 10, 11, 12, and 13: No specific recommendations beyond the general recommendations previously listed in section 7.1.

Range 20: It was noted during discussions with Fort Jackson personnel (ref 24) that removing trees and brush between firing lanes on Range 20 has previously been suggested. ATC does not support this suggestion. The trees and brush between lanes represent the perfect soil stabilization and stormwater runoff solution for this range, particularly given the sloping nature of the range and that the tree/brush lines are somewhat perpendicular to this slope, which is the preferred angle for such a buffer line. The trees and brush also contribute to the realism of the training on the range. No other specific recommendations beyond the general recommendations previously listed in section 7.1.

7.3 Future Range Area Monitoring

7.3.1 Stormwater/Surface Water Monitoring

Instituting a program for monitoring the impact of stormwater runoff on water quality in the three range subwatersheds and for water leaving the installation through Gills Creek is recommended. Possible monitoring locations for the three sub watersheds in the immediate range area are shown in Figures 7-6 through 7-8. Monitoring for off-installation stormwater transport could be performed at the point where Gills Creek leaves the installation boundary.

The screening level sampling by ATC suggests that the ambient surface water in the three subwatersheds typically falls below the 50.0 ppb lead content standard that the South Carolina Department of Health and Environmental Control currently uses to judge surface waters quality. However, the limited amount of stormwater sampling performed suggests, that when under the influence of stormwater runoff, the lead content in the three creeks increases and may potentially exceed this standard. In addition, the South Carolina Department of Health and Environmental Control may lower the standard for surface water classified as freshwater to 15.0 ppb. If this were to come about, the ambient surface water and stormwater in the creeks adjacent to and immediately downstream of the constructed range areas are most likely to exceed this new standard, however, water quality at the installation boundary should easily meet this requirement. At this location, water quality should continue meeting South Carolina standards as long as erosion control measures are maintained within the range areas.

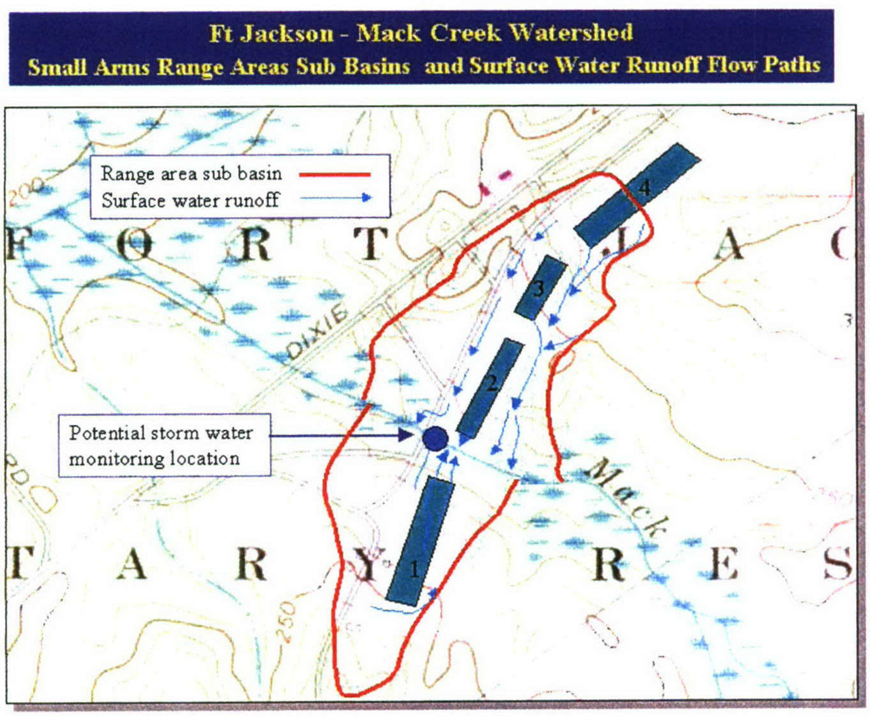


Figure 7-6. Potential Mack Creek Range Area Stormwater Monitoring Location.

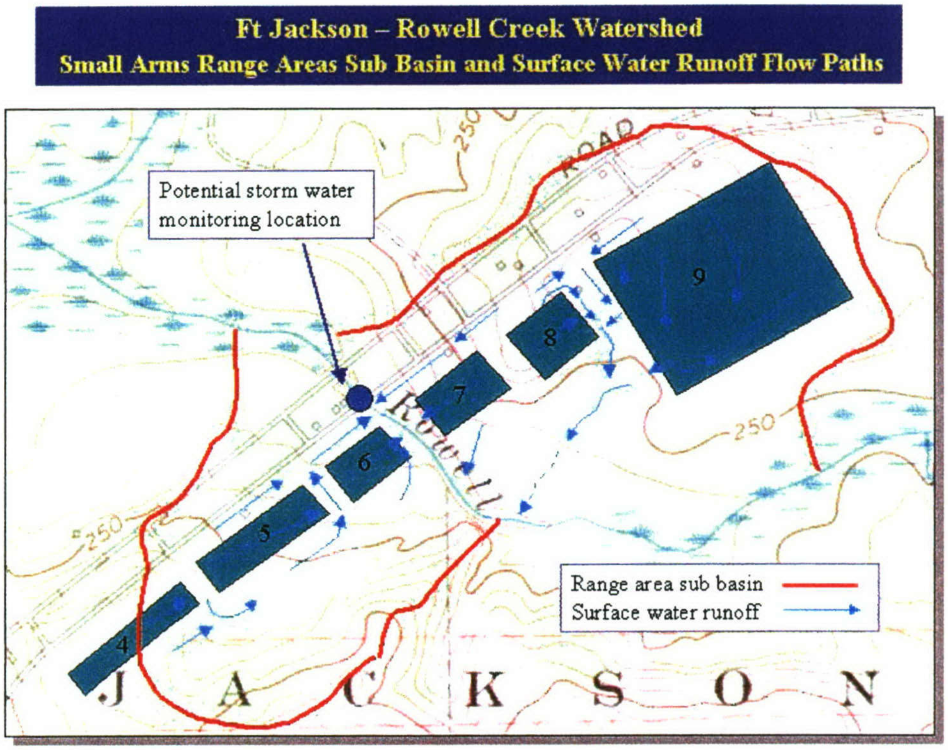


Figure 7-7. Potential Rowell Creek Range Area Stormwater Monitoring Location.

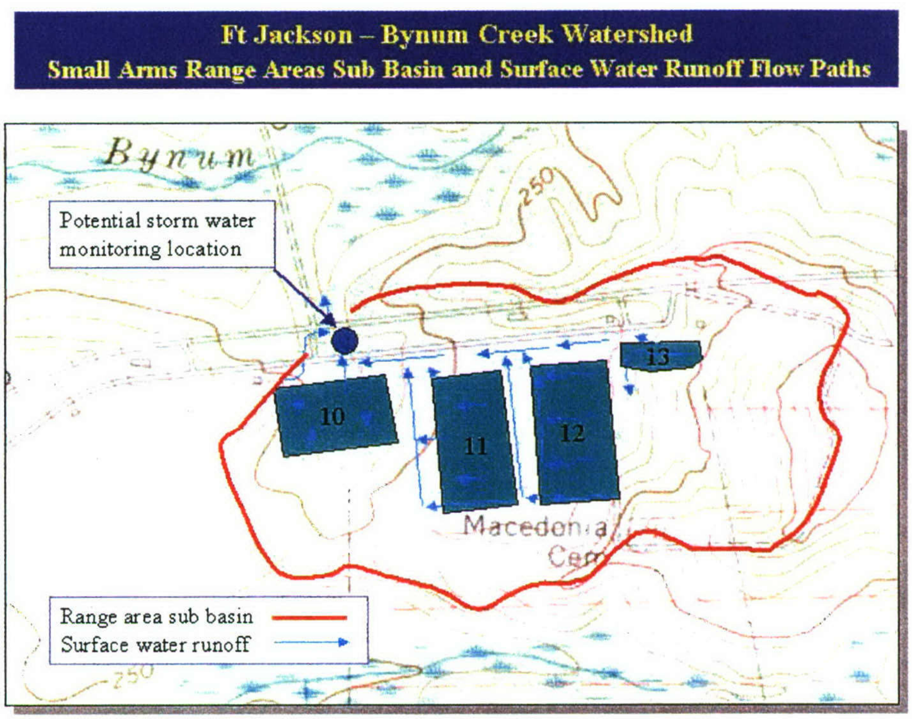


Figure 7-8. Potential Bynum Creek Range Area Stormwater Monitoring Location.

7.3.2 Groundwater Monitoring

Two water supply wells are within or near small arms Ranges 1 through 13 and 20, the Algiers well near Range 8, and the well at Range 20. These are the only identified potential receptors for groundwater that may be influenced by the small arms ranges. Given the proximity to the ranges, the potentially large withdrawal volume from the Algiers well due to its supplying Ranges 1 through 13, and based on a review of the South Carolina Code of Regulations that appears to expand on the EPA definition of a public drinking water supply to include small supply well such as these, routine monitoring of these wells for lead content is recommended. In the sampling and analysis performed by ATC, all samples from these wells were below the Safe Drinking Water Act action limit of 15.0 ppb lead content.

7.3.3 Air Monitoring

Air monitoring is not recommended for the small arms range area. No sensitive areas or receptors were identified within the assumed three hundred meter maximum travel distance for range generated dusts.

8. References

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Appendix A. Rest Model Input Data

Appendix A includes a listing of the various parameters that were used as input data for the REST model evaluations of the ranges at Fort Jackson. The REST model requires the input of a large amount of local climate date. This is found in table A-1. Site specific information on the ranges such as type and amount of training, local soils, vegetation cover, etc., are found in table A-2.

TABLE A-1. FORT JACKSON CLIMATE DATA FOR REST MODEL INPUT

Month	Mean Min Temp (°F)[1]	Mean Max Temp (°F)[1]	Mean Precipitation (inches)[1]	Mean Wind Speed (miles/hr)[2]	Peak Gust (miles/hr)[2]
Jan	32.1	55.2	4.4	7.1	54.0
Feb	34.4	59.2	4.1	7.6	69.0
Mar	42.1	68.1	4.8	8.2	69.0
Apr	49.5	76.6	3.3	8.2	61.0
May	58.3	83.5	3.7	6.9	59.0
Jun	66.1	89.0	4.8	6.5	78.0
Jul	70.1	91.8	5.5	6.3	64.0
Aug	69.4	90.2	6.1	5.6	56.0
Sep	63.3	85.3	3.7	6.0	70.0
Oct	50.1	76.5	3.0	5.9	54.0
Nov	41.5	67.7	2.9	6.2	51.0
Dec	35.0	58.8	3.6	6.6	49.0

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TABLE A-2. REST MODEL SITE DATA INPUT PARMAETERS PER RANGE.

Data Element	Range #20	Range #1	Range #2
Watershed	Mack Creek	Mack Creek	Mack Creek
Regulatory Classification	Freshwater	Freshwater	Freshwater
Type/Quantity of Rounds Fired	M855 ball (5.56mm); 1,798,000/yr	M855 ball (5.56mm); 410,000/yr	M855 ball (5.56mm); 40,000/yr
Total Years Range in Use	50 (assumed)	50 (assumed)	50 (assumed)
Range Type	Qualification	25 Meter Zero	25 Meter Zero
Range Maintenance Frequency	Yearly	Yearly	Yearly
Size of Range	Unknown	2 acres	2 acres
Depth to Water	6 feet (assumed)	6 feet (assumed)	6 feet (assumed)
Depth to Potable Water	75 feet (assumed)	75 feet (assumed)	75 feet (assumed)
Vegetative Cover in Drainage Area (%)	100	100	50
Vegetative Cover on Berm (%)	NA	0	0
Berm Dimensions	None	Length - 243 ft, Height -15 ft, Width @ base - 25 ft, Width @ top - 8 ft	Length - 243 ft, Height -15 ft, Width @ base - 25 ft, Width @ top - 8 ft
Distance to Nearest Down Gradient Surface Water	Mack Creek ~ 6300 ft	Mack Creek ~200 ft	Mack Creek ~ 20 ft
Shortest Distance to Installation Boundary	17,623 ft	9,063 ft	9,063 ft
Distance to Gills Creek	11,441 ft	3,310 ft	3,310 ft
Monthly Temperature and Precipitation Data	See Table A-1	See Table A-1	See Table A-1
Monthly Wind Data	See Table A-1	See Table A-1	See Table A-1
USDA Soil Texture	Loamy Sand	Sand	Loamy sand/sand
pH of soil	5	5.1	5
Cation Exchange Capacity	1.5	2.5	3.3
Organic Content	1	0.5	1.5

TABLE A-2. REST MODEL SITE DATA INPUT PARMAETERS PER RANGE. (CONT'D)

Data Element	Range #3	Range #4	Range #5
Watershed	Mack Creek	(1/2)Mack Creek - (1/2)Rowell	Rowell Creek
Regulatory Classification	Freshwater	Freshwater	Freshwater
Type/Quantity of Rounds Fired	M855 ball (5.56mm); 5,000/yr	M855 ball (5.56mm); 430,000/yr	M855 ball (5.56mm); 494,000/yr
Total Years Range in Use	50 (assumed)	50 (assumed)	50 (assumed)
Range Type	25 Meter Zero	25 Meter Zero	25 Meter Zero
Range Maintenance Frequency	Yearly	Yearly	Yearly
Size of Range	3 acres	4 acres	3 acres
Depth to Water	6 feet (assumed)	6 feet (assumed)	6 feet (assumed)
Depth to Potable Water	75 feet (assumed)	75 feet (assumed)	75 feet (assumed)
Vegetative Cover in Drainage Area (%)	70	60	90
Vegetative Cover on Berm (%)	0	0	0
Berm Dimensions	Length - 153 ft, Height - 8ft, Width @ base 20 ft, Width @ top - 8 ft	Length- 450 ft, Height- 8 ft, Width @ base - 25, Width @ top - 6 ft	Length - 1004 ft, Height - 10 ft, Width @ base - 25 ft, Width @ top - 5 ft
Distance to Nearest Down Gradient Surface Water	Mack Creek ~ 1,000 ft	Mack Creek ~ 1,300 ft	Rowell Creek ~ 500 ft
Shortest Distance to Installation Boundary	11,426 ft	10,844 ft	13,359 ft
Distance to Gills Creek	4,728 ft	4,661 ft	3,900 ft
Monthly Temperature and Precipitation Data	See Table A-1	See Table A-1	See Table A-1
Monthly Wind Data	See Table A-1	See Table A-1	See Table A-1
USDA Soil Texture	Loamy sand, sandy clay	Loamy sand, sandy clay	Loamy sand, sandy clay
pH of soil	5.2	5.2	5.2
Cation Exchange Capacity	1.3	1.3	1.3
Organic Content	0.8	0.3	0.8

TABLE A-2. REST MODEL SITE DATA INPUT PARMAETERS PER RANGE. (CONT'D)

Data Element	Range #7	Range #8	Range #9
Watershed	Rowell Creek	Rowell Creek	Rowell Creek
Regulatory Classification	Freshwater	Freshwater	Freshwater
Type/Quantity of Rounds Fired	M855 ball (5.56mm); 242,000/yr	M855 ball (5.56mm); 331,000/yr	M855 ball (5.56mm); 3,185,000/yr
Total Years Range in Use	50 (assumed)	50 (assumed)	50 (assumed)
Range Type	NBC night	NBC night	Prequalification
Range Maintenance Frequency	Yearly	Yearly	Yearly
Size of Range	3 acres	3 acres	39 acres
Depth to Water	6 feet (assumed)	6 feet (assumed)	6 feet (assumed)
Depth to Potable Water	75 feet (assumed)	75 feet (assumed)	75 feet (assumed)
Vegetative Cover in Drainage Area (%)	100	30	20
Vegetative Cover on Berm (%)	0	0	0
Berm Dimensions	Length - 500 ft, Height - 10 ft, Width @ base - 30 ft, Width @ top - 5 ft	Length - 564 ft, Height - 11 ft, Width @ base - 35 ft; Width @ top - 10 ft	Length - 1,664 ft, Height - 17 ft; Width @ base - 40 ft, Width @ top - 10 ft
Distance to Nearest Down Gradient Surface Water	Rowell Creek ~100 ft	Rowell Creek ~1,500 ft	Rowell Creek ~1,400 ft
Shortest Distance to Installation Boundary	13,466 ft	16,200 ft	16,200 ft
Distance to Gills Creek	3,107 ft	4,341 ft	4,341 ft
Monthly Temperature and Precipitation Data	See Table A-1	See Table A-1	See Table A-1
Monthly Wind Data	See Table A-1	See Table A-1	See Table A-1
USDA Soil Texture	Loamy sand, clay appears at increased depth	Loamy sand, sandy clay	Loamy sand, sandy clay
pH of soil	5	5.2	5.2
Cation Exchange Capacity	1.5	0.8	0.8
Organic Content	1	0.8	0.8

TABLE A-2. REST MODEL SITE DATA INPUT PARMAETERS PER RANGE. (CONT'D)

Data Element	Range #10	Range #12
Watershed	Bynum Creek	Bynum Creek
Regulatory Classification	Freshwater	Freshwater
Type/Quantity of Rounds Fired	M855 ball (5.56mm); 319,000/yr	M855 ball (5.56mm); 1,657,300/yr
Total Years Range in Use	50 (assumed)	50 (assumed)
Range Type	Qualification	Misses and Hits
Range Maintenance Frequency	Yearly	Yearly
Size of Range	23 acres	5 acres
Depth to Water	6 feet (assumed)	6 feet (assumed)
Depth to Potable Water	75 feet (assumed)	75 feet (assumed)
Vegetative Cover in Drainage Area (%)	84	50
Vegetative Cover on Berm (%)	40	60
Berm Dimensions	Natural Hillside	Natural Hillside
Distance to Nearest Down Gradient Surface Water	Bynum Creek ~1,420 ft	Bynum Creek ~ 2,800 ft
Shortest Distance to Installation Boundary	18,509 ft	20,679 ft
Distance to Gills Creek	4,010 ft	6,180 ft
Monthly Temperature and Precipitation Data	See Table A-1	See Table A-1
Monthly Wind Data	See Table A-1	See Table A-1
USDA Soil Texture	Loamy sand, sandy clay	Loamy sand, sandy clay
pH of soil	5.2	5.2
Cation Exchange Capacity	0.8	0.8
Organic Content	0.8	0.8

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Appendix B. List of Acronyms

ASAP	Army Sampling and Analysis Plan
ATC	Aberdeen Test Center
BMP	Best Management Practice
BRM	Basic Rifle Marksmanship
DHEC	Department of Health and Environmental Control
EPA	Environmental Protection Agency
ITAM	Integrated Training Area Management
kg	kilogram
MCL	Maximum Contaminant Level
METDC	Military Environmental Technology Demonstration Center
MOA	Memorandum of Agreement
MW	Monitoring Well
NOV	Notice of Violation
NRCS	Natural Resource Conservation Service
ppb	parts per billion
REST	Range Evaluation Software Tool
RPD	Relative Percent Difference
SOP	Standing Operating Procedure
TSS	Total Suspended Solid
USAEC	U.S. Army Environmental Center
USDW	Underground Source of Drinking Water
USGS	U.S. Geological Service
WWII	World War II

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