A GIS MODEL FOR MINEFIELD AREA PREDICTION:
The Minefield Likelihood Procedure

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(ABSTRACT)

Existing minefields left over from previous conflicts pose a grave threat to humanitarian relief operations, domestic everyday life, and future military operations. The remaining minefields in Afghanistan, from the decade long war with the Soviet Union, are just one example of this global problem. The purpose of this research is to develop a methodology that will predict areas where minefields are the most likely to exist through use of a GIS model. The concept is to combine geospatial data layers to produce a scored raster output of the most likely regions where minefields may exist. It is a "site suitability analysis" for minefield existence.

The GIS model uses elevation and slope data, observer and defensive position locations, hydrographic features, transportation features, and trafficability estimates to form a minefield prediction surface. Through use of the NATO Reference Mobility Model (NRMMII) and the Digital Topographic Support System (DTSS), trafficability estimates are generated for specific vehicles under specific terrain and weather conditions in specific areas of interest.

The model could be used to create prioritized maps for minefield detection sensors, demining teams, or for avoidance. These maps could define the "high payoff" search areas for remote sensors, such as ASTAMIDS, and positively identify minefields. These maps could also be used by humanitarian relief agencies for consideration when planning movement into areas that may contain minefields. The analysis includes a model calibration and sensitivity analysis procedure and compares the model output to known training minefield locations taken from two US Army training centers. The resultant Minefield Likelihood Surface has a 91% accuracy rate when compared to known training minefield data.

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1.0 Introduction

There are millions of land mines strewn across the world from past wars and conflicts dating back as early as World War I. Tourists in Egypt continue to be injured by land mines that were emplaced during World War II. Land mines emplaced during the civil war in Bosnia prevent the complete restoration of peace and stability in the country. Our own military forces and humanitarian agencies must carefully and methodically plan movements in Afghanistan in order to avoid minefields left over from the decade long war with the Soviet Union. The United Nations Secretary-General emphasized the mine problem in Afghanistan in 1992 when he stated the following as a part of the Consolidated Appeal for Emergency Humanitarian Assistance for Afghanistan:

> *"Mines and unexploded bombs are the most cruel and indiscriminate obstacle to a return to normal life in Afghanistan. Mines which were laid in villages, roads, agricultural land and irrigation systems will remain a hazard in many parts of the country for years to come."*

Mines not only prevent free movement in the regions where they exist, they destabilize the region's economy and government. The region's agricultural output is reduced or eliminated, the civil infrastructure is destroyed and maintenance and rehabilitation efforts are hampered, and the local population does not fully return to the region after a conflict. A United Nations mine report detailed the mine problem in Afghanistan in 1994:

> *"Land-mines ... caused the annihilation of thousands of livestock because of the unavailability of grazing land, which is again the result of the implantation of land-mines on these types of land. According to the Mine-Clearance Planning Agency, an area of 11,727,536 square miles was declared potentially mined and, in the last two years of operation, only close to 35 per cent of the area was announced cleared. ...According to the Mine-Clearance Planning Agency, involved in the survey of minefields in support of the United Nations Mine Clearance Programme since 1990, covering 339 districts of 29 provinces, of which 162 districts were reported to have acute mine problems, there are 595 minefields located on agricultural lands, constituting an area of 78,343,231 square miles, which represents only 20.2 per cent of the total mined area."*[1]

The situation in Afghanistan is just one example of this severe, global problem. There needs to be a solution to this problem that will predict certain areas where minefields are most likely to exist. The ability to predict these minefield rich areas would enable relief agencies to locate the individual minefields and mines, to eliminate or remove them, and to reenergize the struggling economy of the region. In a combat situation, the ability to predict minefield rich areas would help the commander to decide where to employ mine detection assets and which areas to avoid when deploying forces.

One of the primary focus areas in the Department of Defense (DoD) is to develop countermine technologies and procedures to locate individual minefields and mines – both surface laid and

[1] Afghanistan Mine Clearance Report (1994)

buried mines. The DoD has been conducting research and sponsoring demonstrations in mine detection technology. The technologies employed include infrared and thermal imaging, ground penetrating radar, lasers, and genetically engineered microbes. These sensors can be mounted in handheld units for soldiers on the ground, in manned and unmanned aircraft, or space-based platforms. Though these sensors are being developed primarily for military use, they could be used in the future by humanitarian relief agencies to focus demining activities in war ravaged countries such as Afghanistan, Bosnia, or Kosovo.

However, developing technologies that will find and detect minefields or individual buried mines is only half of the problem. A method or procedure is needed that will help determine which areas will be the most likely to contain minefields. A Geographic Information System (GIS) is the perfect tool to use in order to develop a model that can predict likely minefield areas.

A GIS can analyze previously collected images and geospatial data to classify likely mined areas within an area of interest. This data can be collected from hardcopy paper maps, aircraft sensors, or orbiting satellite sensors. The most routinely used data for analysis are digital elevation models (DEMs), vegetation or landcover maps, soil maps, hydrography maps, and transportation network maps. These datasets can exist in either raster or vector format. The vector datasets are a set of individual points, lines, or polygons that have either been previously mapped or extracted from aerial photos or satellite imagery. Common vector datasets are transportation networks, river and stream networks, and soil maps. Raster data can be digital images or any data represented by a uniform grid of pixels. Common raster datasets are digital elevation models, land use maps, and background imagery. These datasets can come from governmental agencies or commercial firms. The main two governmental sources of geospatial information are the National Imagery and Mapping Agency (NIMA) and the United States Geological Survey (USGS).

Procedures can be developed to manipulate the vector and raster datasets in order to prioritize likely mined areas for further analysis. The prioritized "search maps" can be used by humanitarian demining teams or relief agencies to help plan convoys in order to avoid the most mine prone areas. This thesis will propose a procedure to do just this – the Minefield Likelihood Procedure.

1.1 Problem Statement

No procedure or methodology exists to predict minefield locations in order to organize minefield search efforts. There are minefield surveys conducted for humanitarian demining operations but they involve intensive field interviews and assessments. A prediction model would help focus these efforts.

1.2 Conceptual Solution

Develop a raster GIS model that will predict likely mined areas given a standard set of geospatial data and imagery in order to produce prioritized search maps for locating minefields. The terrain can be divided up into different categories such as vegetation, transportation, hydrography, and elevation. Based on these categories, the terrain can be given individual values or scores of minefield probability. These probability scores could be combined in an algebraic formula that would result in a surface of total scores. This surface would be the desired search map and would be categorized into Very Likely, Likely, Possible, and Not Likely areas of minefield probability.

1.3 Research Objectives

In order to translate the conceptual solution into an achievable set of steps, research objectives need to be established. These objectives apply the conceptual solution to the problem statement.

1. **Investigate the current state of the art models in use for minefield area prediction.** This involves performing a literature review of previous prediction models in Chapter 2.0.

2. **Explore the data layers commonly used by the Department of Defense (DoD).** The datasets and acronyms used within the DoD are vastly different from those encountered outside of the common defense community. This objective will be accomplished in Chapter 2.0 by describing the standard NIMA datasets.

3. **Design and implement an optimal site suitability type GIS model integrating common NIMA and/or USGS datasets and the best commercially available software.** The model should be logical, intuitive, adaptable for a specific area of interest, and should incorporate trafficability estimates for specific types of vehicles and weather conditions. The methodology and procedure for the development of this GIS model will be described in Chapter 3.0.

4. **Evaluate the performance, accuracy, and sensitivity of the model using training minefield data.** Once the methodology is developed, the model output will be evaluated and tested. This objective will be accomplished in Chapter 4.0.

5. **Suggest future performance enhancements and research directions.** Chapter 5.0 will draw some conclusions from the results of the model and will recommend further improvements and additions to the research.

2.0 Literature and Topical Review

This chapter will describe some of the background material and current literature about minefield area prediction. The first few sections will cover some basic information about mines, minefields, and will discuss how minefields are employed on the modern battlefield. The discussion will then move to minefield information management systems, minefield remote detection systems, NIMA geospatial data formats, trafficability maps, the US Army's Digital Topographic Support System, and lastly the US Army Battle Command System. The last section reviews a reference that is extremely applicable to the subject of this research. Many of the assumptions made in the process of developing the minefield area prediction methodology will be discussed throughout this chapter and in Chapter 3. These assumptions will be summarized in Section 3.2.

2.1 Mine and Minefield Basics

The doctrine for all minefield operations in the United States Army is "Field Manual (FM) 20-32: Mine/Countermine Operations"[2]. All assumptions for a GIS predictive model must be based on the core tenants in this manual.

2.1.1 Anti-Tank and Anti-Personnel Mines

The two main types of land-based mines used in conventional minefields are anti-tank (AT) and anti-personnel (AP) mines. There are several different firing mechanisms and fuses used and literally hundreds of different types of AT and AP mines manufactured by over 50 countries.

Anti-tank mines are designed to incapacitate combat vehicles and/or kill the crew. These mines can be buried or surface-laid and are emplaced while using one of three fuses. See Appendix C for more details about mine firing mechanisms and fuses.

Anti-personnel mines are designed to kill or critically wound foot soldiers but do not normally employ the broad range of technologies of AT mine fuses. These mines are fused with pressure, trip-wire, and vibration/seismic sensors and can also be command detonated. Most AP mines are buried but some are placed on stakes above ground and can be placed off-route – similar to AT mines.

[2] FM 20-32 (2001)

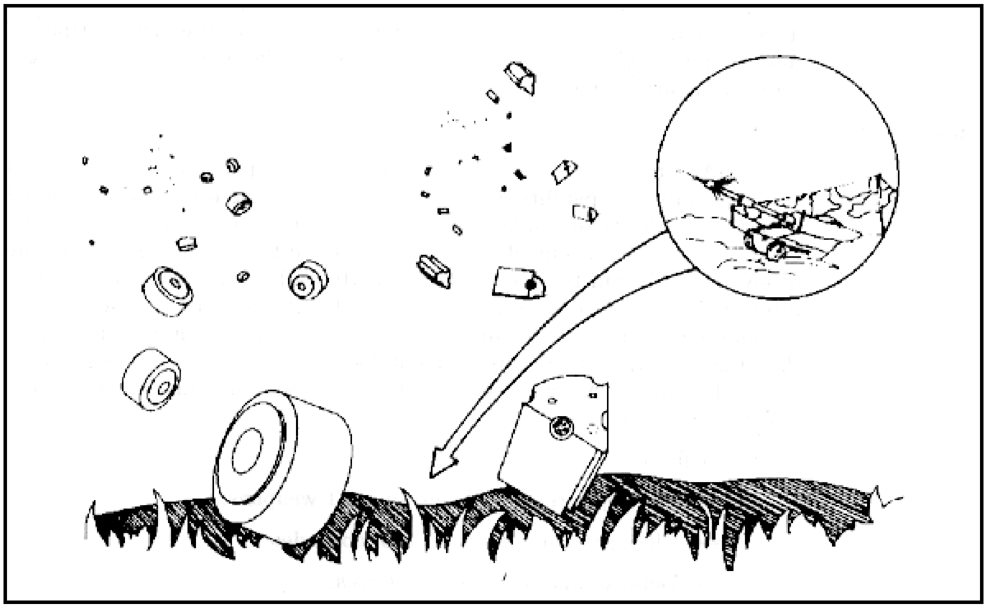

Figure 2.1: Scatterable mines fire from an artillery position[2]

The AT and AP mines discussed so far are termed "conventional" mines and are normally emplaced by soldiers manually and remain in place until triggered or disarmed. There are other mines being used by military units called "scatterable" mines which can be AT and AP and have a set duration. After a set length of time, these mines self-destruct. They can be dispensed by artillery munitions (see Figure 2.1), airplane bombs, helicopters, and by foot soldiers.

The purpose in describing these different types of mines is to provide some background when discussing different types of minefields. In Chapter 4, the performance GIS model will be evaluated using training minefield datasets. These datasets will consist of different types of minefields made-up of different types of mines.

2.1.2 Minefields

The GIS model will predict the locations of only certain types of minefields. Mines can be positioned anywhere but minefields are normally emplaced according to their function or type. A minefield can consist of conventional or scatterable AT and AP mines. The types of minefields that are normally constructed by military soldiers or warring factions are:

1. Protective minefields: These minefields are put out to protect fighting positions, bunkers, trench networks, and vehicle defensive positions. These are normally emplaced by the soldiers defending a piece of terrain.
2. Tactical minefields: These minefields are intended to slow, turn, or stop an advancing enemy formation. These can cover large areas of open terrain or can be concentrated at a point on the ground (i.e. a road intersection).
3. Nuisance minefields: These minefields are small in size and are positioned in unpredictable locations to slow an enemy advance. These minefields can consist of only one mine and are typically used by guerrilla or insurgent forces.

The GIS model will be designed to predict the locations of tactical minefields. Protective minefields could be easily predicted based on known defensive locations through a simple proximity analysis. The challenge is to predict tactical minefield locations because the positioning of these minefields depends on a variety of factors. These factors will form the structure of the model and will be described in Section 3.3.

Tactical minefields can be further categorized into two main types: rectangular and point minefields. The minefields use similar mines but differ in size and employment. The following describes these minefields in more detail:

1. Rectangular Minefields: These normally consist of conventional and Volcano minefields. The US Army's "Volcano" is a scatterable minefield dispensing system that can be mounted in a vehicle or on a helicopter. Conventional minefields are emplaced by hand and are usually rectangular in shape and greater than 100m in depth. Most of these minefields are recorded using two MGRS (Military Grid Reference System) coordinates. These coordinates usually indicate the endpoints, on the friendly or enemy side, of the minefield (in the long direction). See Figure 2.2 for an example of a conventional minefield. Volcano minefields are normally recorded with two MGRS coordinates that indicate the start and end point of the minefield centerline. See Figure 2.3 for an example of a Volcano minefield.

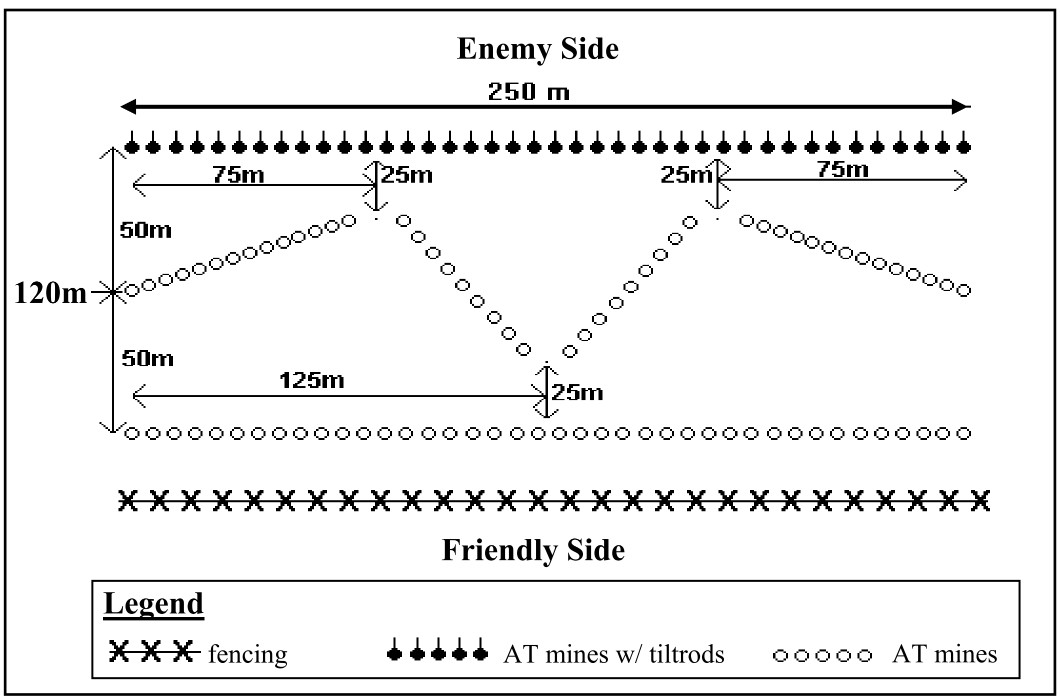

Figure 2.2: Example of Conventional Minefield

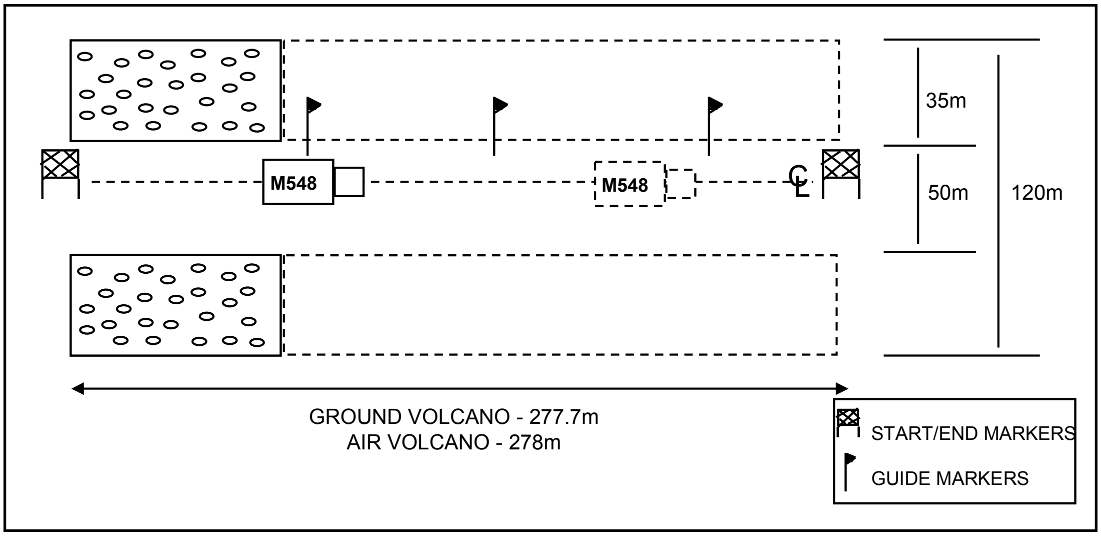

Figure 2.3: Example of Volcano Minefield

2. Point Minefields: Point minefield data is recorded using one MGRS coordinate. A conventional point minefield could be placed at a road intersection and may consist of 10-15 mines (AT and AP mix). The point minefield could be 50-100m in diameter (or 25-50m radius from the given coordinate). Some scatterable point minefields are emplaced by artillery systems can be 400m wide by 400m long. A portable scatterable point minefield system, called MOPMS (Modular Pack Mine System), dispenses mines in a 35m semi-circle. See Figure 2.4 for an example of a deployed MOPMS. The size of the point minefield can be ambiguous if the type and emplacing system is not specified.

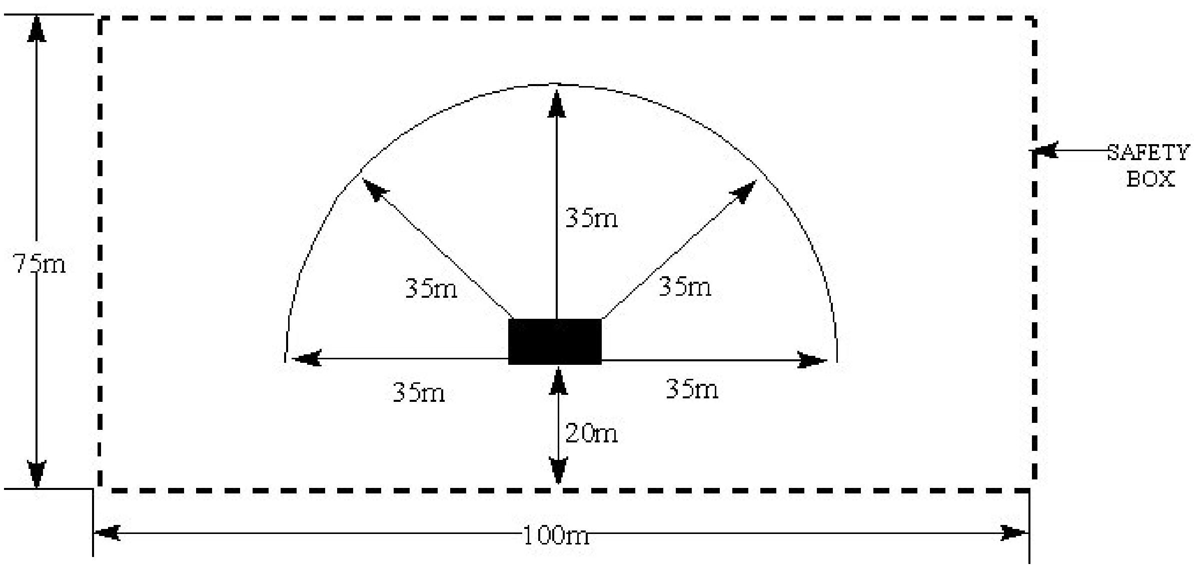

Figure 2.4: Example of Modular Pack Mine System

2.1.3 Minefield Placement Considerations

Tactical minefields are placed where they can best influence the outcome of a battle, intended to slow, turn, or stop an enemy advance. The doctrinal terms are Disrupt, Turn, Fix, and Block. See Appendix C for a diagram using these terms. One of the first steps in planning the placement of tactical minefields is to analyze the terrain and visualize three things: 1) Where you want the enemy to go, 2) Where the enemy doesn't want to go, and 3) Where you want to kill the enemy with direct fire weapons (i.e. tanks, missiles, bullets, etc.)[3]

The next step is to conduct an analysis of the terrain to determine possible friendly minefield emplacement locations. This analysis results in a product called the Modified Combined Obstacle Overlay (MCOO) which allows for refined planning of minefield emplacement locations. A standard analysis includes the consideration of the following factors:

1. Observation and Fields of Fire: Where can the friendly force best observe and engage the enemy force?
2. Cover and Concealment: Which routes can best conceal the enemy formation during movement? Which routes can best cover and protect the enemy formation from direct and indirect fire weapons?
3. Natural and Manmade Obstacles: Where are the obstacles in the area of interest? How will they affect the outcome of the defense?
4. Key terrain: What areas on the ground are significant to either the enemy or the friendly force?
5. Avenues of Approach: What are the primary and secondary routes in the area of interest? What size force can they accommodate?[4]

These factors will be applied to the GIS model and will form the basis for a ranking system within each input layer for the model. For example, observation points can be used to determine what areas are best to place minefields where they can be defended. Also, certain avenues of approach can be given more weight than others when predicting likely areas for minefields. Chapter 3 will develop a methodology for incorporating these terrain analysis factors.

One last key consideration for the placement of minefields is the positioning of direct fire systems. The process of developing defensive preparations prior to a battle is termed "building the engagement area." The process involves seven common steps[5]:

1. Identify all likely enemy avenues of approach.
2. Determine likely enemy schemes of maneuver.
3. Determine where to kill the enemy.
4. Plan and integrate obstacles.
5. Emplace weapon systems.
6. Plan and integrate indirect fires.
7. Rehearse the execution of operations in the engagement area.

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[3] Engineer NTC Trends FY01 (2001)
[4] FM 5-100 (1996)
[5] FM 71-1 (1998)

In steps 4 and 5, direct fire weapon systems (i.e. tanks, machine guns, etc.) are positioned so that they can observe and fire on enemy vehicles when they approach their minefields. This key consideration relates to the terrain analysis factor of "Observation and Fields of Fire" and will later be incorporated into the GIS model as one of the minefield predictors.

2.2 Mine Information Management Systems

Several mine information management databases have been created in the past ten years to help catalog and organize the humanitarian demining effort. Demining is the term used for the process of careful minefield removal. The most widely used database is the Information Management System for Mine Action (IMSMA) developed by Swiss Federal Institute of Technology Zurich (ETHZ) on behalf of the Geneva International Center for Humanitarian Demining (GICHD).

"IMSMA is an information management system that improves capabilities for decision-making, coordination, and information policy related to mine action (humanitarian demining). …[It was] developed in cooperation with the United Nations and with the United Nations Mine Action Service (UNMAS) as the focal point, the project is part of Switzerland's efforts to support and strengthen humanitarian demining."[6]

IMSMA was field tested in Somalia in 1998 and adopted by the United Nations (UN) in 1999 as the international standard for mine information management systems. Its first use was in Kosovo in the form of the IMSMA Field Module. The Field Module is a software package that allows for data collection, statistical and GIS analysis, and creation of reports.

"The purposes of the IMSMA Field Module are:
a. To allow rapid entry of field information on mine and UXO suspected or actual areas, including data on mine incidents, for the planning and execution of mine action programmes.
b. To create digital maps with mine, UXO and accident overlays, for use by deminers, military formations or NGOs operating in the area.
c. To act as host system, to which can be attached important management tools for programme managers in the field."

"The IMSMA Field Module combines a relational database and geographical information system (GIS) functionality. Based on Microsoft Office Professional 2000 and ArcView, the system provides very flexible functionalities based on commercial off the shelf software."[6]

IMSMA has been used successfully in several countries to help coordinate and manage humanitarian demining efforts. These countries include: Kosovo, Azerbaijan, Yemen, Chad, Estonia, Somaliland, Southern Lebanon, Eritrea, Ethiopia, Nicaragua, Thailand, Cambodia, Albania, and Peru.[6]

The second major information management system that is used in humanitarian demining is the Demining Information Management System (DIMS). It was developed by United States Central

[6] IMSMA (2001)

Command (USCENTCOM) in 1994. Its functions are similar to IMSMA – it uses Arabic versions of Microsoft Windows and Office. It has been used in extensively in Egypt, Yemen, and Jordan. DIMS is losing popular support since some organizations and countries are now adopting IMSMA instead of DIMS.[7] However, both DIMS and IMSMA have similar software components. Both use Microsoft Access to manage the database of minefield data and both can export the results from the database to GIS software packages, such as ESRI's ArcView. In this regard, both systems use common software and can be integrated into any organization easily.

2.3 - Review of Minefield Remote Sensing Technologies

Several different sensing technologies are used today to attempt to remotely locate minefields. The most challenging mines to remotely detect are buried, plastic AP and AT mines. Currently, the only available method to detect minefields is with metal detectors which are incapable of detecting plastic mines. See Figure 2.5 for a summary of available technologies that are being applied to the mine detection problem.

Phenomenology	Category	Technology
Anomaly Detection	Magnetometry (MAG)	Magnetometers (total field, vector), Gradiometers, Giant Magnetoresitive Arrays, Superconducting Quantum Inteference Device (SQUID), Spin Dependent Tunneling (SDT)
	Active Electromagnetics (AEM)	Electromagnetic Induction (EMI) (Time Domain, Frequency Domain)
	Radar	Ground Penetrating Radar (GPR), Synthetic Aperture Radar (SAR), Ultra Wide Band Radar, Narrow Band Radar, Impulse Radar, FM Radar, FM Continuous Wave, Airborne Radar , Harmonic Radar
	Electro-optics (EO)	Visual, Infrared (IR) (active, passive), Multispectral/Hyperspectral, Ultraviolet (UV), Millimeter Wave (MMW), LIDAR
	Acoustic	Surface Acoustic Waves, Rayeigh Wave, Sound/ultrasound Imaging, Contact Acoustic, Surface Seismic
Explosive Detection	Bulk Chemical	Thermal Neutron Anaysis, Fast Neutron Analysis, X-Ray/Gamma Ray Backscatter, Quadrupole Resonance (QR), Nuclear Magnetic Resonance (NMR)
	Trace Chemical	Spectroscopy (Mass, Raman, Field Ion), Polymer Absorption, Biosensors, TNT/DNT vapor detector, Biosensors, Bioluminescence, Dogs & other animals/insects
N/A	Signal Processing / ATR	Modeling and Aided Target Recognition

Figure 2.5: Summary of Available Detection Technologies[8]

The various research laboratories of the US Department of Defense are leading the way in testing new technologies to detect minefields. The two most visible projects are the Coastal Battlefield Reconnaissance and Analysis (COBRA) and Light Airborne Minefield Detection (LAMD) programs. The COBRA program is an Office of Naval Research project and is intended for use

[7] Davis (2001)
[8] Strategic Technology Roadmaps (2000)

by the United States Marine Corps. The LAMD program is a U.S. Army Night Vision and Electronic Sensors Directorate project. The following is brief description of each project.

1. **Coastal Battlefield Reconnaissance and Analysis (COBRA):** The system uses optical pattern detection, "two down-looking, spinning-filter wheel, multi-spectral video cameras with overlapping adjacent fields of view for a wide swath" [9]

"COBRA is the only UAV [unmanned aerial vehicle] sensor system specifically developed to conduct littoral reconnaissance and detect minefields, obstacles, and camouflaged defenses. [Goals for] Detection: 1) 90% of minefields with 6" surface laid mines, 2) 75% of minefields with 10" buried mines with 5" overburden, 3) Demonstrated capability of mines in the surf zone (<=10' depth) in Sea State I, 4) False Alarm Rate <= 15%"[10]

During testing in 1997-1998, COBRA had success in detecting surface laid mines/minefields but not in buried mines/minefields.

"The capability gaps in overt airborne reconnaissance for mine/minefield/obstacle detection and location addressed by [COBRA] *fall into three major categories…are:*

1. night operations in the beach and beach exit zones,
2. day/night mine/minefield/obstacle detection in the shallow water and surf zone
3. buried minefield detection capability ashore."[11]

COBRA transitioned to preplanned product improvement in 1998, was contracted to be fielded in 2001, and is planned to be fielded to the Marine Corps in FY2007.[10]

2. **Light Airborne Mine Detection System (LAMD)**: The system used to be called the Airborne Standoff Minefield Detection System (ASTAMIDS). It uses electro-optical and thermal IR sensors and incorporates multispectral and hyperspectral imagery analysis.

LAMD is a developmental effort to provide the military commander with a remote sensor that will detect mine threats. To support the tactical mission, the sensor will fly on a TUAV (tactical unmanned aerial vehicle), with the mission to detect scatterable, recently buried, and surface laid AT mines. The data will be accumulated on the TUAV for later processing using soldiers to assist in the identification of suspected mines and minefields locations. Future applications involve real-time analysis of LAMD data.[12]

"The Army is currently leveraging off of its former dual path Airborne Standoff Mine Detection System (ASTAMIDS), in its new Lightweight Airborne Multispectral Minefield Detection (LAMD) for deployment in the Army tactical UAV for remote minefield

[9] Office of Naval Research (2001)
[10] Gainor (2001)
[11] Office of Naval Research (2001)
[12] TRADOC – Engineer Combat Systems (2000)

detection. ASTAMIDS developed techniques using thermal IR imaging and active scanning polarized laser illumination from an airborne platform for land mine detection. LAMD is also leveraging off of the Marine Corps COBRA multi-spectral minefield detection capabilities. Within the LAMD program, the Army has conducted hyperspectral phenomenology studies for buried mines. Other Army programs are developing a Handheld Standoff Mine Detection System (HSTAMIDS) and a Vehicular Mounted Mine Detector (VMMD)." [13]

ASTAMIDS was tested from 1992 to 1998. It failed to meet certain performance objectives. Then the LAMD program began and started testing in 2001. Additional tests are planned for 2002 and 2003.[14]

The purpose in mentioning the different technologies available for remote minefield detection is to show the future application of the GIS model. A methodology for classifying an area into different zones of minefield likelihood would useful in determining where to best use remote minefield detection sensors, such as COBRA or LAMD. This will be further discussed in Chapter 5.

2.4 – NIMA Geospatial Data Formats

There are several different geospatial data formats that are produced by NIMA. Many of them are similar to the data formats available from the USGS but are tailored to military applications and focus on areas outside of the United States. One set of geospatial data that can be used for GIS analysis is called Foundation Data (FD). FD serves as the base for intensification and densification of geospatial information. There are five components of FD and they are depicted in Figure 2.6.

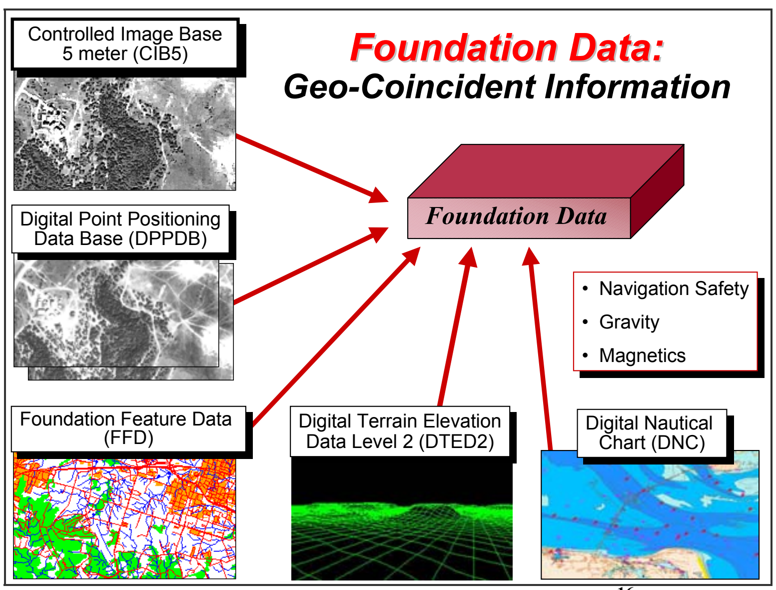

Figure 2.6: Foundation Data Components[16]

[13] Office of Naval Research (2001)
[14] Rupp (2001)

1. Foundation Feature Data (FFD). FFD is the vector feature component of FD. FFD contains a select set of features to support initial planning and operations. Included are roads, streams, built-up areas, vegetation, boundaries, and other features at a variable density ranging from 1:100K to 1:250K.[15] FFD is vector data extracted from different sources of imagery (raster data).

2. Controlled Image Base 5 meter resolution (CIB5). The CIB5 is an imagery dataset that is corrected for relief displacement, or orthorectified, using digital elevation data. The pixel resolution of this imagery is 5m; each pixel in the image represents an area on the ground 5 x 5 meters.

3. Digital Terrain Elevation Data Level 2 (DTED2). This is the NIMA format for digital elevation data. DTED2 comes in three different spatial resolutions – DTED Level 0, Level 1, and Level 2.

    a. DTED Level 0 elevation grid spacing is 30 arc second (nominally one kilometer).
    b. DTED Level 1 is the basic medium resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or gross terrain roughness in a digital format. DTED Level 1 is a uniform matrix of terrain elevation values with grid spacing every 3 arc seconds (approximately 100 meters). The information content is approximately equivalent to the contour information represented on a 250,000 scale map.
    c. DTED Level 2 is the basic high resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or terrain roughness in a digital format. DTED 2 is a uniform gridded matrix of terrain elevation values with grid spacing of one arc second (approximately 30 meters).[16]

4. Digital Point Positioning Data Base (DPPDB). The DPPDB is database of stereo-pairs of imagery and reference information used to plot precise coordinates and to make precise measurements. DPPDB is routinely used for military targeting of GPS-aided precision munitions.

5. Digital Nautical Chart (DNC). The DNC is a navigational map, in digital form, intended for use by the US Navy and US Coast Guard for the purposes of marine navigation.

FD will be used to derive five raster layers that will serve as input into the GIS model. Section 3.1 will describe, in more detail, the NIMA datasets used to develop the model.

2.5 – Trafficability Maps

One of the key assumptions of this research is that minefields are normally emplaced where it is easiest for a force, either mounted or dismounted, to travel and where the terrain is most trafficable. A minefield predictive model should incorporate trafficability, or mobility, maps in

[15] Mission Specific Data Set Concept Paper (1998)
[16] Pike (2000)

order to improve prediction. Trafficability is a measure of how well a force can maneuver in a specific type of terrain. These maps can be created by incorporating different geospatial data layers into a mobility model. Commonly used data layers include: 1) terrain slope, 2) obstacles, 3) soil types, 4) vegetation type, density, and spacing, 5) linear and hydrographic feature data, and 6) road and trail data. Trafficability maps commonly depict specific vehicle speeds under specific weather conditions or can classify the terrain into trafficable and untrafficable regions for specific vehicles.

One of the most widely used mobility models is the NATO Reference Mobility Model (NRMM). The mobility performance prediction model was developed in the early 1970s by US Army Corps of Engineers (USACE) and was proposed to NATO in 1978 as its standard mobility model. A Technical Management Committee meets every 18 to 24 months to review the mobility model and recommend improvements.

The NRMM is a set of equations and algorithms that predict the performance of a particular vehicle based on vehicle physics and terrain properties. The main prediction module considers vehicle, terrain, and vehicle- and terrain-independent scenario data (such as weather conditions) to determine the maximum possible speed versus resisting force at which the vehicle can operate. The primary prediction product of NRMM is vehicle speed in a specific type of terrain. Mobility estimates can be determined for on-road, off-road, and obstacle-crossing maneuvers.

In 1992, NRMM II was developed to include enhanced mobility algorithms, a better organized modular structure and a more flexible user interface. It was adapted from NRMM for specific US requirements and needs. NRMM II ver 2.5.10, which was developed in Spring 1999, supports on-road, off-road, and obstacle crossing vehicle speed prediction capabilities in addition to applied mobility products such as time contours and optimum route prediction.[17]

NRMM II consists of three modules: a vehicle dynamics module, and obstacle-crossing performance module, and a primary prediction module. The primary prediction module consists of two submodules: an on-road prediction submodule and a cross-country prediction submodule.[18] The GIS model will use the results from these three modules to create a mobility surface.

The on-road and cross-country prediction submodule uses several different submodels to create its results. These submodels include: power-train submodel, surface roughness submodel, soil submodel, longitudinal and lateral slope submodels, tire submodel, speed limit relation submodel, obstacle override submodel, and vegetation override submodel.[18] See Appendix C for the cross-country and on-road prediction submodule schematics.

A software package called the Digital Topographic Support System (DTSS – discussed in next section) will be used to create mobility maps using the NRMM II model. The software developed relationships between the original NRMM II submodules/submodels and attributes in the vector NIMA data formats. The specifics of those relationships are beyond the scope of this research.

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[17] Joint Mapping Toolkit Webpage
[18] Ahlvin (1992)

2.6 – Digital Topographic Support System (DTSS)

The US Army integrates topographic expertise into the combat forces through use of topographic detachments and teams. These teams perform terrain analysis and produce terrain products for the division commanders and their staff. Most of the analysis was done by hand in the past, but is now performed by computers. The Digital Topographic Support System (DTSS) is used by the topographic teams to perform automated terrain analysis. The following overview was adapted from the "DTSS Point Paper" written by the TRADOC Program Integration Office – Army Battle Command System [TPIO-ABCS] Requirements Division.[19]

> *DTSS was [fielded] in 1985 and was intended to modernize the topographic teams throughout the US Army. In 1995, [upgrade began] to provide a common operating picture for all systems in the new digital divisions.*
>
> *The DTSS consists of six distinct configurations that will provide a common map for all the digital force systems and will provide direct topographic support to the commanders and staff throughout the Army from theater down to brigade.* See Figure 2.7 for an example of one of these configurations. These configurations are:

DTSS-Base (DTSS-B)	**DTSS-Light (DTSS-L)**
DTSS-Deployable (DTSS-D)	**DTSS-High-Volume Map Production (DTSS-HVMP)**
DTSS-Heavy (DTSS-H)	**DTSS-Survey (DTSS-S)**

Figure 2.7: A US Army truck configured with the Digital Topographic Support System -Deployable

These configurations will use a combination of government and commercial software, operating within the Army Common [Operating] environment. The DTSS-B, H, L, and D configurations have similar capabilities in that they will use compatible hardware, software, *and operating procedures to provide terrain analysis and related topographic support throughout the US Army. The DTSS-B, H, L, D, and S configurations will provide large-format, plotting capabilities to support low-volume output requirements. The DTSS-HVMP will provide high-volume, large-format, digital printing capabilities to support high-volume printing of topographic products, and the DTSS-S will provide geodetic survey support across the battlefield.*

The DTSS will provide the capability to generate, collect, manage geospatial information, and provide a suite of geospatial information services that will provide the soldier with terrain analysis products, map reproduction capabilities, and geodetic survey support. The system will be a standardized, automated tactical combat support system capable of receiving, reformatting, creating, storing, retrieving, updating, merging, and manipulating digital topographic data, and provide for the reproduction of hardcopy topographic products. The DTSS can accept topographic and multispectral imagery data from NIMA standard digital databases and from other sources. The DTSS is going through another upgrade to include moving to Windows NT (previously UNIX based).

The DTSS can generate Tactical Decision Aids (TDAs) from input terrain data. The six different TDA product categories include: (1) Intervisibility, (2) Mobility, (3) Special Purpose Products, (4) Tactical Dam Analysis (TACDAM), (5) Integrated Meteorological System (IMETS), and (6) Terrain Elevation. TDAs generated on the DTSS-D can be output as Map Products or as geospatial data layers. In addition to TDA generation, the DTSS provides the capability to generate and print image maps from commercial and national imagery, and perform terrain analyses based on attribute inspection of the imagery available. ERDAS Imagine image processing software is being used to process commercial, NIMA standard and national digital imagery in order to perform imagery rectification, image map generation, thematic layer generation, limited digital database creation, and 3D terrain perspective viewing. [19]

The DTSS Mobility TDA will generate on-road and cross-county mobility or trafficability estimates that will form a raster trafficability layer within the GIS model.

2.7 – Army Battle Command System (ABCS)

The Department of Defense is in the process of consolidating and standardizing digital communications within and across the different branches of the armed forces. This system is referred to as the Global Command and Control System (GCCS). The Army's current system within GCCS is the Army Battle Command System (ABCS). All systems that operate with or within GCCS must adhere to standard operating system, applications, and computer hardware. This set of specifications is the Defense Information Infrastructure / Common Operating Environment (DII COE – or just COE). See Appendix C for further details about ABCS and GCCS.

One of the most important aspects of the ABCS and GCCS is that the framework of these systems is based on GIS software and functionality. Although these systems are constantly

[19] DTSS Point Paper (2000)

evolving, the GIS functionality has been improved within the GCCS through the Commercial Joint Mapping Toolkit (C/JMTK), a newly developed contract. Two systems, within ABCS, have GIS capabilities for display and spatial data analysis. They are MCS-Engineer (MCS-Eng) and DTSS. Any future GIS model or analysis procedure could be directly integrated into one of these systems and throughout the GCCS through use of the C/JMTK interface. The following is a discussion of these systems:

1. **Maneuver Control System (MCS):** MCS provides tactical commanders and staffs with an automated, near-real time view of the battlefield for planning, coordinating, monitoring, and controlling tactical operations. The MCS operator can tailor the applications to display the picture of the battlefield he or she chooses. The battlefield view is derived from data fed by information automatically provided by a combination of both local and remote ABCS systems. Its primarily use is for creating and sending operations orders and plans throughout the chain of command. It is also equipped with digital collaborative tools that commanders and staffs can use to plan future operations and review past operations.[20]

   1a. Maneuver Control System – Engineer (MCS-Eng): MCS-Eng is being developed for all combat engineer units within the MCS framework. MCS-Eng will assist engineers by giving engineer units an easy-to-use, comprehensive command and control capability that allows for planning, executing, reporting, and visualization. MCS-Eng capabilities address four major functional areas: Countermobility, Survivability, Mobility, and General Engineering. It will be incorporated directly into future releases of MCS and will be part of the ABCS. The current prototype exists as module within ESRI's ArcGIS software.[20]

2. **Digital Topographic Support System (DTSS):** ***<u>See discussion in Section 2.6</u>*.** DTSS is an automated battlefield system that provides geospatial data analysis, in digital format, for use within ABCS systems. The DTSS provides a means of producing a variety of tactical decision aids using terrain analysis models and high-resolution imagery. The system also provides the capability to produce multiple, full color hardcopy products of the battlefield terrain. Maps not otherwise available in digital format may be scanned in full color. Future releases of DTSS will incorporate Battlespace Terrain Reasoning and Awareness (BTRA). DTSS also operates within ESRI's ArcGIS software.[20]

   2a. Battlespace Terrain Reasoning and Awareness (BTRA): BTRA consists of set of detailed terrain analysis tactical decision aids (TDAs). BTRA is distributed, analytic, decision, and execution software. The three primary analytic functions within BTRA are Tactical Terrain Analysis (TTA), Movement Prediction (MP) and Dynamic State (DS) Battlespace Environment modeling. The primary purpose of TTA is to automatically identify key terrain and pick optimal defensive positions. DS uses either measured or forecasted weather data from IMETS and predicts weapon sensor performance and the effects of weather on both on- and off-road trafficability. MP is an interactive tool to predict and analyze maneuver options. MP predicts movement based on trafficability estimates and the tactically significant aspects of maneuver (e.g. concealment). BTRA

[20] TASC, Inc. (2002)

extracts an off-road maneuver product based on the edges and centerlines of mobility corridors defined by the terrain, and couples it with the available transportation network data. The resultant MP product can be edited and updated and allows for quick large-scale network analysis. Commanders can play out "what if" scenarios on the network to determine optimum and alternate courses of action.[21]

3. **Commercial Joint Mapping Toolkit (C/JMTK):** This is a new developmental program that uses commercially available GIS and imagery analysis software and incorporates them into the COE architecture and specifications. C/JMTK will be used to display geospatial data within the ABCS and GCCS. It has the ability to display output from DTSS/BTRA and MCS-Eng to all systems within the ABCS.

2.8 – Previous Work

An extensive review of the literature revealed only one reference that dealt directly with the problem of minefield site prediction. It was a set of three papers called "Expert System for Minefield Site Prediction (Phase I-III)".[22] The papers were part of a project performed in the late 1980s by Par Government Systems Corporation for the US Army Corps of Engineers (USACE) Engineer Topographic Laboratories now called the Topographic Engineering Center (TEC).

The research used an expert system as an inference engine and prototype GIS software developed by the University of Maryland. One of the greatest challenges of the research was data storage and manipulation using 1980s microcomputer and workstation technology. "GIS primitives" or subroutines within the GIS software were developed to identify the following:

1. Canalized terrain or choke points
2. The distance from principal road networks
3. The line-of-sight from known defensive locations

The data layers that were used are similar to those available today: elevation models, slope layers, cross-county mobility (trafficability maps), vegetation/landcover maps, transportation networks, and hydrographic feature maps.

The study used a relatively simple set of steps:

1. Create cross-country mobility layers
2. Identify canalized terrain and important road networks
3. Select locations where mobility is possible within canalized terrain in close proximity to a road network
4. Further refine locations that can also be observed from defensive locations

It is unclear from the study if these steps were performed manually by the user or automatically by the prototype GIS software. These locations were categorized as very likely, likely, possible, and not likely to be a mined area. Much of the study was spent formatting available data,

[21] Research and Development Center (ERDC) (2002)
[22] Dillencourt et al (1988); Doughty et al (1989)

developing data storage and referencing techniques to enhance processing speeds, and improving the GIS software.

This same approach will be used within a GIS model by incorporating trafficability estimates, a viewshed analysis, and an analysis of important vector datasets. The intent to recreate and improve the research performed by Par Government Systems Corporation by using current datasets, the latest in GIS software, and by developing a methodology that can be customized to any region in the world.

3.0 METHODOLOGY

The purpose of this research is to develop a procedure that will create a GIS model to predict areas where minefields are more likely to exist. This chapter will describe the specific datasets used with the GIS model and discuss some of the issues with this data. The chapter will also list some of the major assumptions made prior to the development of the GIS model. Then the procedure, named the Minefield Likelihood Procedure, will be described in a series of steps followed by a discussion of the specific model implementation and evaluation methodology.

3.1 Data Issues

There are many types of geospatial data used for a minefield area prediction model and some of the issues involved with these data layers are complex. This section will discuss the details of the individual datasets, the sources of the datasets, the spatial accuracy of the datasets, and the manipulations that were performed on the datasets in order to input them into the GIS model. The spatial accuracy of each dataset will become important in Section 4.5 when the spatial accuracy of the model output is assessed.

3.1.1 Data Types, Sources, & Accuracy

The GIS model developed in this methodology requires the following raster and vector data as inputs:

- 3.1.1.1 – Digital Elevation Model (raster)
- 3.1.1.2 – Vector Interim Terrain Data (VITD) (vector)
- 3.1.1.3 – Observer locations / defensive positions (vector)

3.1.1.1 Digital Elevation Models (DEMs): The GIS model uses two different types of digital elevation model data: DTED2 from NIMA and USGS 7.5 minute DEMs. The model uses primarily DTED2 but uses the USGS DEMs where DTED2 is not available. DTED2 has a spatial resolution or pixel size of 1 arc-second or approximately 30 meters (at the equator). The elevation values are comparable to those found on a 1:50,000 contour map. Each DTED2 tile spans an area that is 1^{o} by 1^{o} or approximately 69 by 69 miles (at the equator). DTED2 is not available everywhere, just as with FFD, but this need is quickly being filled by new data from the Shuttle Radar Topography Mission (SRTM). SRTM data, once it has been processed, will provide detailed DEMs (both bare earth and reflective surface) for more than 80% of the world. See Appendix C for a DTED2 coverage map.

The positional accuracy of DTED2 is measured in two ways: 1) absolute horizontal accuracy is ± 50 meters at a 90% confidence interval; and 2) absolute vertical accuracy is ± 30 meters at a 90% confidence interval.

Digital elevation data over the United States is also available through the USGS. The focus of DTED2 collection is outside the United States but digital elevation data of equal spatial resolution is available for areas within the United States through the USGS. There are three scales of DEMs available: large scale (1:24,000), intermediate scale, and small scale (1:250,000). The large scale DEMs are 7.5 minute quadrangles that have 30m spatial resolution and, in some areas, 10m spatial resolution. They are equivalent to DTED2 in spatial resolution. The intermediate scale DEMs are 30' by 30' tiles that have 2 arc second (~60m) spatial resolution. The small scale DEMs are 1^o by 1^o tiles that have 3 arc second (~90m) spatial resolution. They are equivalent to DTED Level 1.[23] The positional accuracy of USGS DEMs is comparable to DTED2 positional accuracy.

3.1.1.2 Vector Interim Terrain Data (VITD): NIMA produces vector datasets that contain thematic coverages extracted from imagery. These datasets are detailed vector data extracted from imagery or are recreated from previous datasets. One of the most detailed vector data sets available from NIMA is Vector Interim Terrain Data (VITD). It has, on average, a level of detail found in standard 1:50,000 scale maps. Unfortunately, there are very few areas where VITD is available. Feature Foundation Data (FFD) is being produced by NIMA as part of the Foundation Data concept but it has a level of detail found in standard 1:250,000 maps. FFD is therefore more available than VITD – see Appendix C for a coverage map of FFD. FFD is given more detail, or intensified, when it is used within the Mission Specific Data Set (MSDS) environment. MSDS DTOP Level 3 contains data that has the same level of detail that VITD has. Unfortunately, the MSDS concept is still in its infancy and is not in full production. See Appendix C for more information about the MSDS levels.

This GIS model uses VITD as input but any evolving NIMA vector format could be used in the future. In addition to NIMA, the Rapid Terrain Visualization (RTV) program has also created VITD datasets. In March 2000, a VITD dataset of Fort Polk, Louisiana was created during a demonstration of the capability of the program. This VITD dataset is used in this analysis. See Appendix C for description of the RTV program.

The attributes in FFD and VITD data follow certain specifications. Each feature type is assigned a specific feature code (FCODE) according to the Digital Geographic Information Exchange Standard (DIGEST), Part 4 - Feature and Attribute Coding Catalogue. For example, railroads are given the FCODE of AN010 and roads are given the FCODE of AP030.[24] These FCODEs will be used in the GIS model to select certain minefield predictors.

VITD spatial accuracy: VITD can range in map scale level of detail from 1:50,000 to 1:250,000. The VITD datasets used in this research have a level of detail equivalent to 1:50,000. The horizontal resolution for the geographic coordinates is equivalent to precision of 0.01 arc-seconds or 0.000002 decimal degrees ~ 0.22m (using: distance [m] = 6378137.0 [m] $\times \pi \times$ distance [decimal degrees] / 180.0 – where 6378137.0 is the earth's radius in meters)

3.1.1.3 Observer and Defensive Position Location Data: The minefield area prediction model incorporates visibility as one of the five GIS raster input layers. A minefield is only effective if it is covered by direct or indirect fire. According to US minefield doctrine, a minefield is normally within direct fire range of a machine gun position, tank defensive position, or within eyesight of an artillery forward observer. If any of these positions are known through actual observation, past history, or evidence (i.e. empty prepared defensive position), a GIS can be used to calculate areas that are visible and those that are not. The GIS process used to do this is called

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[23] USGS (2002)
[24] DIGEST Part 4 (2000)

a Viewshed Analysis. Digital elevation models are used in conjunction with the known positions to calculate visible and non-visible areas.

The positions can come from a wide range of sources to include GPS coordinates, estimated visual distance from a known point, and aerial identification. The locations used in this research came from GPS coordinates and from estimated locations taken from training operations map overlays. The sources of this information are the National Training Center (NTC) in Fort Irwin, California and the Joint Readiness Training Center (JRTC) in Fort Polk, Louisiana. The training minefield data that is used to evaluate the GIS model (discussed later in Section 3.4.4.1) uses these same sources of information.

Estimated Accuracy: Because the observer locations and defensive position locations were just estimates, a 6-digit MGRS (Military Grid Reference System) grid coordinate was used. In the MGRS, a 4-digit coordinate references a 1000m by 1000m area, a 6-digit coordinate references a 100m by 100m area, and an 8-digit coordinate references a 10m by 10m area. Due to this, 6-digit coordinates have an accuracy of ± 100m and 8-digit coordinates, if used, have an accuracy of ± 10m.

Import into the GIS: The MGRS coordinates of the observer locations were entered into an ASCII text file and then converted to UTM coordinates using a coordinate conversion program. The program, called GEOTRANS, was developed by the US Army's Topographic Engineering Center (TEC). The coordinate conversion was necessary since most GIS software packages do not recognize MGRS coordinates as input. The converted coordinates were then brought into the GIS as a comma separated value (.csv) table. Once in the GIS, these points were converted to a point vector data layer.

3.1.2 Preprocessing of Data

Many of the input data layers needed to be manipulated and transformed so that they were compatible with other data layers in the GIS. The preprocessing operations performed on the input data prior to integration into the GIS model were:

DEM Conversion: The DTED DEMs are in a NIMA specific file format (.dt1 or .dt2). Most GIS software does not recognize this format. A 'DTED to GRID' conversion was performed with ArcToolbox in order to get the DEM data into a usable raster format – GRID.

Reprojection: The model uses a horizontal datum of WGS-84 and the UTM coordinate system. Some of the input data was in geographic latitude and longitude coordinates. In order to transform the input data into the desired coordinate system and datum, the data was reprojected. This is a simple process within ArcToolBox using the Project Wizard. This process had to be executed twice. Some of the input data was in the NAD-27 datum and had to be reprojected into the NAD-83 datum and then projected again into the WGS-84 datum. This is due to differences in the base spheroid used to represent the surface of the earth. Coordinates were also converted, using the GEOTRANS software, from MGRS to the UTM coordinate system, as discussed in Section 3.1.1.

Vector to Raster Conversion: The final calculation of this GIS model is performed in raster space. All of the final input needed to be in raster format to be used in the model. All vector data had to be converted to raster data and had to be of similar grid size resolution (i.e., 30m).

Clipping: This is a standard GIS process that limits a vector or raster to a specific boundary. All of the output raster data was clipped prior to analysis. It is also an option to clip all of the input data first before running the GIS model which would speed up processing time.

Geodatabase Creation: In order to use VITD in some of the processes of the GIS model, it had to exist as a geodatabase. This is an import function that is programmed into DTSS. The resulting geodatabase consisted of all of the feature classes that existed within the six thematic layers of the VITD. Geodatabases can be created within ArcToolbox but the DTSS import function was quicker and easier.

3.2 Assumptions

The assumptions that were made prior to the implementation of the GIS model were:

1) Areas that are trafficable by common military vehicles are more likely to be mined than areas that are not trafficable. Due to this assumption, the GIS model used a trafficability layer created by the Mobility TDA from within DTSS. One trafficability map was created for each area of interest based on an M1 Abrams tank.

2) Areas that can be observed from observation points or defensive positions are more likely to be mined that those areas that are not directly observable. Positions were selected from both areas of interest to represent observer and defensive position locations. See the further discussion about this assumption in Section 3.3.5.

3) One of the input layers for the GIS model is trafficability. This is generated by using the Mobility TDA within DTSS. The author does not know which VITD attributes are used by the TDA to create the trafficability output, however the attributes used can be assumed. Through inspection of the NRMM II User's Guide, it was assumed that these VITD attributes were used to predict trafficability:

a) Soil Type
b) Soil Moisture or Wetness Index
c) Slope
d) Vegetation thickness (tree spacing & canopy density)

4) The VITD Slope Layer is a polygon coverage depicting areas of homogenous slope values. It is unclear by looking at the metadata how the VITD Slope Layer was created. It could have been imported from the original ITD, created from DTED Level 1 or Level 2, or derived from hardcopy contour maps. For this model and areas of interest, the slope layer will be derived from DTED Level 1 and Level 2 and then compared to the VITD Slope Layer. This will give an estimation of the slope level of detail and accuracy.

5) High speed roads are more likely to be mined than other roads. Minefields will be placed on those roads that a defending force is attempting to deny to an invading force.

6) Hydrographic features are less likely to be mined than areas not covered by surface water. This also assumes that the hydrographic features are NOT navigable waterways. However, the Minefield Likelihood Score can be adjusted to account for navigable waterways and different minefield doctrine (to be covered in Section 3.3).

7) Flat terrain is more likely to be mined than moderate or high slope areas. Regions where the slope exceeds 45% are excluded from the model since vehicles can not traverse these regions effectively.

8) This research assumed that the training minefield data was collected using handheld GPS units using the MGRS coordinate system and the WGS-84 horizontal datum within 50m of each minefield.

9) The training minefield data coordinates were assumed to form the centerlines of each minefield, regardless of type. The depth of the minefields was assumed to be 120m (or 60m from the centerline in both directions). If more than two coordinates were given, then the coordinates were assumed to be minefield perimeter coordinates.

10) The methodology developed in this research is intended to predict areas where tactical minefields are most likely to be found based on US minefield doctrine. It is NOT intended to predict locations of nuisance minefields or single mines placed by guerilla or non-conventional forces. These mines could be placed anywhere without regard to the topographic and visibility assumptions used in this research. Non-conventional forces us mines to surprise and to inflict casualties which makes the mine locations unpredictable.

3.3 The Minefield Likelihood Procedure

A GIS site suitability analysis is usually used to identify areas best suited for future land development. These are areas where people want to live, work, and enjoy the outdoors. A site suitability analysis performs calculations between different raster layers that results in a prediction surface as an end result. For example, in order to locate an ideal location for a park in a neighborhood, several data layers could be combined to include slope data, a zoning map, distance to existing parks, and a hydrography layer. Each layer could be given equal or variable weighting to form a raster surface.

The Minefield Likelihood Procedure uses this same site suitability analysis approach but customizes it for minefield prediction. Input data layers are preprocessed and manipulated in order to build five raster data layers for the model. These raster layers are then combined, using different weighting factors, to yield a resulting minefield likelihood surface. See Figure 3.1 of an overview of the Minefield Likelihood Procedure.

Each of the input raster layers are formed by assigning specific scores to specific attributes of the input data. These scores will be referred to as Minefield Likelihood Surface (MLS) scores. For instance, in the creation of the Transportation Layer, hard paved roads were assigned an MLS score of 10 and unpaved roads were assigned an MLS score of 8. This 1-10 scale of scores is used to approximate probability of minefield existence, where 10 would equal 100% probability that the feature could be mined. An MLS score -99 was used to exclude a feature from the model because it was not likely to be mined. Section 3.3.6 will discuss how these scores are added together and categorized into minefield likelihood classes.

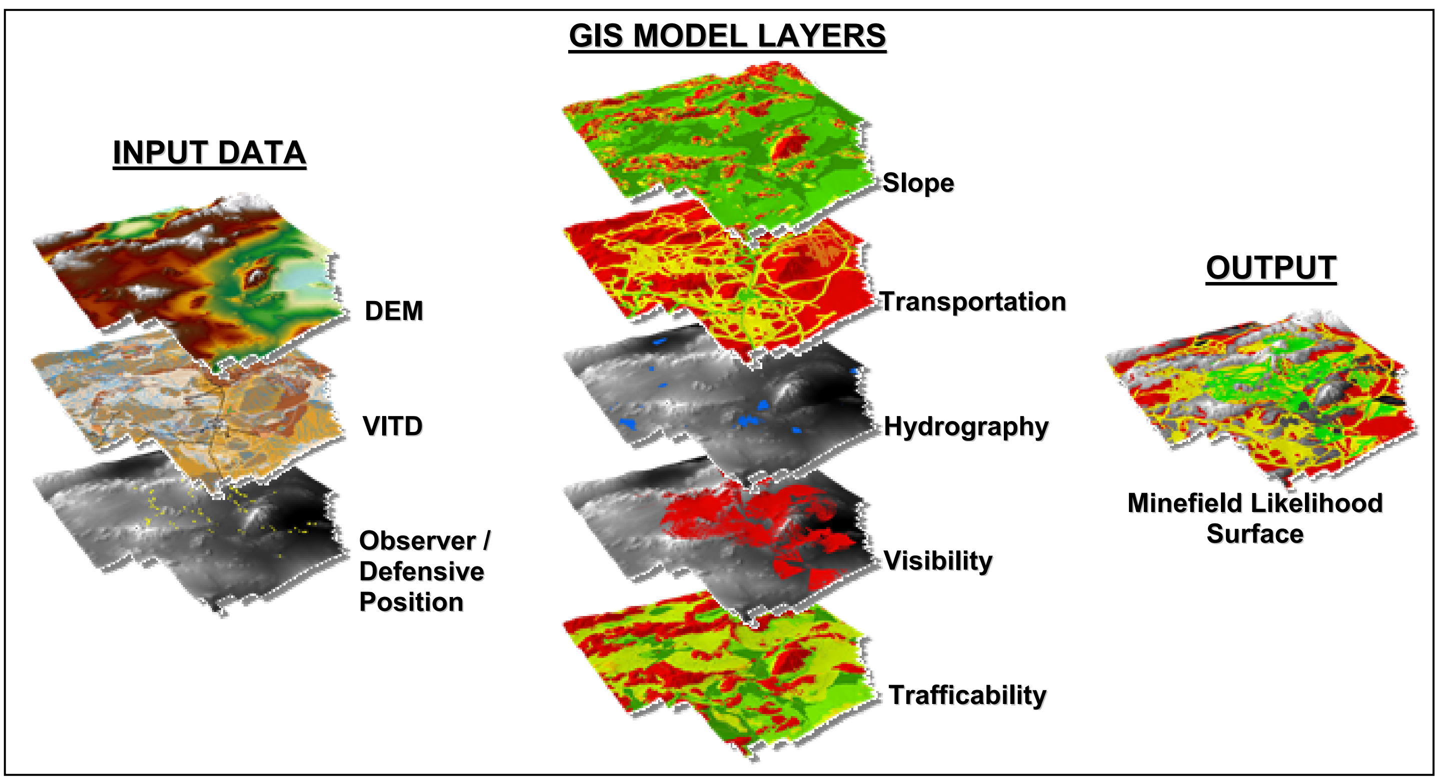

Figure 3.1: Minefield Likelihood Procedure

See Appendix D for the *Minefield Likelihood Procedure Schematic.* The five raster layers that form the GIS model are explained in more detail in the following sections:

3.3.1 Hydrography Layer
3.3.2 Transportation Layer
3.3.3 Trafficability Layer
3.3.4 Slope Layer
3.3.5 Visibility Layer
3.3.6 Final Output – Minefield Likelihood Surface

3.3.1 Hydrography Layer [Hydrography Merge Subroutine]

The purpose of this layer is to exclude hydrographic features from consideration in the GIS prediction model. Areas where there are perennial streams, lakes, and rivers are unlikely to be mined. It is possible for minefields to be moved by floods and to be shifted into streams or rivers but that is not the focus of this research.

The challenge in the creation of this layer is to combine different feature classes within the VITD and then assign an MLS score to those attributes that are present within a specific area of interest. The different VITD feature classes are combined by using a GIS MERGE function. After the vector layers are merged together, they are converted to a raster layer based on a specific attribute. An MLS score of -99 is assigned to those features that should be excluded from consideration in the model. An MLS score of 0 is given to those features that neither hinder nor promote minefield likelihood (i.e. have no effect).

Due to the way feature codes are arranged within the VITD, other features beside hydrography are available to be scored. For example, croplands (FCODE = EA010) are grouped under Vegetation_Areas. This may be a possible mined area if an invading force wants to deny croplands to the local populace. This is not an example of tactical mining but is an example of how the MLS scores can be customized for specific areas and for specific mining doctrine. Built-up Areas (urban areas) are grouped under Vegetation_Water_Areas. These areas may be a priority for mining if they are determined as key terrain for a defending force. Note that ford sites, in the Surface_Drainage_Node feature class, may be included in this layer or the Transportation Layer depending on where the feature is stored in the VITD. See Table 3.1 for an example of the MLS scores.

Table 3.1: VITD feature classes considered for the Hydrography Layer with assigned Minefield Likelihood Surface Scores

VPF file name	VITD Feature Class	Feature Code (FCODE)	FCODE Description	MLS score ‡	Attribute used to Convert to Raster
Vegarea	Vegetation_Area	BH090	Land Subject to Inundation	-99	FCODE
		EA010	Cropland	5	FCODE
		EB010	Grassland	0	FCODE
		EB020	Scrub/Brush	0	FCODE
		DA020	Barren Ground	0	FCODE
Sdrarea	Surface_Drainage_Area	SA010	Common Open Water †	-99	FCODE
		ZD012	Geographic Information Point: Intermittent Lake	-99	FCODE
Vgwarea	Vegetation_Water_Area	SA010	Common Open Water †	-99	FCODE
		AL020	Built-up Areas	10	FCODE
Smwarea	Surface_Materials_Water_Area	SA010	Common Open Water †	-99	FCODE
		SA020	Disturbed Soil	-99	FCODE
Slwarea	Slope_Water_Area	SA010	Common Open Water †	-99	FCODE
Sdcarea	Surface_Drainage_Channel_Area	BH140	River/Stream	-99	FCODE or HYC
Sdcline	Surface_Drainage_Channel_Line	BH140	River/Stream	-99	FCODE or HYC
Sdrnode	Surface_Drainage_Node	BH070	Ford Site	10	FCODE

Notes:

† *The "Common Open Water" feature code (SA010) is repeated in four different VITD layers. Most of the information, but not all, is the same in all four layers. In order to be complete and not miss any information, all four layers are considered and merged together.*

‡ *The MLS score of "-99" excludes the feature area from the minefield likelihood consideration. In the final minefield likelihood output, these areas are designated as "NOT LIKELY".*

3.3.2 Transportation Layer [Transportation Merge Subroutine]

This layer identifies key transportation features from the VITD and assigns MLS scores according to a probability estimate. The transportation features are then combined from several different VITD feature classes. This process takes several steps, since the features are line features (roads, railroads, runways) and point features (bridges). The MERGE function is performed on both the vector layers and the raster layers in order to form one raster layer. Similar to the Hydrographic Layer, the vector feature classes are converted to raster based on specific attributes. See Table 3.2 for an example of MLS scores and attributes used in the creation of this layer.

Table 3.2: VITD feature classes considered for the Transportation Layer with assigned Minefield Likelihood Surface Scores

VPF file name	VITD Feature Class	Feature Code (FCODE)	FCODE Description	MLS score	Attribute used to Convert to Raster
Trnline	Transportation_Line	AP010	Cart Track	6	FCODE
		GB055	Runway	10	FCODE
Trrline	Transportation_Railroad_Line	AN010	Railroad	8	FCODE
		AN050	Railroad Siding/Spur	5	FCODE
trdline	Transportation_Road_Line	AP030	Hard/Paved (RST=1)	10	RST
		AP030	Loose/Unpaved (RST=2)	8	RST
trbline	Transportation_Bridge_Line	AQ040	Bridge: Bypass= easy	3 ‡	FCODE or BCC (see note)
		AQ040	Bridge: Bypass= difficult	10 ‡	FCODE or BCC (see note)
		AQ040	Bridge: Bypass= unknown	3 ‡	FCODE or BCC (see note)
trbdgnd	Transportation_Bridge_Node	AQ040	Bridge: Bypass= easy	3 ‡	FCODE or BCC (see note)
		AQ040	Bridge: Bypass= difficult	10 ‡	FCODE or BCC (see note)
		AQ040	Bridge: Bypass= unknown	3 ‡	FCODE or BCC (see note)
trnnode	Transportation_Node	AQ118	Sharp Road Curve/Bend	8 ‡‡	FCODE
		ZD012	Geo Info Point: Culvert	0 ‡‡	FCODE

Notes:
‡ Bridges can be converted to raster using the FCODE attribute or by using the Bypass Condition Code or BCC attribute. This allows the user to reclassify based on an "easy", "difficult", or "unknown" bypass by assigning different scores to each bypass code.

‡‡ Sharp curves or bends in roads could be a potential choke points in forested areas where off-road movement in limited. Visibility at these points is limited and the sharp curves are ideal locations for point minefields. Culvert could be possible locations for command detonated mines or munitions. However, this research focuses on predicting tactical minefields and not nuisance mining.

In order to add importance to the transportation features, a raster buffer was used. This buffer is called the Straight-Line Distance Allocation function. The function allows the user to radiate individual raster values away from the features to a specified buffer distance. This function is necessary since a simple vector buffer would not contain the different raster values inherent within a road network. For example, the Transportation_Line feature contains paved road (RST=1) and unpaved roads (RST=2). If this line feature was buffered and then converted to raster, it would not show where the different RST values exist and intersect.

The intent behind this raster buffer is to predict where minefields may be emplaced, in open terrain, to block or deny key transportation features and bypasses around them. For example, a 10m road may be blocked by a 300m wide minefield that extends off to the side of the road. This minefield probably would extend to the side of a mountain to prevent the bypass of the minefield by vehicles traveling on the road. The allocation function attempts to account for this type of activity. See Figure 3.2 below for an example of this allocation function. The green areas are paved roads (RST=1) and the orange areas are unpaved roads (RST=2). An airstrip is in black.

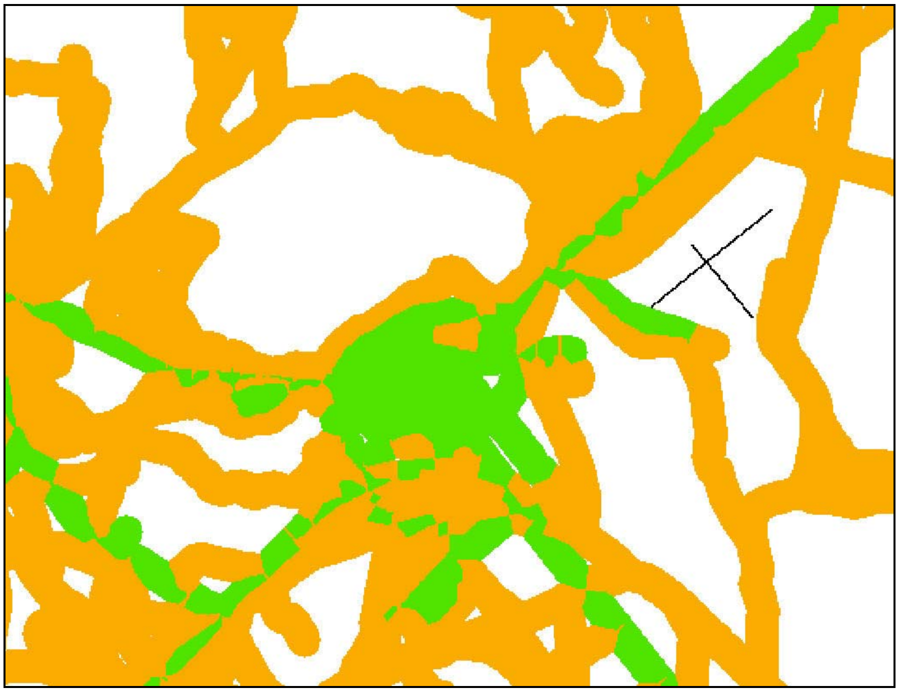

Figure 3.2: An Example of the Straight-Line Distance Allocation Function (where the green areas show the paved roads, orange areas show the unpaved roads, and black areas show areas not considered in the model)

3.3.3 Trafficability Layer

The creation of this layer requires the use of DTSS – specifically the Mobility TDA within DTSS. Access to DTSS is limited to Department of Defense (DoD) personnel and can only operate on DoD compliant computers. It consists of a collection of government off-the-shelf (GOTS) and commercial off-the-shelf (COTS) software packages. The COTS software packages include ESRI's ArcGIS and ERDAS IMAGINE.

Within ArcGIS, DTSS appears as an additional toolbar and the Mobility TDA is an available application on the toolbar. The Mobility TDA input screens can be seen in Figure 3.3. It requires a source geodatabase and exports a trafficability geodatabase as an output. The import geodatabase can be created within DTSS from a VITD or a FFD dataset.

The value in using the Mobility TDA in conjunction with this GIS model for Minefield Area Prediction is that the entire analysis can be performed within ArcGIS. This eliminates the need for multiple programs and models as well as additional data pre-processing. If this GIS model becomes accepted, it could very easily be integrated into DTSS as an additional TDA.

The 'Mobility Parameters' of the DTSS Mobility TDA require certain assumptions about soil/terrain surface condition (Dry, Average, or Wet), soil slippery condition (Normal or Slippery), water level (Low, Medium, or High), historical or almanac rain information by month of interest, and about which military vehicle is used to estimate trafficability. These assumptions are combined with data from VITD to produce cross country, on-road, and gap mobility maps.

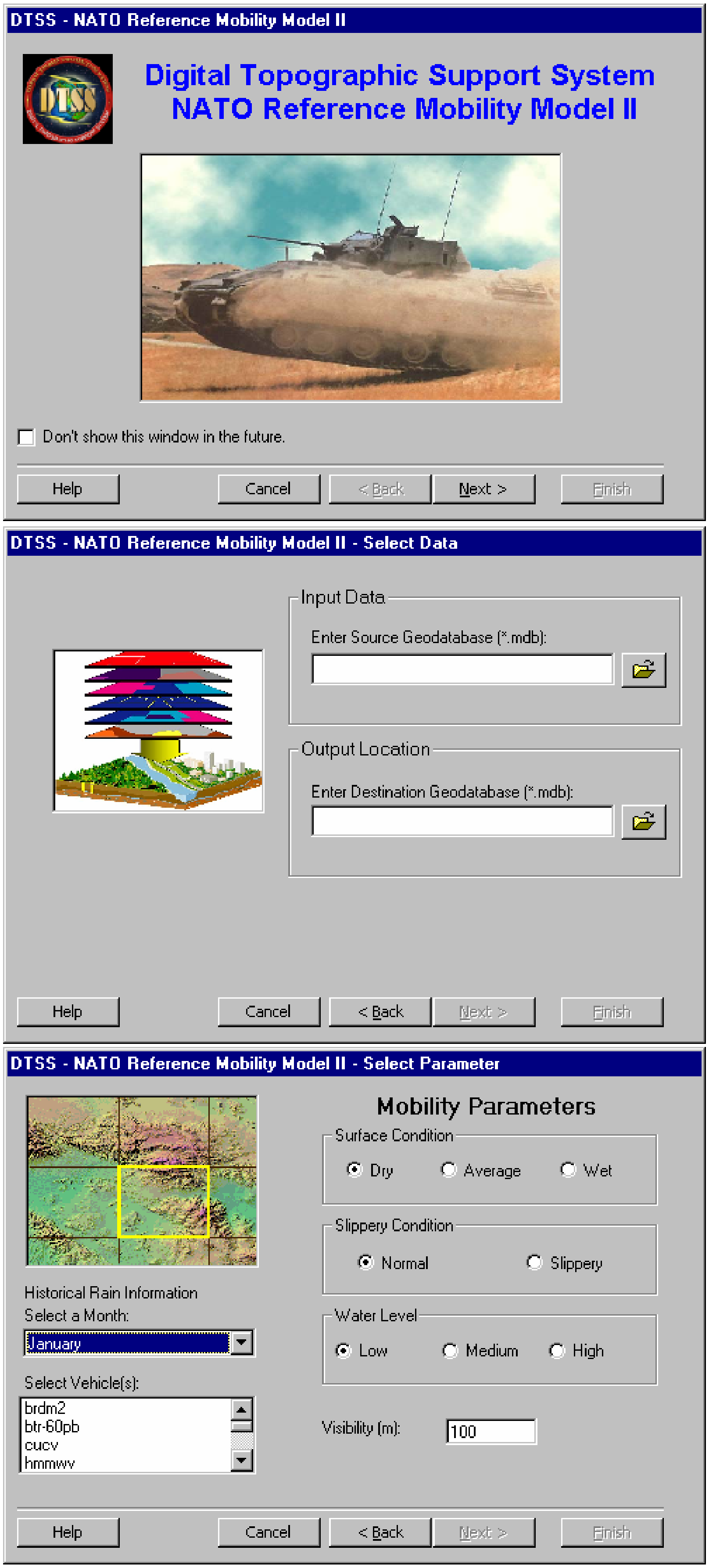

Figure 3.3: The Mobility TDA within DTSS

The trafficability estimates are based on one single vehicle and not on the movement of columns of similar vehicles or task force movement formations. Most dirt roads, given the right conditions, will turn into muddy, swampy pools after a column of tanks have passed through. This is not always the case if just one tank travels down a dirt road.

The Mobility TDA uses slope data as one of the inputs to create the trafficability output. The slope data can come from the input vector dataset (i.e. VITD) or a vector slope coverage can be generated, through use of the DTSS Slope Generator, from a user specified DEM.

Lastly, DTSS is tied to VITD and FFD as input. VITD is an extremely detailed data set but will soon be replaced by Digital TOPographic data (DTOP) or possibly a new dataset. FFD does not always work as an input to DTSS and it is not detailed enough for thorough terrain analysis and predictive models. A new release of DTSS (version 8.0) is due to be released in Fall of 2002 and may correct for some of these deficiencies.

Since this methodology was performed using both DoD and non-DoD computers, the trafficability geodatabases were exported from DTSS so that the results could be used on any computer. The results were classified into five arbitrary classes of average speed (AVG_SPD attribute) using the Natural Breaks (Jenks) method. Both the cross country and the on-road mobility layers were converted to raster and then were merged together to form one single trafficability surface (Note:

The ranges of average speed classified from the cross country mobility layer were used to convert BOTH mobility layers to raster). See Table 3.3 below for some sample MLS scores used to create the Trafficability Layer.

Table 3.3: DTSS Average Speed Ranges used in the Trafficability Layer with assigned Minefield Likelihood Surface Scores

AVG SPD Range (range from Natural Breaks)	MLS Score
0 kph	-99
> 0 – 3 kph	2
> 3 – 20 kph	4
> 20 – 30 kph	6
> 30 – 40 kph	8
> 40 – 65 kph	10
NoData	0

3.3.4 Slope Layer

The consideration of topographic slope is the most important factor in this GIS model. Slope controls how fast and where vehicles can maneuver -- a key predictor in trafficability estimates.

There are different sources of slope in the model. The VITD contains a "Slope_Area" feature class that has polygons that represent areas of equal slope. The slope is derived by a variety of means: migrated from earlier digital sources (like Interim Terrain Data – ITD), from 1:50,000 and 1:100,000 paper contour maps, and from DTED Level 1 (100m) and DTED Level 2 (30m) elevation models. These slope polygons are given five different slope ranges: 0-3% (flat), 3-10% (low), 10-20% (moderate), 20-30% (high) , 30-45% (steep), and > 45% (very steep).

The Mobility TDA within DTSS uses Slope_Area feature class from the VITD dataset to create the trafficability estimates. Depending on how it has been derived, these slope polygons are very generalized for a specific area of interest and are not as detailed as raster slope data (i.e. an individual slope estimate for each 30x30m pixel). A better estimate of slope can be derived from DTED2 and from USGS 30m DEMs. Due to these concerns, a separate slope layer is created within the GIS model. Due to data availability, slope is derived from different elevation data sets for different areas of interest. The effects on the model output by using different slope layers are compared during the sensitivity analysis in Chapter 4.

Slope can be expressed as a percentage, of rise over run, or in degrees. There are several different slope algorithms for deriving slope within GIS. Most are based on computing slope from an array of nine (3 x 3) pixels of elevation data. One of the most common algorithms is depicted below which was developed by B.K.P Horn in 1981.[25] This is the method that ESRI's ArcGIS software uses to derive slope. See Figure 3.4 for an explanation of this method.

[25] Horn (1981)

A 3x3 pixel array of nine elevation values within a DEM

Z1	**Z2**	**Z3**
Z4	**Z5**	**Z6**
Z7	**Z8**	**Z9**

The slope for cell Z5 is computed by using the following formulas:

$$\frac{\delta z}{\delta x} = \frac{(Z1 + (2 \times Z4) + Z7) - (Z3 + (2 \times Z6) + Z9)}{8 \times \Delta x}$$

$$\frac{\delta z}{\delta y} = \frac{(Z1 + (2 \times Z2) + Z3) - (Z7 + (2 \times Z8) + Z9)}{8 \times \Delta y}$$

$$\text{Slope (in percent \%)} = \text{S\%} = \sqrt{(\delta z / \delta x)^2 + (\delta z / \delta y)^2}$$

$$\text{Slope (in degrees)} = \tan^{-1}(S\%) \times {}^{180^\circ}\!/_{\pi}$$

Figure 3.4: Slope Algorithm used in ArcGIS

In the minefield likelihood process, the VITD Slope_Area feature class is converted to a raster layer. It is then reclassified into the standard VITD slope ranges and given an MLS value. Table 3.4 lists the MLS scores.

Table 3.4: VITD Slope Ranges used in the Slope Layer with assigned Minefield Likelihood Surface Scores

Slope Range (range from VITD)	**MLS Score**
0 – 3%	10
> 3 – 10%	8
> 10 – 20%	6
> 20 – 30%	4
> 30 – 45%	1
> 45%	-99
NoData	0

The results of the slope calculation (Horn algorithm) are reclassified into integer data according to the VITD slope range values and the MLS scores in the table above.

3.3.5 Visibility Layer [Visibility Subroutine]

No tactical minefield is effective if it is not directly visible by a forward artillery observer, machine gun position, tank defensive position, or something similar. The concept behind tactical minefield doctrine is to slow or stop an invading force with minefields and other obstacles and kill them with direct or indirect fire. If a minefield is not observed, it can be removed or destroyed by the invading force with little repercussion.

This GIS model implements this concept of tactical minefield doctrine by incorporating a viewshed analysis. Observation points were collected from each of the areas of interest and multiple viewsheds were created. The same elevation model used to derive the slope layer is used in this step to create the viewsheds. The end result is a raster layer of multiple viewsheds merged together. The layer is a binary surface comprised of visible areas and not visible areas. Each area is assigned an MLS score – a perfect '10' if the areas is visible and a '-5' if the area is not. See Table 3.5 for an example of the information needed to perform the viewshed analysis.

Table 3.5: Observer Attribute Table used in creation of the Visibility Layer

ID	TYPE	OFFSETA	OFFSETB	RADIUS1	RADIUS2
1	M1 Tank	2	0	0	3000
2	COLT	1	0	0	7000

TYPE = observer/position type
OFFSETA = observer height (in meters)
OFFSETB = minefield height (normally 0)
RADIUS1 = minimum observation range (normally 0)
RADIUS2 = maximum effective range of weapon system (in meters) or effective visual range of observer (in meters)

This layer has a lot of influence over the end result of the GIS model and it is one of the most difficult to simulate in a modeling environment. The input observer locations can come from a variety of sources. In a pure tactical context, these locations could come from an enemy spot report transmitted by FM radio or digitally through ASAS (All Source Analysis System – part of the ABCS). In a humanitarian or a post-conflict context, these locations could be detected by analysis of imagery, by interview of the local populace, or from tactical defensive plans and orders. Due to the difficulty in collecting this data, this layer can be used as an optional input into the GIS model. Chapter 4 will investigate the inclusion and exclusion of this layer in the GIS model as part of the sensitivity analysis.

3.3.6 Final Output – Minefield Likelihood Surface

Once the five input raster layers are created, they are combined using simple algebraic formulas.

The first case is to combine them without using weighting coefficients:

Output = **Hydro** + **Transpo** + **Slope** + **Traffic** + **Visibility**

Alternative approaches are to explore different weighting schemes to emphasize a specific layer:

Output = **Hydro** + **Transpo** + 2*__Slope__ + 2.5*__Traffic__ + 0.5*__Visibility__
Output = 0.25*__Hydro__ + 1.5*__Transpo__ + **Slope** + 1.5*__Traffic__ + 0.75*__Visibility__
Etc….

These weighting schemes will be explored in the sensitivity analysis of Chapter 4.

The output display pixels that are classified into four minefield likelihood classes: Very Likely, Likely, Possible, and Not Likely to be mined. Expressing the output is very sensitive to what ranges of likelihood are used. For example, what does "very likely to be mined" mean? Is that a probability of 75%, 95%, or 51%? These ranges are based on the user's knowledge, judgment, and past experiences. This research used a conservative approach and classified the output into the following minefield likelihood classes:

Model Output Value	Classification Range	Minefield Likelihood Class
< 0	< 0%	Not Likely
0 – 13.2	0 – 33%	Possible
> 13.2 – 26.4	> 33 – 66%	Likely
> 26.4 - 40	> 66 – 100%	Very Likely

Every pixel that receives a negative model output value is placed in the "Not Likely" class. These may be urban areas, lakes, areas with greater than 45% slope, or any other feature that received a -99 MLS score. The positive model output values were categorized into ranges of 33% that represent the "Possible", "Likely", and "Very Likely" classes.

The model output is only as good as the accuracy of the input data. The results should be presented with an accuracy assessment of the minefield likelihood score and location. This will be explored in Chapter 4 as well.

3.4 Model Implementation and Evaluation Methodology

The Minefield Likelihood Procedure must be customizable for the areas of interest where the GIS model is applied. Certain attributes will receive different MLS scores depending on the terrain and hydrographic conditions present. Certain raster layers may receive different weighting in the creation of the Minefield Likelihood Surface. All of this depends on the areas of interest used. Ideally, the GIS model for minefield area prediction can be executed on any area of interest in the world. However, the input data that is required is not available for the entire world. Therefore, this methodology will use two separate areas of interest to demonstrate how the Minefield Likelihood Procedure can be adapted and can use different types of geospatial data depending on data availability.

After the GIS model is customized for a specific area of interest and the weighting of variables is determined, the Minefield Likelihood Surface is evaluated with known training minefield data from the areas of interest. The minefield data is imported into the GIS and then compared to the raster minefield prediction surface to evaluate its prediction accuracy. Before describing this process in more detail, it is important to describe the two areas of interest to show how they are different.

3.4.1 Description of Fort Irwin, California

Fort Irwin is located in San Bernardino County in the Mojave Desert in the southeastern corner of California. The fort was first established in the late 1800's to protect settlers in the region. In 1940, it was reestablished as a maneuver training center for forces during World War II. In 1981, the National Training Center (NTC) was opened. It is now home of the best maneuver training in the world. An entire brigade of soldiers and vehicles can train at a time against a real enemy force (termed OPFOR or Opposing Force). Soldiers and vehicles are equipped with laser sensors and emitters to simulate real combat. Everything is tracked with GPS and radio frequency sensors so to provide detailed feedback on the results of each battle. More information is available about the history of Fort Irwin at GlobalSecurity.org.[26]

Area of Interest Size: The NTC training area is 2575 square kilometers (636,000 acres) in size. It is a vast training area where mechanized (tracked) and wheeled vehicles can maneuver cross country, where live artillery and missiles can be fired, and where military aircraft can drop munitions in conjunction with joint live fire exercises.

Brief Terrain Description: Fort Irwin is comprised of open desert broken by high mountains and rocky narrow passes. Elevation ranges from 1840m in the high mountains to 265m above sea level in the desert flats of the several wide corridors. There is very little vegetation due to the dry weather – Fort Irwin averages four inches of rainfall a year. The terrain is dissected by dirt trails and dry stream beds and wadis. These fill up quickly during the rare rain storms. The terrain is perfect for cross country maneuver of tracked and wheeled vehicles.

See Layout 1 in Appendix D for an overview map of Fort Irwin.

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[26] http://www.globalsecurity.org/military/facility/fort-irwin.htm

3.4.2 Description of Fort Polk, Louisiana

Fort Polk is located in Vernon County in the western side of Louisiana. It is home to the Joint Readiness Training Center (JRTC) – the premiere training center for light infantry forces. The fort was opened in the 1940's for the Louisiana Maneuvers prior to WWII. In 1991, the JRTC was moved from Fort Chaffee, AR to Fort Polk. It has the same training facilities as those of the NTC but it is geared towards light infantry battalions and brigades instead of mechanized battalions and brigades. More information is available about the history of Fort Polk at GlobalSecurity.org.[27]

Area of Interest Size: The southern half of the Fort Polk training area (called South Fort Polk) is 470 square kilometers (116,000 acres) in size.

Brief Terrain Description: Fort Polk is a relatively flat training area with very little relief – elevation ranges from 50m to 135m above sea level. Over 80% of the post is covered in forest which limits cross country maneuver by tracked and wheeled vehicles. Several perennial and intermittent streams split up the training area vertically. Although dismounted infantry soldiers have virtually unlimited maneuver, tracked and wheeled vehicles are limited to the network of paved and unpaved roads. The weather can be very rainy at times especially in the early spring and late summer.

See Layout 2 in Appendix D for an overview map of Fort Polk.

3.4.3 Implementation of the Minefield Likelihood Procedure

As discussed before, any minefield area predictive model must be customizable for the specific area of interest. This GIS model is based on the MLS scores that are assigned to specific attributes of the terrain. For example, a stream network in one area may be dry most of the year while in another area, a stream network may frequently flood the surrounding terrain and would inhibit possible minefield emplacement. The modified Minefield Likelihood Procedures for both the Fort Irwin and for the Fort Polk areas of interest follow.

[27] http://www.globalsecurity.org/military/facility/fort-polk.htm

<u>3.4.3.1 Minefield Likelihood Procedure for Fort Irwin:</u>

1. Hydrography: The MLS scores were changed to match the environment and terrain of Fort Irwin. See Table 3.6 for the specific MLS scores.

Table 3.6: Hydrography Layer customized for Fort Irwin

VPF file name	VITD Feature Class	Feature Code (FCODE)	FCODE Description	MLS score	Attribute used to Convert to Raster
vegarea	Vegetation_Area	BH090	Land Subject to Inundation	-99	FCODE
		EA010	Cropland	0	FCODE
		EB010	Grassland	0	FCODE
		EB020	Scrub/Brush	0	FCODE
		DA020	Barren Ground	0	FCODE
sdrarea	Surface_Drainage_Area	SA010	Common Open Water	-99	FCODE
		ZD012	Geographic Information Point: Intermittent Lake	-99	FCODE
vgwarea	Vegetation_Water_Area	SA010	Common Open Water	-99	FCODE
		AL020	Built-up Areas	-99	FCODE
smwarea	Surface_Materials_Water_Area	SA010	Common Open Water	-99	FCODE
		SA020	Disturbed Soil ††	-99	FCODE
slwarea	Slope_Water_Area	SA010	Common Open Water	-99	FCODE
sdcarea	Surface_Drainage_Channel_Area	BH140	River/Stream †††	0	FCODE
sdcline	Surface_Drainage_Channel_Line	BH140	River/Stream †††	0	FCODE
sdrnode	Surface_Drainage_Node	BH070	Ford Site †††	0	FCODE

<u>Notes:</u>

*†† The "Disturbed Soil" feature code features are identical to the "Built-up Areas" feature code features **IN THIS INSTANCE**. Built-up areas are not mined in this example since they are not within the designated Training Area. It may be possible in some other VITD datasets where disturbed soil may represent buried mines or man-made obstacle construction. If this were the case, the MLS score would be completely different.*

††† Rivers, streams, and ford sites were not considered in the hydrography layer in this example. This is because the rivers and streams are dry during most of the year and do not prevent minefield emplacement. Most dry river/stream beds can be used as avenues of approach for military vehicle formations. However, if the streams prove to be a formidable obstacle, it would be wise to reclassify the rivers/streams using the HYC (hydraulic category) FCODE. If the HYC attribute = 8 (perennial stream) then MLS score = -99; if HYC = 6 (intermittent) then MLS score = 0.

2. Transportation: The MLS scores were changed to match the transportation features of Fort Irwin. See Table 3.7 for the specific MLS scores.

Table 3.7: Transportation Layer customized for Fort Irwin

VPF file name	VITD Feature Class	Feature Code (FCODE)	FCODE Description	MLS score	Attribute used to Convert to Raster
trnline	Transportation_Line	AP010	Cart Track	6	FCODE
		GB055	Runway	-99†	FCODE
trrline	Transportation_Railroad_Line	AN010	Railroad	-99†	FCODE
		AN050	Railroad Siding/Spur	-99†	FCODE
trdline	Transportation_Road_Line	AP030	Hard/Paved (RST=1)	10	RST
		AP030	Loose/Unpaved (RST=2)	8	RST
trbline	Transportation_Bridge_Line	AQ040	Bridge: Bypass= easy	-99†	FCODE
		AQ040	Bridge: Bypass= difficult	-99†	FCODE
		AQ040	Bridge: Bypass= unknown	-99†	FCODE
trbdgnd	Transportation_Bridge_Node	AQ040	Bridge: Bypass= easy	-99†	FCODE
		AQ040	Bridge: Bypass= difficult	-99†	FCODE
		AQ040	Bridge: Bypass= unknown	-99†	FCODE
Trnnode	Transportation_Node	AQ118	Sharp Road Curve/Bend	8 ‡‡	FCODE
		ZD012	Geo Info Point: Culvert	0 ‡‡	FCODE

Notes:
† Runways, railroads, and bridges are not mined in this example due to training area restrictions. They are excluded from minefield likelihood consideration in this model. To include them, just change the MLS score.

3. Slope: No change in MLS scores.

4. Trafficability: The parameters set within DTSS for the Mobility TDA were specific to Fort Irwin. The specific parameters used are as follows:

Fort Irwin trafficability parameters:
Surface Condition: Dry
Slippery Condition: Normal
Water Level: Low
Month: July
Vehicle: M1A2

5. Visibility: No change in MLS scores. Specific observation points were selected for Fort Irwin.

3.4.3.2 Minefield Likelihood Procedure for Fort Polk:

1. Hydrography: The MLS scores were changed to match the environment and terrain of Fort Polk. See Table 3.8 for the specific MLS scores.

Table 3.8: Hydrography Layer customized for Fort Polk

VPF file name	VITD Feature Class	Feature Code (FCODE)	FCODE Description	MLS score	Attribute used to Convert to Raster
Vegarea	Vegetation_Area	BH090	Land Subject to Inundation	-99	FCODE
		EA010	Cropland	0	FCODE
		EB010	Grassland	0	FCODE
		EB020	Scrub/Brush	0	FCODE
		DA020	Barren Ground	0	FCODE
Sdrarea	Surface_Drainage_Area	SA010	Common Open Water	-99	FCODE
		ZD012	Geographic Information Point: Intermittent Lake	-99	FCODE
Vgwarea	Vegetation_Water_Area	SA010	Common Open Water	-99	FCODE
		AL020	Built-up Areas	-99	FCODE
Smwarea	Surface_Materials_Water_Area	SA010	Common Open Water	-99	FCODE
		SA020	Disturbed Soil [††]	-99	FCODE
Slwarea	Slope_Water_Area	SA010	Common Open Water	-99	FCODE
Sdcarea	Surface_Drainage_Channel_Area	BH140	River/Stream [†††]	0	FCODE
Sdcline	Surface_Drainage_Channel_Line	BH140	River/Stream [†††]	-99	HYC = 8
Sdcline	Surface_Drainage_Channel_Line	BH140	River/Stream [†††]	0	HYC = 6
Sdrnode	Surface_Drainage_Node	BH070	Ford Site [†††]	0	FCODE

Notes:

[††] *The "Disturbed Soil" feature code features are identical to the "Built-up Areas" feature code features* ***IN THIS INSTANCE****. Built-up areas are not mined in this example since they are not within the designated Training Area. It may be possible in some other VITD datasets where disturbed soil may represent buried mines or man-made obstacle construction. If this were the case, the MLS score would be completely different.*

[†††] *Rivers and streams* ***were*** *considered in the hydrography layer for Fort Polk. The streams prove to be a formidable obstacle and are classified based on the HYC (hydraulic category) FCODE. If the HYC attribute = 8 (perennial stream), then MLS score = -99; if HYC = 6 (intermittent) then MLS score = 0. Surface_Drainage_Node (ford sites) and Surface_Drainage_Channel_Area (lakes) feature classes were missing in the VITD – if they were populated, MLS scores would be assigned according to a similar logic.*

2. Transportation: The MLS scores were changed to match the transportation features of Fort Polk. See Table 3.9 for the specific MLS scores.

Table 3.9: Transportation Layer customized for Fort Polk

VPF file name	VITD Feature Class	Feature Code (FCODE)	FCODE Description	MLS score	Attribute used to Convert to Raster
Trnline	Transportation_Line	AP010	Cart Track	6	FCODE
		GB055	Runway	10†	FCODE
Trrline	Transportation_Railroad_Line	AN010	Railroad	-99†	FCODE
		AN050	Railroad Siding/Spur	-99†	FCODE
Trdline	Transportation_Road_Line	AP030	Hard/Paved (RST=1)	10	RST
		AP030	Loose/Unpaved (RST=2)	8	RST
Trbline	Transportation_Bridge_Line	AQ040	Bridge: Bypass= easy	10 †	FCODE
		AQ040	Bridge: Bypass= difficult	10 †	FCODE
		AQ040	Bridge: Bypass= unknown	10 †	FCODE
Trbdgnd	Transportation_Bridge_Node	AQ040	Bridge: Bypass= easy	10 †	FCODE
		AQ040	Bridge: Bypass= difficult	10 †	FCODE
		AQ040	Bridge: Bypass= unknown	10 †	FCODE
Trnnode	Transportation_Node	AQ118	Sharp Road Curve/Bend	0 ‡‡	FCODE
		ZD012	Geo Info Point: Culvert	0 ‡‡	FCODE
		BH070	Ford Site	10‡‡	

Notes:

† *Runways, bridges, and ford sites are high priority for point minefields. The VITD for Fort Polk did not contain useful information about bridge bypass (BCC feature code) so all bridges were given the same MLS score. Railroads are not mined due to training area restrictions. They are excluded from minefield likelihood consideration in this model. To include them, just change the MLS score.*

‡‡ *The Transportation_Node feature class of Fort Polk contains ford site information where as the Fort Irwin Transportation_Node feature class contained information about road curves and culverts. This is an error in interpretation between to the NIMA and the RTV produced VITD datasets. No information about road curves could be found in the Fort Polk VITD.*

3. Slope: No change in MLS scores.

4. Trafficability: The parameters set within DTSS for the Mobility TDA were specific to Fort Polk. A standard set of three military vehicles was chosen.

Fort Polk trafficability parameters: Surface Condition: Wet Slippery Condition: Slippery Water Level: Medium Month: March Vehicle: M1A2

5. Visibility: No change in MLS scores. Specific observation points were selected for Fort Polk.

3.4.4 Evaluation Methodology for the Minefield Likelihood Procedure

The results of the Minefield Likelihood Procedure must be evaluated using known minefield data in order to: 1) determine the accuracy of the GIS model; and 2) find ways to improve the model. The challenge is to acquire accurate minefield data, preprocess the data, and represent it accurately within the GIS. The following sections describe the minefield data, how it was brought into the GIS model, and the method used to evaluate results of the model.

3.4.4.1 Description of Minefield Data: In order to validate the results of this minefield area prediction model, known minefield data was used. Due to information releasability issues, this model uses training minefield data taken from US Army training centers. This data comes from minefields that have been emplaced by US Army soldiers during the conduct of tactical training exercises at Fort Irwin, California and Fort Polk, Louisiana. Ideally, this model should be tested at a later date against known minefield data from past conflicts in areas such as Bosnia, Kosovo, or Afghanistan.

The data can be collected by a variety of means:

- Minefield record reports (that contain magnetic azimuths and pace counts from a known benchmark)
- Handheld GPS units
- Field sketches
- Foreign army minefield reports
- Interviews with the local populace
- Aerial survey

The minefield data used in this model was sent via e-mail and fax. The data came from minefield log reports, each specific to a training facility, and from PowerPoint files summarizing minefield locations. The minefield data was divided into two types of minefields: rectangular and point minefields. See the discussion in Section 2.1.2 that describes rectangular and point minefields.

3.4.4.2 Estimated Accuracy of Minefield Data: The minefield data used in this model is very inaccurate. This is due to the way the information is collected, stored, and transmitted. The Department of Defense does not have a standard minefield database that is used throughout the armed forces for the purposes of minefield data dissemination, sharing, and collection. Each military post, training facility, and headquarters has developed their own internal system for minefield data. One of the goals of MCS-Engineer (see Section 2.7) is to use it as a minefield database, but it will not be available until 2003 or 2004. An interim solution is IMSMA but it needs to be tailored to US military information needs and requirements. Due to this lack of standardization and specific minefield data requirements, many assumptions have to be made about minefield data. This model will use conventional, Volcano, and point minefield data in order to evaluate the results of the GIS model. Each minefield can have a different positional accuracy depending on how each type of minefield is represented in the GIS model and how each minefield location was recorded.

Another problem in estimating minefield location accuracy is the non-standardized data collection and reporting performed by military personnel. Most minefields are spotted from a distance and the minefield location is estimated based on the observer's location with handheld GPS units. Because the coordinate is an estimate, a 6-digit MGRS grid coordinate is used. In the MGRS, a 4-digit coordinate references a 1000m by 1000m area, a 6-digit coordinate references a 100m by 100m area, and an 8-digit coordinate references a 10m by 10m area. The coordinate system and horizontal datum is fairly standard across the US Army – MGRS and the WGS-84 horizontal datum. However, if the only available paper maps use a different datum, the GPS units must be switched to this datum and the minefield coordinates would be reported using this datum. Transmitting minefield coordinates with a datum is unheard of in the US Army. An assumption must be made concerning which datum was used while the GPS points were collected.

It is assumed that the minefield data was either collected on the perimeter of the minefield or from within 50m of the minefield using handheld GPS units. It is also assumed that the GPS units were set to the WGS-84 datum and the MGRS. The best horizontal accuracy of a US Army portable GPS is ±10m. Also, some of the minefield coordinates were given as 8-digit coordinates and some as 6-digit coordinates. In order to be on the conservative side and to factor in all of the assumptions, this model will use a horizontal accuracy of ± 50m for 8-digit coordinates and ± 100m for 6-digit coordinates.

3.4.4.3 Processing of Minefield Data & Import into the GIS: The best way for a GIS model to process minefield data would be from a minefield database – such as IMSMA. However, these mine information systems are designed to process extremely detailed information about minefields for the purposes of demining. They can not function properly without a minimal amount of detail for each minefield. IMSMA was unable to be used to process training minefield data because of missing information such as benchmark/landmark locations and perimeter minefield coordinates. However, if data already existed in an IMSMA database, it could be exported directly into a GIS.

In order to bring the minefield data collected into the GIS, a data manipulation process, similar to the one used to import the observer and defensive locations, was required. The data was first entered into a simple ASCII text file as a column of complete MGRS grid coordinates (e.g. 11SNV34111700). The GEOTRANS software used the ASCII text file as input and converted the MGRS coordinates to UTM (Universal Transverse Mercator) coordinates. It was not necessary to transform the datum since the data was already in the WGS-84 datum.

The UTM coordinates were then loaded into a spreadsheet program and reordered into X & Y columns. If the minefield data only included a start and end point, then just two columns were necessary. If the minefield data contained four perimeter coordinates, then four columns were used – X1, Y1, X2, and Y2. These coordinates were then transformed into polylines of minefields within the GIS using Visual Basic for Applications (VBA). The code is available from the ESRI ArcObjects website.[28]

[28] http://arconline.esri.com/arcobjectsonline

In order to better represent the area of the minefields within the GIS, the minefield polylines were buffered to display the total area occupied by the minefields and then further buffered to show the spatial uncertainty of the data. The polylines were assumed to be the centerlines of each minefield, regardless of type. The depth of the minefields was assumed to be 120m (or 60m from the centerline in both directions). Based on these two assumptions, the minefields were transformed into polygons of minefield area by buffering each polyline 60m in both directions. The minefield buffer was then buffered again to represent the spatial uncertainty of the minefield. A minefield that was recorded using 6-digit MGRS coordinates used a buffer of 100m. A minefield that was recorded using 8-digit coordinates used a buffer of 50m. See Figure 3.5 for an example of the final minefield output. The end product of all of this manipulation was a vector data layer with UTM coordinates using the WGS-84 datum depicting the locations of the training minefields.

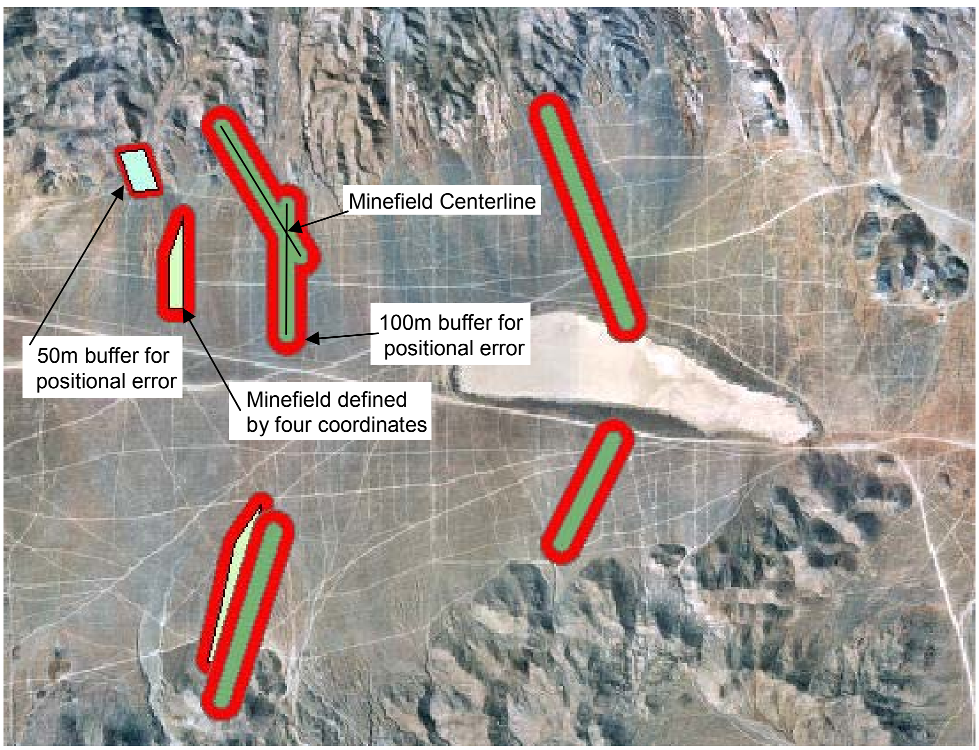


Figure 3.5: Example of Training Minefield Data Buffered to Reflect Spatial Uncertainty

<u>*3.4.4.4 Model Evaluation Methodology:*</u> The GIS model was evaluated two ways. One approach evaluated the total land area that was classified by each minefield likelihood class. The second approach evaluated the accuracy of the Minefield Likelihood Surface against known minefield data. The goal was to minimize the total land area classified within the "Very Likely" minefield likelihood class while maximizing the accuracy of the Minefield Likelihood Surface.

Evaluation of the total land area was performed by simply subtotaling the number of pixels in the output surface by each minefield likelihood class. The Minefield Likelihood Surface was classified into four classes:

“Very Likely” (raster value of 3)
- “Likely” (raster value of 2)
- “Possible” (raster value of 1)
- “Not Likely” (raster value of 0)

The subtotals were summarized in a table and then percentages of land area were calculated based on the total number of pixels in the output. See Table 3.10 for a sample of these statistics. The percentage that this methodology focused on, and attempted to minimize, was the percentage of land area classified by the “Very Likely” class.

In order to evaluate the accuracy of the model versus the known minefields, data needed to be collected from a comparison of minefield data to the GIS model output. This comparison to the Minefield Likelihood Surface (MLS) was conducted through the use of zonal statistics. Each minefield was considered to be a zone and summary statistics were gathered based on the values from the raster surface beneath each zone. In order to collect accurate zonal statistics, the MLS had to be separated from the original raster output layer into four separate raster layers – one for each minefield likelihood class. Then, the zonal statistics were computed for each layer and the statistics were aggregated in a spreadsheet for an analysis. See Figure 3.6 for a schematic of this process and Table 3.11 for a sample MLS Accuracy Report. This methodology enables the user to total the number of pixels by minefield likelihood class and to sum the number of minefield likelihood class pixels for each individual minefield. For example, minefield ID #5 may consist of 3 “Not Likely” pixels, 10 “Possible” pixels, 38 “Likely” pixels, and 68 “Very Likely” pixels.

A minefield is successfully predicted by the model output surface when greater than 50% of the minefield falls within the “Possible”, “Likely”, or “Very Likely” classes. The goal is to create a model output surface where all or most of the minefields fall within the Very Likely class. The model output surface fails when greater than 50% of a minefield falls within the “Not Likely” class.

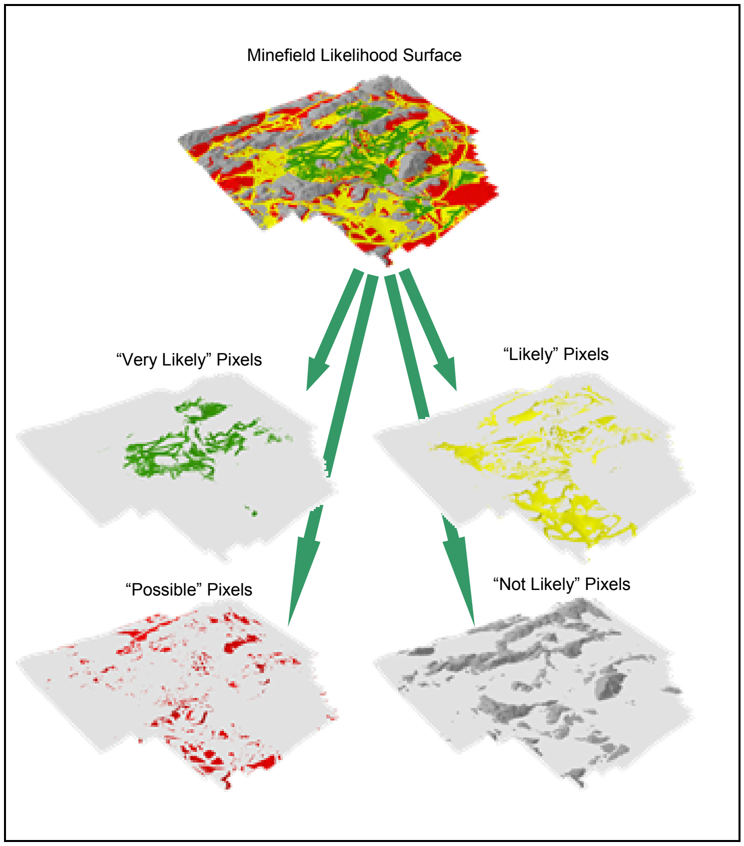


Figure 3.6: Schematic of Minefield Data and Minefield Likelihood Surface

Table 3.10: Sample Summary Statistics for a Minefield Likelihood Surface

Minefield Likelihood for Fort Irwin - 30m Resolution					
Using VITD Slope Layer & DTED2 30m Digital Elevation Model					
Clipped to NTC Boundary					
like1_c_r	pixels	km2	acres		
Total Pixels=	2,860,818	2,575	636,243		
mf pixels=	6,295				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	1,083,861	37.89%	1,379	21.91%
Possible	> 0 - 33%	608,630	21.27%	386	6.13%
Likely	> 33 - 66%	818,741	28.62%	1,829	29.05%
Very Likely	> 66 - 100%	349,586	12.22%	2,701	42.91%
		2,860,818	100.00%	6,295	100.00%

Table 3.11: Sample Minefield Likelihood Surface Accuracy Report

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	8	116	124	0.00%	0.00%	6.45%	93.55%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	4	3	7	7	21	19.05%	14.29%	33.33%	33.33%
43	G1BSV05	Volcano	0	28	194	0	222	0.00%	12.61%	87.39%	0.00%
44	G1ASV05	Volcano	0	3	51	0	54	0.00%	5.56%	94.44%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	13	2	178	106	299	4.35%	0.67%	59.53%	35.45%
47	M2ASV01	Volcano	0	0	85	169	254	0.00%	0.00%	33.46%	66.54%
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%
			17	36	589	979	1621				
		Overall Accuracy =	**1.05%**	**2.22%**	**36.34%**	**60.39%**					

The MLS scores internal to each of the GIS model raster input layers can be adjusted in order to improve overall accuracy and performance based on the known minefield data. Chapter 4 will discuss model calibration and sensitivity analysis where the actual model evaluation will take place.

4.0 RESULTS

The Minefield Likelihood Procedure was performed on the Fort Irwin data first. The training minefield data was used to calibrate the Minefield Likely Surface (MLS) scores internal to each of the GIS model input layers. After the GIS model was calibrated, a sensitivity analysis was performed to answer two questions:

1. How should the GIS model layers be weighted when creating the Minefield Likelihood Surface?
2. How should "Slope" be considered in the model?

This same analysis was then applied to the Fort Polk data. The last section of this chapter discusses the accuracy of the source data and approximates an overall accuracy of the GIS model output.

4.1 Model Calibration for Fort Irwin Data

The initial MLS scores for each model input layer were set arbitrarily in Section 3.4.3 (Model Implementation). In order to test these initial scores, the model output was evaluated iteratively against a set of training minefield data. The first set of training minefield data was taken from an NTC rotation in the summer of 2002. It consisted of 49 minefields – 16 point minefields, 6 conventional minefields, and 27 Volcano minefields. The model parameters internal to each raster layer were adjusted until an optimal set of MLS scores was selected. The next series of model runs will describe this model calibration process.

4.1.1 First Model Run

The first "run" of the GIS model included the original set of MLS scores initially set in Section 3.4.3. Each of the five raster layers was weighted equally to derive the output. The combination is as follows:

Run1: ***Output*** *=* ***Hydro*** *+* ***Transpo*** *+* ***Slope*** *+* ***Traffic*** *+* ***Visibility***

The Slope Layer is a raster conversion of the vector slope layer that is contained within the VITD geodatabase – referred to as VITD Slope for the rest of this analysis. The output was evaluated by examining the output accuracy as compared to known training minefield data. See Tables 4.1a and 4.1b for these results.

Table 4.1a: Initial Minefield Likelihood Surface Accuracy Assessment

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	38	0	0	0	38	100.00%	0.00%	0.00%	0.00%
2	A1SM01	Conventional	55	0	5	0	60	91.67%	0.00%	8.33%	0.00%
3	ACASF04	Point - ADAM/RAAM	50	46	43	1	140	35.71%	32.86%	30.71%	0.71%
4	ACASF05	Point - ADAM/RAAM	123	9	8	0	140	87.86%	6.43%	5.71%	0.00%
5	ACASF06	Point - ADAM/RAAM	67	0	17	56	140	47.86%	0.00%	12.14%	40.00%
6	G1*SF03	Point - ADAM/RAAM	140	0	0	0	140	100.00%	0.00%	0.00%	0.00%
7	F2BSF01	Point - ADAM/RAAM	70	0	2	68	140	50.00%	0.00%	1.43%	48.57%
8	F2ASF02	Point - ADAM/RAAM	65	28	48	0	141	46.10%	19.86%	34.04%	0.00%
9	L*SF01	Point- ADAM/RAAM	120	20	0	0	140	85.71%	14.29%	0.00%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
13	F1BSM01	Point - MOPMS	4	0	0	0	4	100.00%	0.00%	0.00%	0.00%
14	F1BSM03	Point - MOPMS	2	0	2	0	4	50.00%	0.00%	50.00%	0.00%
15	F2ASM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	36	3	40	0	79	45.57%	3.80%	50.63%	0.00%
17	ACASF04	Point - ADAM/RAAM	11	27	41	0	79	13.92%	34.18%	51.90%	0.00%
18	A1SV02	Volcano	47	0	32	55	134	35.07%	0.00%	23.88%	41.04%
19	A1SV01	Volcano	90	0	2	81	173	52.02%	0.00%	1.16%	46.82%
20	A2ASV02	Volcano	12	0	101	133	246	4.88%	0.00%	41.06%	54.07%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	104	19	167	0	290	35.86%	6.55%	57.59%	0.00%
23	G1ASV01	Volcano	38	24	135	0	197	19.29%	12.18%	68.53%	0.00%
24	G1ASV02	Volcano	28	0	65	0	93	30.11%	0.00%	69.89%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	16	0	77	66	159	10.06%	0.00%	48.43%	41.51%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	29	14	110	0	153	18.95%	9.15%	71.90%	0.00%
29	G2ASV01	Volcano	33	0	2	137	172	19.19%	0.00%	1.16%	79.65%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	7	0	35	243	285	2.46%	0.00%	12.28%	85.26%
34	L2CSV01	Volcano	0	0	116	122	238	0.00%	0.00%	48.74%	51.26%
35	L2ASV01	Volcano	47	0	32	0	79	59.49%	0.00%	40.51%	0.00%
36	??	Volcano	32	1	30	76	139	23.02%	0.72%	21.58%	54.68%
37	A2BSV01	Volcano	26	1	45	116	188	13.83%	0.53%	23.94%	61.70%
38	G1AMF01	Conventional	66	0	0	0	66	100.00%	0.00%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	8	116	124	0.00%	0.00%	6.45%	93.55%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	4	3	7	7	21	19.05%	14.29%	33.33%	33.33%
43	G1BSV05	Volcano	0	28	194	0	222	0.00%	12.61%	87.39%	0.00%
44	G1ASV05	Volcano	0	3	51	0	54	0.00%	5.56%	94.44%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	13	2	178	106	299	4.35%	0.67%	59.53%	35.45%
47	M2ASV01	Volcano	0	0	85	169	254	0.00%	0.00%	33.46%	66.54%
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%
			1379	386	1829	2701	6295				
		Overall Accuracy =	**21.91%**	**6.13%**	**29.05%**	**42.91%**					

Table 4.1b: Summary of Model Run #1 Statistics

MODEL RUN #1 Used VITD Slope

Minefield Likelihood for Fort Irwin - 30m Resolution

Using VITD Slope Layer & DTED2 30m Digital Elevation Model

Clipped to NTC Boundary

like1_c_r	**pixels**	**km^2**	**acres**
Total Pixels=	2,860,818	2,575	636,243
mf pixels=	6,295		

	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	1,083,861	37.89%	1,379	21.91%
Possible	> 0 - 33%	608,630	21.27%	386	6.13%
Likely	> 33 - 66%	818,741	28.62%	1,829	29.05%
Very Likely	> 66 - 100%	349,586	12.22%	2,701	42.91%
		2,860,818	100.00%	6,295	100.00%

11 of 49 minefields fail (>50% of the minefield within "Not Likely")
6 of the 11 are point minefields
22% failure rate (78% pass rate)

One goal of model calibration is to maximize the percentage of minefields classified within the "Very Likely" minefield likelihood class while minimizing the percentage of land area classified within the "Very Likely" class. It would be very easy to simply classify the entire area of interest as "Very Likely" for minefield likelihood and the accuracy of the output would be 100% for minefields within that class. This will be explored more at the end of the model calibration phase. A second goal of model calibration is to examine the performance of the GIS model output by individual minefield. If 100% of a known minefield falls within the "Not Likely" minefield likelihood class, then the model has failed and the parameters must be adjusted.

In this first run of the model, 12% of the land area (approximately 309 km^2) and 43% of the known minefields were classified within the "Very Likely" class. The percentage of land area seemed like a good start but the percentage of minefields classified seemed very low. Also, the output classified 11 of the 49 minefields in the dataset as falling within the "Not Likely" class (having >50% of the minefield within this class). After examining each of the individual minefields (highlighted in Table 4.1a), the reasons for these failures were:

1. The minefield area was classified as untrafficable and excluded from the model by assigning a -99 MLS score (MFID #2, 4, & 19).
2. Rectification errors in the VITD transportation network feature class caused some portions of the transportation network to be out of alignment with rectified imagery. The alignment error was over 200 meters in some locations. These errors affected the trafficability estimates which, in turn, affected the output (MFID #1 & 6).
3. Artillery-Delivered Anti-personnel Mines / Remote Anti-Armor Mines (ADAM/RAAM) have different employment considerations than other minefields. The entire ADAM/RAAM minefield does not have to be within trafficable or low slope terrain to be effective – only a portion of the minefield is intended to target a road network or trafficable terrain. For this reason, the model output failed for three ADAM/RAAM minefields (MFID #4, 6, & 9).
4. Poor minefield placement or incorrect MGRS grid coordinate (MFID #13).
5. There were trails and roads missing in the VITD transportation network feature class. This also affected the trafficability estimates (MFID #9, 12, 15, 35, & 38).
6. The minefield areas were not visible from the observer locations that were input into the model (MFID #2, 6, 9, 12, 15, 35, & 38).

The model performed much better when predicting areas where conventional and Volcano minefields may exist than when predicting areas where point minefields may exist. This was due to the spatial inaccuracy of the minefield data. This problem was amplified by converting vector geospatial data to a 30m by 30m grid of raster values. An analysis of any type of point data is always made more difficult in the raster environment. If the raster resolution was reduced to 1-5 meters, this problem would not be as severe. However, the elevation data available is only valid at 30 meter resolution and drove the entire model to remain at that resolution. Section 4.5 covers this in more detail. Also, as stated in **Failure Reason #3**, some types of point minefields have different employment considerations than other minefields. This problem in predicting ADAM/RAAM minefields will be discussed further in Chapter 5.

Model performance was improved by removing all of the point minefields from consideration when determining the accuracy of the output. See Tables 4.2a and 4.2b for the results. This improvement to the model reduced the number of minefields that failed from 11 to 5 and increased the percentage of minefields that fell within the "Very Likely" class from 43% to about 50%. However, the model still failed to predict for 5 minefields and further improvements were necessary.

Table 4.2a: Minefield Likelihood Surface Accuracy Assessment after Removing Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
1	A2CMD01	Conventional	38	0	0	0	38	100.00%	0.00%	0.00%	0.00%
2	A1SM01	Conventional	55	0	5	0	60	91.67%	0.00%	8.33%	0.00%
18	A1SV02	Volcano	47	0	32	55	134	35.07%	0.00%	23.88%	41.04%
19	A1SV01	Volcano	90	0	2	81	173	52.02%	0.00%	1.16%	46.82%
20	A2ASV02	Volcano	12	0	101	133	246	4.88%	0.00%	41.06%	54.07%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	104	19	167	0	290	35.86%	6.55%	57.59%	0.00%
23	G1ASV01	Volcano	38	24	135	0	197	19.29%	12.18%	68.53%	0.00%
24	G1ASV02	Volcano	28	0	65	0	93	30.11%	0.00%	69.89%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	16	0	77	66	159	10.06%	0.00%	48.43%	41.51%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	29	14	110	0	153	18.95%	9.15%	71.90%	0.00%
29	G2ASV01	Volcano	33	0	2	137	172	19.19%	0.00%	1.16%	79.65%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	7	0	35	243	285	2.46%	0.00%	12.28%	85.26%
34	L2CSV01	Volcano	0	0	116	122	238	0.00%	0.00%	48.74%	51.26%
35	L2ASV01	Volcano	47	0	32	0	79	59.49%	0.00%	40.51%	0.00%
36	??	Volcano	32	1	30	76	139	23.02%	0.72%	21.58%	54.68%
37	A2BSV01	Volcano	26	1	45	116	188	13.83%	0.53%	23.94%	61.70%
38	G1AMF01	Conventional	66	0	0	0	66	100.00%	0.00%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	8	116	124	0.00%	0.00%	6.45%	93.55%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	4	3	7	7	21	19.05%	14.29%	33.33%	33.33%
43	G1BSV05	Volcano	0	28	194	0	222	0.00%	12.61%	87.39%	0.00%
44	G1ASV05	Volcano	0	3	51	0	54	0.00%	5.56%	94.44%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	13	2	178	106	299	4.35%	0.67%	59.53%	35.45%
47	M2ASV01	Volcano	0	0	85	169	254	0.00%	0.00%	33.46%	66.54%
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%
			685	253	1628	2530	5096				
		Overall Accuracy =	**13.44%**	**4.96%**	**31.95%**	**49.65%**					

Table 4.2b: Summary of Model Run #1 Statistics without Point Minefields

MODEL RUN #1		Used VITD Slope			
Minefield Likelihood for Fort Irwin - 30m Resolution					
Using VITD Slope Layer & DTED2 30m Digital Elevation Model					
Clipped to NTC Boundary		***Without Point Minefield Data***			
like1_c_r	**pixels**	**km^2**	**acres**		
Total Pixels=	2,860,818	2,575	636,243		
mf pixels=	5,096				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	1,083,861	37.89%	685	13.44%
Possible	> 0 - 33%	608,630	21.27%	253	4.96%
Likely	> 33 - 66%	818,741	28.62%	1,628	31.95%
Very Likely	> 66 - 100%	349,586	12.22%	2,530	49.65%
		2,860,818	100.00%	5,096	100.00%
5 of 33 minefields fail (>50% of the minefield within "Not Likely)					
15% failure rate (85% pass rate)					

In order to further enhance the performance of the model output, model parameters were adjusted based on the reasons for the GIS model failure. The largest problem was the transportation network rectification and missing data errors **(Failure Reasons #2 & 5)**. See Figure 4.1 for an example of missing data within the Transportation feature class of the VITD. See Figure 4.2 for an example of the VITD rectification errors.

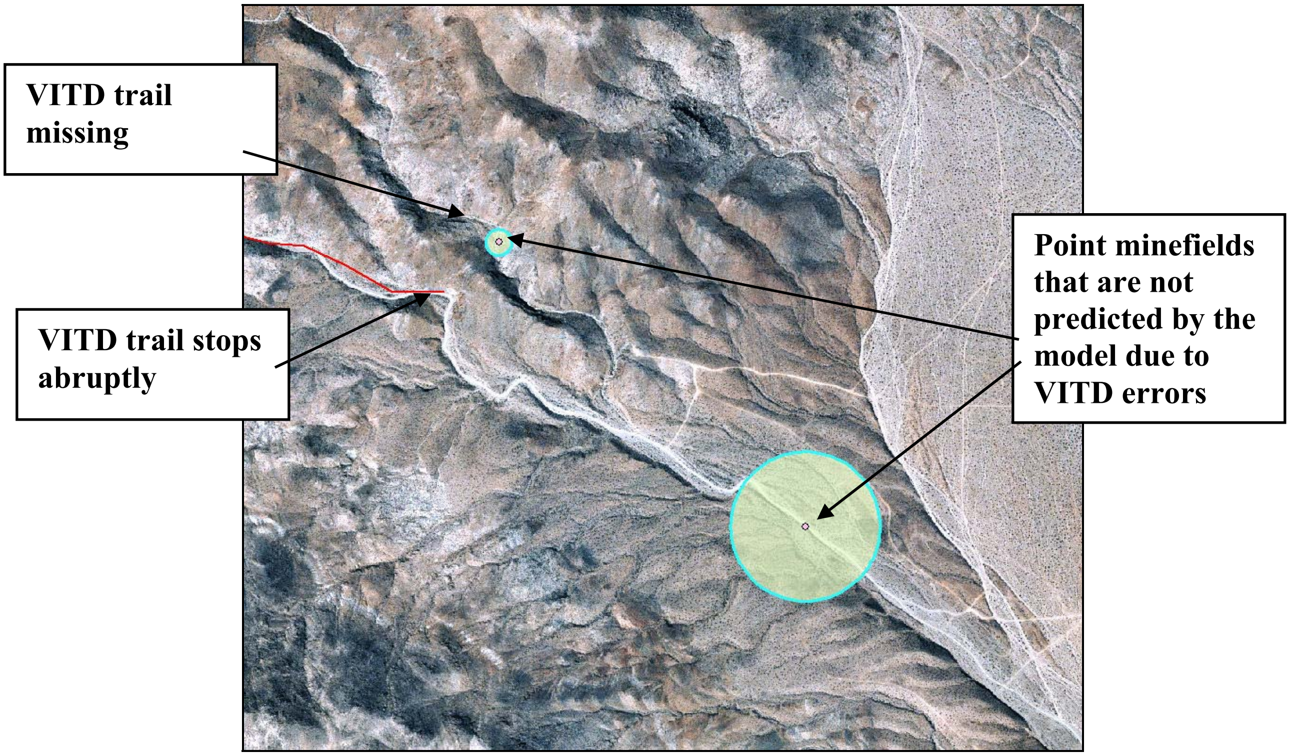


Figure 4.1: Example of Missing Data in the VITD Transportation Feature Class

Both of these errors caused the Trafficability Layer have inaccurate trafficability estimates **(Failure Reason #1)**. The best way to correct for this would be to: 1) extract more trail and road features from imagery and then add them to the VITD geodatabase; and 2) rectify the VITD transportation feature class to imagery and ground collected GPS coordinates. However, this is not a practical expectation of a standard GIS user and it would contradict one of the research objectives of this research which was to use standard NIMA datasets.

The next best, and easier, way to correct for the inaccurate trafficability estimates is to adjust the MLS scores given to the trafficability classes within the Trafficability layer. When a portion of the terrain is estimated to be untrafficable, or have a travel speed of zero, the MLS score is -99. The score excludes this portion of the area of interest from the model. The intent behind this score was to maximize areas classified as “Not Likely” for minefields and to minimize areas classified as “Very Likely” for minefields. If this MLS score of -99 was changed to 0 (zero), then these areas would not be excluded from the model and model performance would improve. This change in MLS score was made prior to the second model run.

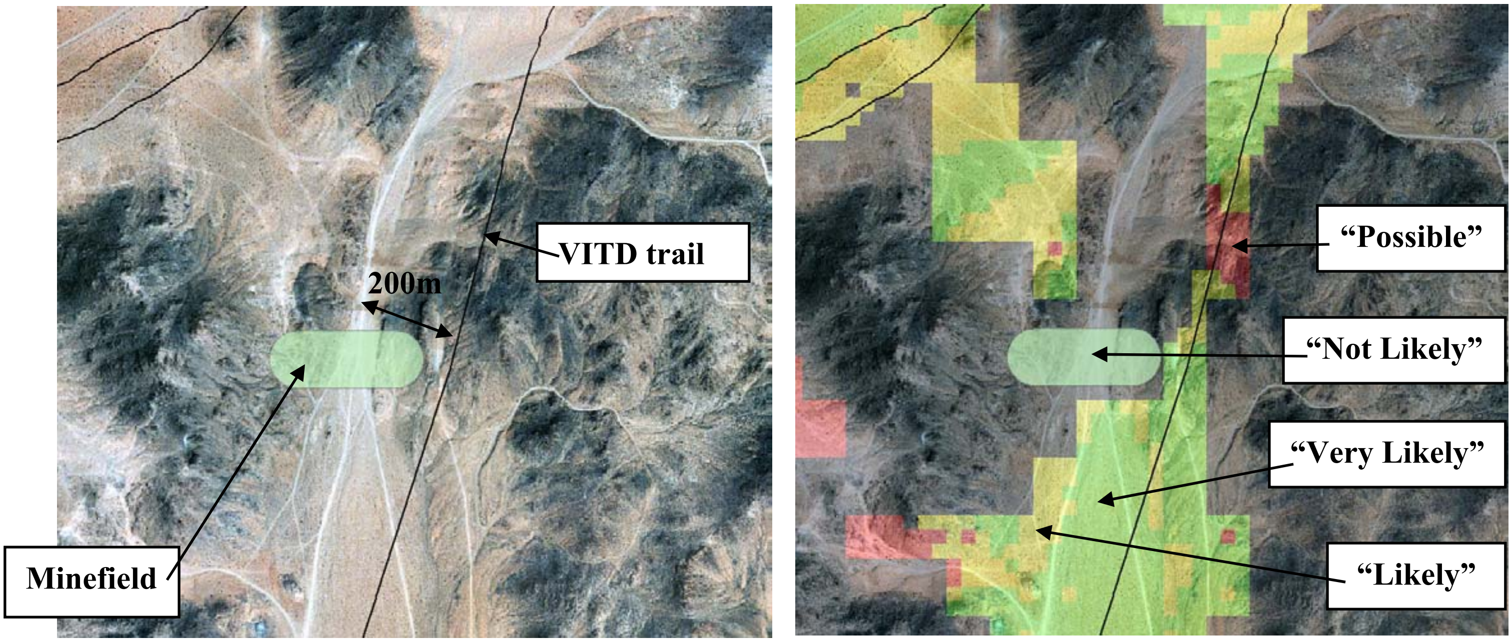


Figure 4.2: Example of VITD Transportation Feature Class Rectification Errors

The next improvement made to the model was to lessen the effect of visibility. The observer and defensive position locations were difficult to determine and gather. Originally, the model assigned a -5 MLS score to any area not visible from the observer locations. This was, again, an aggressive attempt to improve model performance. However, after looking at the results of the accuracy assessment, it seemed that if this score was changed from a -5 to a 0 (zero), then the model would perform better.

One last adjustment made to the model was to the MLS scores given to the different attributes within the transportation network. Based on the logic that faster, better roads are more likely to be mined than slower, poorer roads, MLS scores of 10, 8, and 6 were assigned to hard-paved roads, unpaved roads, and cart tracks respectively. After examining these roads against imagery, there did not seem to be a large difference between cart tracks and unpaved roads. Therefore, the MLS score for cart tracks (FCODE of AP010) was changed from 6 to 8. See Table 4.3 for a review of these changes.

Table 4.3: MLS Score Adjustment

Trafficability Layer			
AVG SPD Range		**MLS Score**	**Adjusted MLS Score**
0 kph		-99	**0**
> 0 – 3 kph		2	2
> 3 – 20 kph		4	4
> 20 – 30 kph		6	6
> 30 – 40 kph		8	8
> 40 – 65 kph		10	10
NoData		0	0
Visibility Layer			
Visible		10	10
Not Visible		-5	**0**
Transportation Layer			
AP010	Cart Track	6	**8**
AP030	Hard/Paved (RST=1)	10	10
AP030	Loose/Unpaved (RST=2)	8	8

4.1.2 Second Model Run

The results for the second model run after the initial calibration show much improvement. All of the model runs used two subsets of the first training minefield dataset: 1) one subset that included point minefields, and 2) one subset without point minefields. Since the results improved when the second subset of minefield data was used, only those results will be presented in the following tables for the following model runs. However, the final analysis of all the model runs will consider both subsets of training minefield data.

See Tables 4.4a and 4.4b for the results of the second model run.

From this point forward in the document, the percentage of minefields within the "Very Likely" class will be referred to as %mf in VL. The percentage of land area with in the "Very Likely" class will be referred to as %LA in VL. The same abbreviations will be used for the "Likely" or L class.

Table 4.4a: Minefield Likelihood Surface Accuracy Assessment for Model Run #2 (without point minefields)

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total		% NL	% P	% L	% VL
1	A2CMD01	Conventional	0	5	35	0	40		0.00%	12.50%	87.50%	0.00%
2	A1SM01	Conventional	0	27	33	0	60		0.00%	45.00%	55.00%	0.00%
18	A1SV02	Volcano	0	29	50	53	132		0.00%	21.97%	37.88%	40.15%
19	A1SV01	Volcano	0	66	26	80	172		0.00%	38.37%	15.12%	46.51%
20	A2ASV02	Volcano	10	0	104	137	251		3.98%	0.00%	41.43%	54.58%
21	G1DSV01	Volcano	0	0	6	127	133		0.00%	0.00%	4.51%	95.49%
22	G1ESV01	Volcano	0	101	149	42	292		0.00%	34.59%	51.03%	14.38%
23	G1ASV01	Volcano	0	39	157	0	196		0.00%	19.90%	80.10%	0.00%
24	G1ASV02	Volcano	0	15	84	0	99		0.00%	15.15%	84.85%	0.00%
25	G1BSV01	Volcano	0	0	0	149	149		0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	0	10	82	68	160		0.00%	6.25%	51.25%	42.50%
27	G2ASV02	Volcano	0	0	0	153	153		0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	21	137	1	159		0.00%	13.21%	86.16%	0.63%
29	G2ASV01	Volcano	0	0	32	140	172		0.00%	0.00%	18.60%	81.40%
30	G2CSV06	Volcano	0	0	0	84	84		0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	157	0	157		0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	78	0	78		0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	11	0	19	255	285		3.86%	0.00%	6.67%	89.47%
34	L2CSV01	Volcano	0	0	94	138	232		0.00%	0.00%	40.52%	59.48%
35	L2ASV01	Volcano	0	0	57	21	78		0.00%	0.00%	73.08%	26.92%
36	??	Volcano	0	3	61	75	139		0.00%	2.16%	43.88%	53.96%
37	A2BSV01	Volcano	0	26	44	114	184		0.00%	14.13%	23.91%	61.96%
38	G1AMF01	Conventional	0	66	0	0	66		0.00%	100.00%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	264	264		0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	10	115	125		0.00%	0.00%	8.00%	92.00%
41	M3ASV01	Volcano	0	0	0	78	78		0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	0	20	7	27		0.00%	0.00%	74.07%	25.93%
43	G1BSV05	Volcano	0	1	220	0	221		0.00%	0.45%	99.55%	0.00%
44	G1ASV05	Volcano	0	0	48	6	54		0.00%	0.00%	88.89%	11.11%
45	G2CSV05	Volcano	0	0	0	210	210		0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	0	7	186	113	306		0.00%	2.29%	60.78%	36.93%
47	M2ASV01	Volcano	0	0	76	181	257		0.00%	0.00%	29.57%	70.43%
48	A2BSV01	Volcano	0	0	50	38	88		0.00%	0.00%	56.82%	43.18%
			21	416	2015	2649	5101					
		Overall Accuracy =	0.41%	8.16%	39.50%	51.93%						

Table 4.4b: Summary of Model Run #2 Statistics (without point minefields)

MODEL RUN #2	Adjusted MLS Scores of Trafficability, Transportation, and Visibil				
Minefield Likelihood for Fort Irwin - 30m Resolution					
Using VITD Slope Layer & DTED2 30m Digital Elevation Model					
Clipped to NTC Boundary	***Without Point Minefield Data***				
like2_c_r	**pixels**	**km²**	**acres**		
Total Pixels=	2,860,818	2,575	636,243		
mf pixels=	5,101				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	219,811	7.68%	21	0.41%
Possible	> 0 - 33%	762,191	26.64%	416	8.16%
Likely	> 33 - 66%	1,422,023	49.71%	2,015	39.50%
Very Likely	> 66 - 100%	456,793	15.97%	2,649	51.93%
		2,860,818	100.00%	5,101	100.00%
No minefields fail					

No minefields fell within the "Not Likely" class so the model output passed. The % mf in VL improved from 49.7% to almost 52%. However, the %LA in VL increased from 12.2% to almost 16% (an increase of 97 km^2).

In order to further improve model performance, the minefields where no portion fell within the VL class (i.e. %mf in VL that equal 0) were individually examined. These minefields are highlighted in Table 4.4a. There were two main reasons for these minefields not being classified in "Very Likely":

1. The minefields cut off trails and road that were not in the VITD transportation feature class.
2. The minefields were not visible from within the input observer/defensive position locations.

These reasons were discussed in Section 4.1.2. Since adding trails and road to the VITD and rectification of the VITD is not feasible, the only adjustment that can be made is to the Visibility Layer. At the end of model run #1, the visibility MLS scores were adjusted from -99, for a non-visible area, to 0. However, if the visible areas were given an MLS score of 5 instead of 10, the Visibility Layer would have less influence over the final model output. This adjustment was made and model run #3 was started in order to attempt to classify more minefields in the VL class.

4.1.3 Third Model Run

The results improved again in this model run. See Tables 4.5a and 4.5b for the results.

Table 4.5a: Minefield Likelihood Surface Accuracy Assessment for Model Run #3 (without point minefields)

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
1	A2CMD01	Conventional		3	35		38	0.00%	7.89%	92.11%	0.00%
2	A1SM01	Conventional		6	48	6	60	0.00%	10.00%	80.00%	10.00%
18	A1SV02	Volcano		28	26	80	134	0.00%	20.90%	19.40%	59.70%
19	A1SV01	Volcano		71	27	75	173	0.00%	41.04%	15.61%	43.35%
20	A2ASV02	Volcano	9		103	134	246	3.66%	0.00%	41.87%	54.47%
21	G1DSV01	Volcano				132	132	0.00%	0.00%	0.00%	100.00%
22	G1ESV01	Volcano		98	30	162	290	0.00%	33.79%	10.34%	55.86%
23	G1ASV01	Volcano		28	51	118	197	0.00%	14.21%	25.89%	59.90%
24	G1ASV02	Volcano		25	68		93	0.00%	26.88%	73.12%	0.00%
25	G1BSV01	Volcano				150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano		12	77	70	159	0.00%	7.55%	48.43%	44.03%
27	G2ASV02	Volcano				161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano		31	118	4	153	0.00%	20.26%	77.12%	2.61%
29	G2ASV01	Volcano		29	12	131	172	0.00%	16.86%	6.98%	76.16%
30	G2CSV06	Volcano				85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano			158		158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano			66	13	79	0.00%	0.00%	83.54%	16.46%
33	L2BSV01	Volcano	9		6	270	285	3.16%	0.00%	2.11%	94.74%
34	L2CSV01	Volcano			40	198	238	0.00%	0.00%	16.81%	83.19%
35	L2ASV01	Volcano			44	35	79	0.00%	0.00%	55.70%	44.30%
36	??	Volcano		10	57	72	139	0.00%	7.19%	41.01%	51.80%
37	A2BSV01	Volcano		14	59	115	188	0.00%	7.45%	31.38%	61.17%
38	G1AMF01	Conventional		65	1		66	0.00%	98.48%	1.52%	0.00%
39	G2BMN01	Conventional				268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional			20	104	124	0.00%	0.00%	16.13%	83.87%
41	M3ASV01	Volcano				81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional			14	7	21	0.00%	0.00%	66.67%	33.33%
43	G1BSV05	Volcano			75	147	222	0.00%	0.00%	33.78%	66.22%
44	G1ASV05	Volcano			9	45	54	0.00%	0.00%	16.67%	83.33%
45	G2CSV05	Volcano				208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano		6	179	114	299	0.00%	2.01%	59.87%	38.13%
47	M2ASV01	Volcano			70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano			8	82	90	0.00%	0.00%	8.89%	91.11%
			18	426	1401	3251	5096				
		Overall Accuracy =	**0.35%**	**8.36%**	**27.49%**	**63.80%**					

Table 4.5b: Summary of Model Run #3 Statistics (without point minefields)

MODEL RUN #3	Returned to VITD Slope and adjusted MLS score for Visibility (10				
Minefield Likelihood for Fort Irwin - 30m Resolution					
Using VITD Slope Layer & DTED2 30m Digital Elevation Model					
Clipped to NTC Boundary	*Without Point Minefield Data*				
like4_c_r	pixels	km^2	acres		
Total Pixels=	2,860,525	2,574	636,178		
mf pixels=	5,096				
	Range	Pixels	% Land Area	mf pixels	%mf
Not Likely	< 0%	219,766	7.68%	18	0.35%
Possible	> 0 - 33%	760,626	26.59%	426	8.36%
Likely	> 33 - 66%	1,128,679	39.46%	1,401	27.49%
Very Likely	> 66 - 100%	751,454	26.27%	3,251	63.80%
		2,860,525	100.00%	5,096	100.00%
No minefields fail					

The %mf in VL showed a large improvement, increasing from 51.9% to 63.8%. However, %LA in VL increased from 16% to 26.3% (an increase of 265 km^2). Another improvement was made by classifying more minefields with the VL class. In model run #2, 9 minefields were not classified in the VL class where in model run #3 only 4 minefields were not classified in the VL class.

This ends the model calibration phase and sets “the stage” for the sensitivity analysis. However, one model was chosen from the three model runs. See Figure 4.3 for a summary of the %mf and %LA statistics for the three model runs.

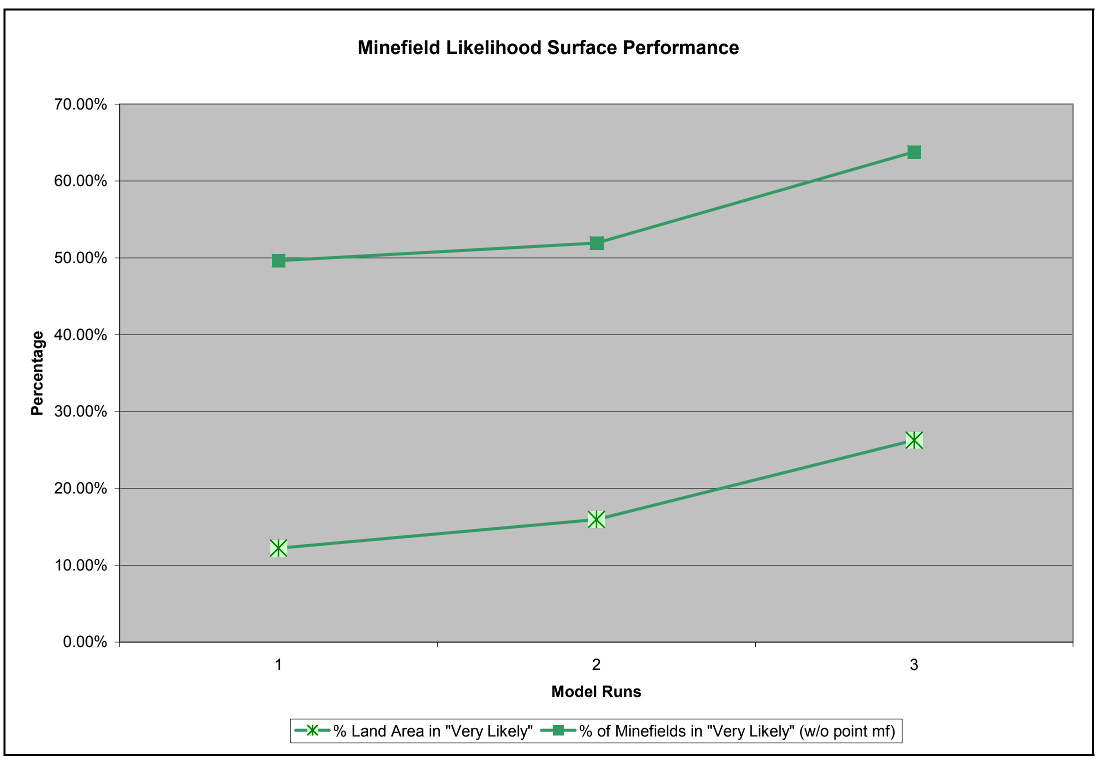


Figure 4.3: Minefield Likelihood Surface Performance

Figure 4.3 seems to indicate that model run #3 was the best set of model parameters. However, since both the %mf and %LA values are higher than in the other model runs, it is not clear which model is better. In order to quantitatively determine the best model run, a ratio was used. The ratio is called the Minefield Likelihood Surface Performance Ratio (or MLS PR). It is a ratio of the percentage of minefields classified in a specific minefield class and of the percentage of land area classified in the same class.

MLS Performance Ratio = (% mf in minefield class$_i$) / (% LA in minefield class$_i$)

where i = minefield classes "Very Likely", "Likely", "Possible", or "Not Likely"

A higher ratio value indicates better model performance since the goal is to maximize the percentage of minefields classified and minimize the percentage of land area classified. The only caveat to this is that ALL minefields must fall within the "Possible", "Likely", and "Very Likely" classes in order to be valid. See Figure 4.4 for a summary of the MLS PR values from the model calibration runs.

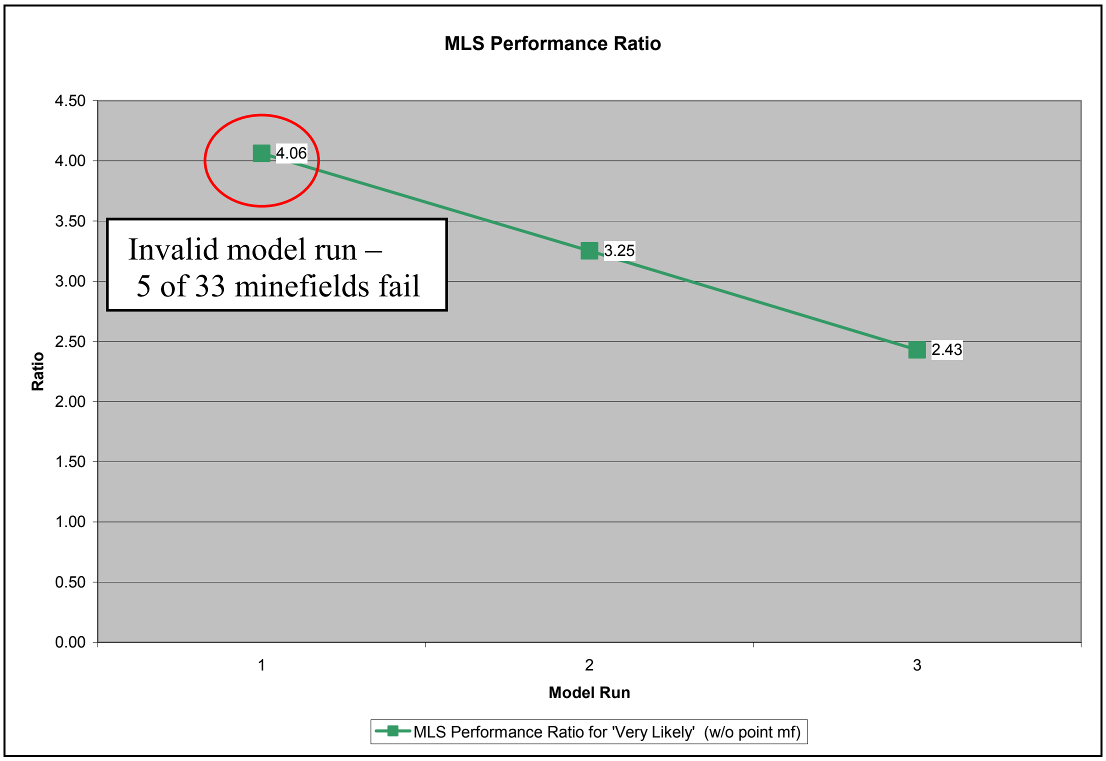


Figure 4.4: Minefield Likelihood Surface Performance Ratio for Model Runs #1, 2, & 3

Based on these MLS PRs for the "Very Likely" minefield class, model run #2 was better than model run #3 (3.23 > 2.43). Thus, the MLS scores used in model run #2 were held constant for the remainder of the analysis.

The MLS PR values can not be used to blindly evaluate model performance. The user of the GIS model must balance the ratio values against what they represent in reality. For instance, if 100% of the minefields from a training minefield dataset were correctly classified in the VL class by a specific model run and 100% of the land area was classified by this same class, then the MLS PR value would be 1.0. But a MLS PR value of 1.0 could also represent 50% of the minefields over 50% of the land area or any other equal set of percentages. The user has to interpret these ratio values and decide which is better. It is possible that a specific portion of the land area classified by a specific model run would be desirable over others although the MLS PR values were equal. Small percentages can also have a lot of influence and result in abnormally high MLS PR values. For instance, a 9% of minefields classified over %1 percent of the land area would results in a MLS PR value of 9.0. The model performance, in this instance, is not as good as the ratio suggests. Again, the user must decide how much importance to give the MLS PR when using it to evaluate model runs during model calibration and the sensitivity analysis.

4.2 Sensitivity Analysis

The purpose of performing a sensitivity analysis is to determine the effect of changing variables in a formula or model output. This section will explore the impact of slope and the weighting of the five raster layers that serve as input into the GIS model.

4.2.1 Impact of Slope

The GIS model is heavily influenced by slope. It exists as an individual raster Slope Layer, as input into the model, and is also used, among other attributes, to create the raster Trafficability Layer. The individual raster layer can be a raster version of VITD Slope or can be a raster slope layer derived from a digital elevation model (DEM). This methodology used DTED2 to derive the slope data (in percent). Similarly, the Trafficability Layer can be created from VITD Slope or from a derived slope layer. A sensitivity analysis was necessary to:

1. Determine whether or not the Slope Layer adds value to the model output
(investigated in Section 4.2.2)
2. Determine which individual Slope Layer to use in the model
3. Determine which slope layer to use in creation of the Trafficability Layer

4.2.1.1 Fourth Model Run: The first analysis of the impact of slope looked at the Slope Layer that is one of the five raster input layers into the model. The layer can be a raster version of the VITD Slope Layer or can be derived from DTED2. The model used VITD Slope in model runs #1 through #3 but the fourth run used a DTED2 derived slope layer instead. See Table 4.6 for a summary of these results. For the remainder of Chapter 4, only the summary table will be included in the text. The tables listing the accuracy assessment by minefield will be included in Appendix D.

Table 4.6: Summary of Model Run #4 Statistics (without point minefields)

MODEL RUN #4	Used DTED2 Slope instead of VITD Slope				
Minefield Likelihood for Fort Irwin - 30m Resolution					
Clipped to NTC Boundary	***Without Point Minefield Data***				
like3_c_r	**pixels**	**km^2**	**acres**		
Total Pixels=	2,860,525	2,574	636,178		
mf pixels=	5,096				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	151,017	5.28%	44	0.86%
Possible	> 0 - 33%	838,894	29.33%	366	7.18%
Likely	> 33 - 66%	1,438,471	50.29%	2,112	41.44%
Very Likely	> 66 - 100%	432,143	15.11%	2,574	50.51%
		2,860,525	100.00%	5,096	100.00%
No minefields fail					

The %mf in VL dropped from 63.8% to 50.5% but the %LA in VL decreased from 26.3% to 15.1%. At the conclusion of model runs #4, 5, and #6, the MLS PR will show the best model run.

<u>*4.2.1.2 Fifth Model Run*</u>: The next model run examined the Trafficability Layer. As discussed previously, the Trafficability Layer was created from within DTSS using the VITD geodatabase. The VITD includes a slope feature class and, by default, DTSS used this feature class along with other feature classes to create the trafficability estimates. An alternative to this approach is to create a slope feature class using DTED2, replace the VITD slope feature class with the DTED2 slope feature class, and create the trafficability output with DTSS. DTSS includes a utility called the "Slope Generator" to do this. The Mobility TDA does <u>not</u> include an option in the menus to use an alternate slope feature class but replacing the feature class within the VITD geodatabase is not difficult.

Model run #5 used this "New Trafficability Layer" and the VITD Slope Layer along with the other three raster layers as input into the GIS model. Model run #6 used the New Trafficability Layer with the DTED2 Slope Layer (tested in model run #4) along with the other three raster layers. See Table 4.7 for a summary of the model run #5 results.

Table 4.7: Summary of Model Run #5 Statistics (without point minefields)

MODEL RUN #5	Used Trafficability Layer created by using DTED2 Slope				
Minefield Likelihood for Fort Irwin - 30m Resolution					
Using VITD Slope Layer & DTED2 30m Digital Elevation Model					
Clipped to NTC Boundary	***Without Point Minefield Data***				
like5_c_r	**pixels**	**km^2**	**acres**		
Total Pixels=	2,860,525	2,574	636,178		
mf pixels=	5,096				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	219,766	7.68%	18	0.35%
Possible	> 0 - 33%	769,922	26.92%	437	8.58%
Likely	> 33 - 66%	1,372,507	47.98%	2,114	41.48%
Very Likely	> 66 - 100%	498,330	17.42%	2,527	49.59%
		2,860,525	100.00%	5,096	100.00%
No minefields fail					

These results were worse than the results from model run #4. %mf in VL dropped from 50.5% to 49.6% and %LA in VL increased from 15.1% to 17.4%. This was probably due to the incompatibility of the two different slope layers – DTED2 slope in the New Trafficability Layer and VITD slope in the Slope Layer.

4.2.1.3 Sixth Model Run: This run used DTED2 slope values throughout the model. It used the New Trafficability Layer and the DTED2 Slope Layer along the other three raster layers as input into the GIS model. See Table 4.8 for a summary of the model run #6 results.

Table 4.8: Summary of Model Run #6 Statistics (without point minefields)

MODEL RUN #6		Used DTED2 Slope Layer combined with new Trafficability layer			
Minefield Likelihood for Fort Irwin - 30m Resolution					
Clipped to NTC Boundary		***Without Point Minefield Data***			
like7_c_r	**pixels**	**km^2**	**acres**		
Total Pixels=	2,860,525	2,574	636,178		
mf pixels=	5,096				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	151,017	5.28%	44	0.86%
Possible	> 0 - 33%	1,083,537	37.88%	380	7.46%
Likely	> 33 - 66%	1,234,285	43.15%	2,201	43.19%
Very Likely	> 66 - 100%	391,686	13.69%	2,471	48.49%
		2,860,525	100.00%	5,096	100.00%
No minefields fail					

These results showed some improvement. The %LA in VL was the lowest of the three model runs – a decrease from 17.4%, in run #5, to 13.7%. However, the %mf in VL was also the lowest – a decrease from 49.6% to 48.5%. An analysis of the last three model runs is shown in Figure 4.5.

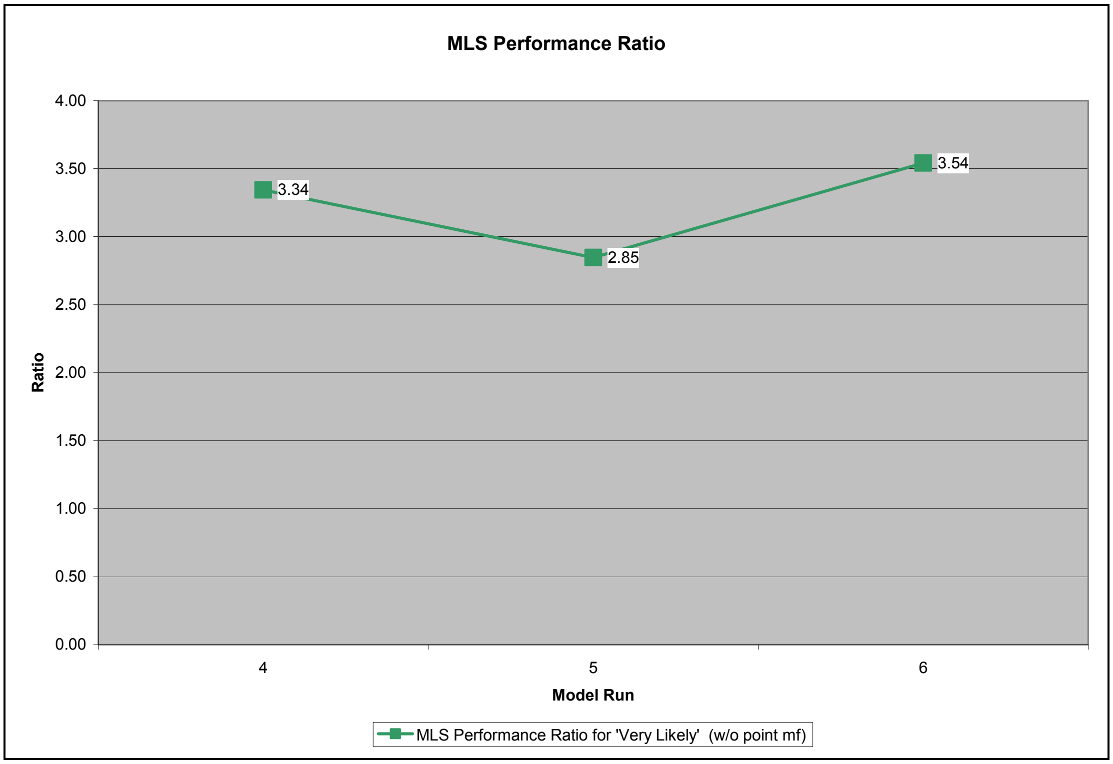


Figure 4.5: Minefield Likelihood Surface Performance Ratio for Model Runs #4, 5, & 6

Based on the MLS PR, model run #6 seemed to be the best combination of raster layers and used the best slope values. It also makes sense that using a combination of the VITD Slope Layer and the old Trafficability Layer, or, the DTED2 Slope Layer and the New Trafficability Layer works better than mixing the sources of slope data. The raster layers should operate in pairs.

4.2.2 Raster Layer Weighting Schemes

The sensitivity analysis also investigated the importance of the individual model input raster layers and the weighting of these input layers. If a layer is removed from the model and the results improve, then it should be removed from the model permanently – assuming the model output still performs within the set conditions. The performance of the following model runs was compared to the model run #6 where the model was created by equally weighting these five raster input layers:

Output = ***Hydrography*** + ***Transportation*** + ***DTED2 Slope*** + ***New Trafficability*** + ***Visibility***

In order to weight the layers consistently, the sum of the layer weights was kept equal to one. Thus the equivalent formula for model run #6 is:

0.2*Output = *0.2**Hydrography*** + *0.2**Transportation*** + *0.2**DTED2 Slope*** + *0.2**New Trafficability*** + *0.2**Visibility***

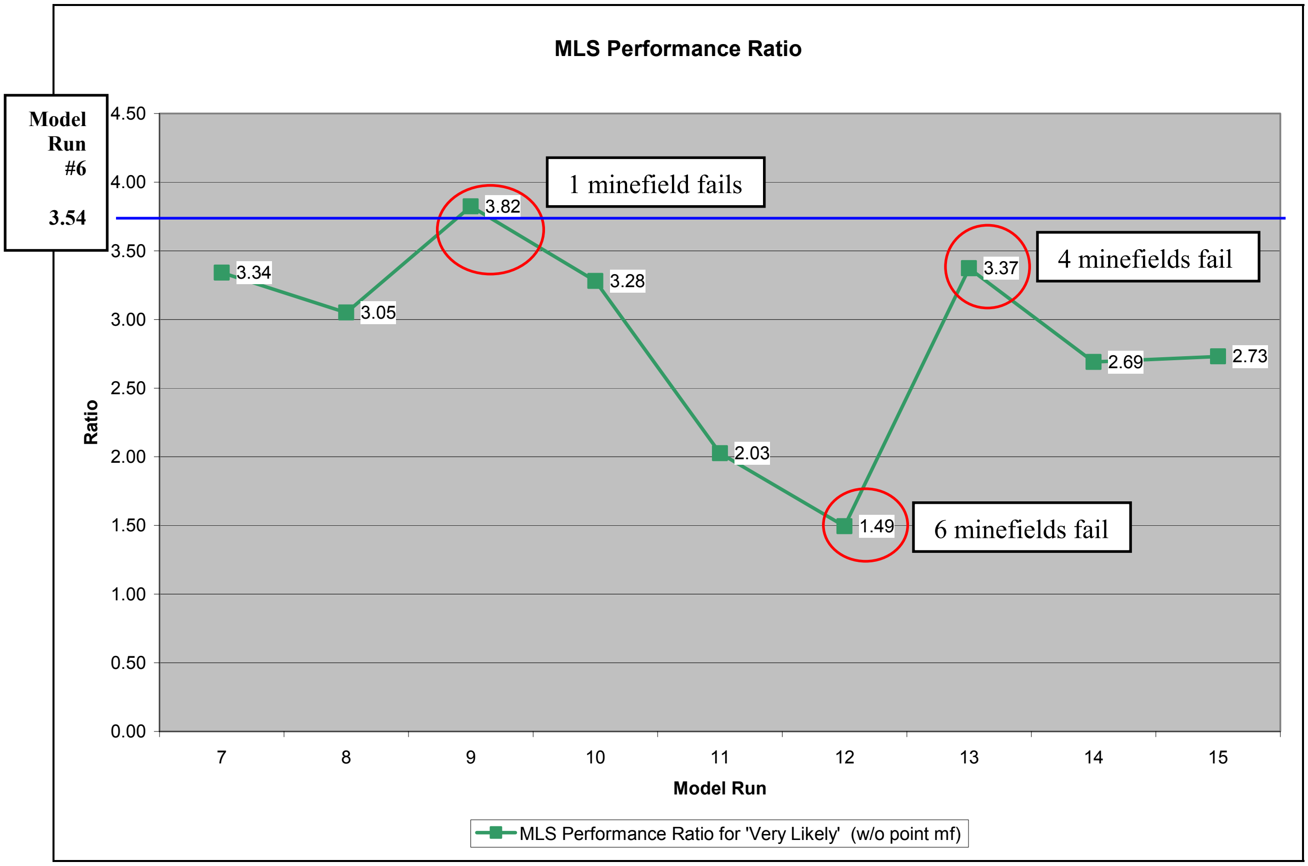
The output values are reduced (by 4/5ths) but since the output is separated into four classes representing percentiles of the total output values, there is no net effect on the end results.

The MLS Performance Ratio from model run #6 of 3.54 was used to compare the performance ratios of model runs #7 - #15. Listed in Table 4.9 are each model run and what weighting scheme it investigated.

Table 4.9: GIS Model Layer Weighting Schemes for Fort Irwin

Model Run #	Weighting Scheme	Description
#6	***Output*** *=0.2****Hydro*** *+ 0.2****Transpo*** *+ 0.2****Slope*** *+ 0.2****Traffic*** *+ 0.2****Visibility***	The base model that all other results are compared to
#7	***Output*** *=0****Hydro*** *+ 0.25****Transpo*** *+ 0.25****Slope*** *+ 0.25****Traffic*** *+ 0.25****Visibility***	Removed the "Hydrography" layer from the model
#8	***Output*** *=0.25****Hydro*** *+ 0****Transpo*** *+ 0.25****Slope*** *+ 0.25****Traffic*** *+ 0.25****Visibility***	Removed the "Transportation" layer from the model
#9	***Output*** *=0.25****Hydro*** *+ 0.25****Transpo*** *+ 0****Slope*** *+ 0.25****Traffic*** *+ 0.25****Visibility***	Removed the "Slope" layer from the model
#10	***Output*** *=0.25****Hydro*** *+ 0.25****Transpo*** *+ 0.25****Slope*** *+ 0****Traffic*** *+ 0.25****Visibility***	Removed the "Trafficability" layer from the model
#11	***Output*** *=0.25****Hydro*** *+ 0.25****Transpo*** *+ 0.25****Slope*** *+ 0.25****Traffic*** *+ 0****Visibility***	Removed the "Visibility" layer from the model
#12	***Output*** *= 0****Hydro*** *+ 0****Transpo*** *+ 0****Slope*** *+* ***Traffic*** *+ 0****Visibility***	Used only the "Trafficability" layer in the model
#13	***Output*** *=0.333****Hydro*** *+ 0****Transpo*** *+ 0****Slope*** *+ 0.333****Traffic*** *+ 0.333****Visibility***	Removed the "Transportation" and "Slope" layers from the model
#14	***Output*** *= 0.1****Hydro*** *+ 0.1****Transpo*** *+0.35****Slope*** *+ 0.35****Traffic*** *+ 0.1****Visibility***	Weighted "Slope" and "Trafficability" by 25%
#15	***Output*** *=0.35****Hydro*** *+ 0.35****Transpo*** *+ 0.1****Slope*** *+ 0.1****Traffic*** *+ 0.1****Visibility***	Weighted "Hydro" and "Transportation" by 25%

Instead of describing these model runs individually, they will be discussed in comparison to each run's performance ratio. See Figure 4.6 for the MLS PRs for all of the model runs. Again, the summary tables and accuracy assessment tables are included in Appendix D.



		6	7	8	9	10	11	12	13	14	15
VL	% LA	13.7%	14.5%	20.9%	12.6%	14.9%	32.3%	10.6%	18.8%	18.2%	17.4%
	%mf	48.5%	48.5%	63.6%	48.3%	48.8%	65.5%	15.8%	63.4%	49.0%	47.5%

Figure 4.6: Minefield Likelihood Surface Performance Ratio for Model Runs #7 - #15 for Fort Irwin

Based solely on the performance ratio, model run #9 seemed to be the best with 3.82. In this run, the DTED2 Slope Layer was excluded from the model and the output was derived from equal weighting of the remaining four raster layers. However, this model run failed in prediction on one minefield (MFID #38). Thus, none of the other performance ratios of the other model runs were greater than the performance ratio from model run #6.

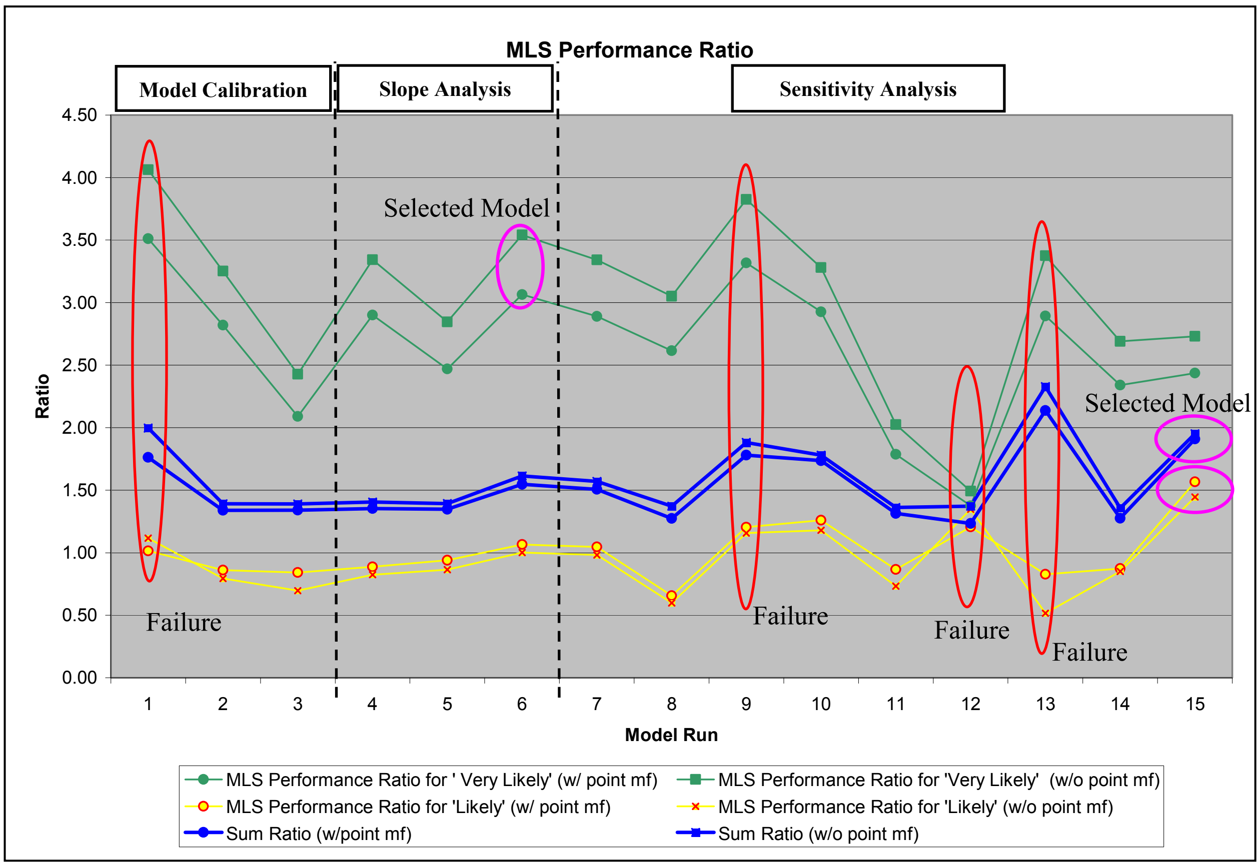
The sensitivity analysis, so far, showed that using different weighting schemes on the input raster layers did not improve model performance. The model used in model run #6 yielded the best results – it was the best at minimizing the percentage of land area classified and at maximizing the percentage of minefields classified. However, model run #6 only classified 48.5% of the minefields from the training minefield dataset. This is not reliable enough to be used for minefield detection or avoidance purposes.

The analysis was then expanded by including statistics from the next minefield likelihood class – "Likely". By using the same performance ratio, a model run can be selected with the highest ratio where no minefields fail the prediction surface. Furthermore, the sum of the percentage of minefields classified in VL and L classes can be added together and divided by the sum of percentage land area in "Very Likely" and "Likely" to form a Sum Ratio. Stated another way:

Sum Ratio = [(% mf in class$_i$) + (% mf in class$_{(i+1)}$)] / [(% LA in class$_i$) + (% LA in class$_{(i+1)}$)]

The Sum Ratio simply combines the statistics from two different minefield classes and then divides the parameters to yield a ratio value. The same limitations apply to the interpretation of the Sum Ratio that applied to the interpretation of the MLS Performance Ratio.

This ratio can be used to select the best model run. Figure 4.7 shows this analysis.



		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
VL	% LA	12.2%	16.0%	26.3%	15.1%	17.4%	13.7%	14.5%	20.9%	12.6%	14.9%	32.3%	10.6%	18.8%	18.2%	17.4%
	%mf w/pointmf	42.9%	45.0%	54.9%	43.8%	43.0%	42.0%	41.9%	54.6%	41.9%	43.5%	57.8%	14.6%	54.4%	42.6%	42.4%
	%mf w/o pointmf	49.6%	51.9%	63.8%	50.5%	49.6%	48.5%	48.5%	63.6%	48.3%	48.8%	65.5%	15.8%	63.4%	49.0%	47.5%
L	% LA	28.6%	49.7%	39.5%	50.3%	48.0%	43.1%	43.6%	45.3%	33.8%	37.1%	34.1%	52.9%	10.9%	48.0%	26.8%
	%mf w/pointmf	29.1%	42.8%	33.2%	44.6%	45.1%	46.0%	45.7%	29.7%	40.7%	46.8%	29.6%	63.8%	9.0%	41.9%	42.0%
	%mf w/o pointmf	31.9%	39.5%	27.5%	41.4%	41.5%	43.2%	42.8%	27.1%	39.1%	43.8%	25.1%	71.3%	5.6%	40.9%	38.7%
	Model Run Description	Initial Input Layers	Modified Transpo, Traffic, & Vis Layers	Remodified Visibility Layer	DTED2 Slope	New Trafficability Layer	DTED2 Slope & New Trafficability	No Hydrography Layer	No Transportation Layer	No Slope Layer	No Trafficability Layer	No Visibility Layer	Only Trafficability Layer	No Transpo & Slope Layers	Weighted Slope & Traffic Layers	Weighted Hydro & Transpo Layers

Figure 4.7: Minefield Likelihood Surface Performance Ratio for All Model Runs for Fort Irwin

Based on the performance ratios within the "Very Likely" class, model run #6 was the best for both sets of minefield data (with point minefields and without point minefields). Based on the performance ratios within the "Likely" class, model run #15 was the best. Based on the Sum Ratio, model run #15 was also the best. A larger version of Figure 4.5 is in Appendix D. See Chapter 5 for conclusions about these results.

4.2.3 Measure of Model Repeatability

A second set of training minefield data was collected in the Fall of 2002. It consisted of 65 minefields – 10 point, 15 conventional, and 40 Volcano minefields. The second minefield dataset was applied to one of the successful model runs (#6) in order to evaluate the repeatability of the GIS model. See Table 4.10 for the results of the GIS model compared to the minefield dataset #2.

Table 4.10: MLS Summary Statistics Comparing Minefield Datasets #1 (Run #6) and #2 (Run #16)

MODEL RUN #6 Used DTED2 Slope Layer combined with new Trafficability layer

Minefield Likelihood for Fort Irwin - 30m Resolution

Clipped to NTC Boundary

like7_c_r	**pixels**	**km^2**	**acres**
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	151,017	5.28%	78	1.24%
Possible	> 0 - 33%	1,083,537	37.88%	682	10.83%
Likely	> 33 - 66%	1,234,285	43.15%	2,893	45.96%
Very Likely	> 66 - 100%	391,686	13.69%	2,642	41.97%
		2,860,525	100.00%	6,295	100.00%

No minefields fail

MODEL RUN #16 New Minefield Data - Model #6

Minefield Likelihood for Fort Irwin - 30m Resolution

Used DTED2 Slope Layer combined with new Trafficability layer

Clipped to NTC Boundary

like7_c_r	**pixels**	**km^2**	**acres**
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,982		

	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	151,017	5.28%	34	0.49%
Possible	> 0 - 33%	1,083,537	37.88%	413	5.92%
Likely	> 33 - 66%	1,234,285	43.15%	3,598	51.53%
Very Likely	> 66 - 100%	391,686	13.69%	2,937	42.07%
		2,860,525	100.00%	6,982	100.00%

No minefields fail

The results were almost identical. Table 4.10 shows a comparison of minefield datasets #1 and #2 and includes point minefields in the analysis. The MLS did not fail at predicting any of the minefields from the second dataset. Both %mf in VL were equal to 42%. The MLS PR for both minefield datasets was 3.07. When point minefields were excluded from both datasets, the MLS PR for minefield dataset #1 was 3.54 and for minefield dataset #2 was 3.34. These results show that the model procedure is repeatable.

4.3 Model Calibration for Fort Polk Data

The lessons learned from the Fort Irwin model calibration were applied to the Fort Polk data. No further adjustments were made to the MLS scores internal to each raster input layer. The following sections describe a series of model runs that were performed on the Fort Polk data.

4.3.1 First Model Run

The minefield dataset for Fort Polk was not nearly as dense as the Fort Irwin minefield datasets. The data was collected from two JRTC training rotations in late summer and early fall of 2002. In sharp contrast to the Fort Irwin data, the minefields from Fort Polk were mostly point minefields and there were very few conventional or Volcano minefields used. The dataset consisted of 22 minefields – 20 point and 2 conventional minefields.

The first model run used the same five input layers that were used in the first Fort Irwin model run:

Run1: ***Output*** = ***Hydro*** + ***Transpo*** + ***Slope*** + ***Traffic*** + ***Visibility***

However, based on the outcome of the first Fort Irwin model run, the MLS scores for the Visibility Layer was adjusted prior to executing the first Fort Polk model run. All visible areas were given an MLS score of 10 and non-visible areas were given a zero. The trail network at Fort Polk is not as dense as the network at Fort Irwin and the VITD did not seem to be missing any of the trails. Also, the VITD trail network seemed to be rectified to known imagery. Since there were no problems with the VITD transportation network, the Trafficability Layer MLS scores were not initially adjusted and all non-trafficable areas kept an MLS score of -99. See Table 4.11 for a summary of the results from model run #1.

Table 4.11: Summary of Model Run #1 Statistics

MODEL RUN #1		Used VITD Slope			
Minefield Likelihood for Fort Polk - 30m Resolution					
Using VITD Slope Layer & USGS 30m Digital Elevation Model					
like1_r	**pixels**	**km^2**	**acres**		
Total Pixels=	517,677	466	115,131		
mf pixels=	258				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	76,778	14.83%	1	0.39%
Possible	> 0 - 33%	7,285	1.41%	0	0.00%
Likely	> 33 - 66%	393,765	76.06%	231	89.53%
Very Likely	> 66 - 100%	39,849	7.70%	26	10.08%
		517,677	100.00%	258	100.00%
No minefields fail					

The initial model did not fail in predicting any of the minefield locations; none of the minefields were classified within the "Not Likely" class. This indicated that the model was well calibrated and was ready for the sensitivity analysis. However, the low %mf in VL percentage of 10% indicated a poorer performance base than in the Fort Irwin models. Another model run excluding point minefield data from the dataset was impractical since 90% of the minefield data set were point minefields.

The MLS PR of the first model run was 1.31 within the VL class.

4.4 Sensitivity Analysis of Fort Polk Data

This section will explore the impact of slope and the weighting of the five raster layers that serve as input into the GIS model. It is a similar analysis that was performed on the Fort Irwin data.

4.4.1 Impact of Slope

DTED2 coverage was not fully available for the Fort Polk area of interest and USGS digital elevation data was used instead. A slope layer was derived from the USGS DEM and was named the "USGS Slope Layer". The VITD Slope Layer was replaced with the USGS Slope Layer and the second model run was performed.

4.4.1.1 Second Model Run: The use of the USGS Slope Layer yielded slightly better results. See Table 4.12 for a summary of these results.

Table 4.12: Summary of Model Run #2 Statistics

MODEL RUN #2		Used USGS Slope			
Minefield Likelihood for Fort Polk - 30m Resolution					
Using VITD Slope Layer & USGS 30m Digital Elevation Model					
like2_r	**pixels**	**km^2**	**acres**		
Total Pixels=	519,226	467	115,475		
mf pixels=	258				
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**
Not Likely	< 0%	76,833	14.80%	1	0.39%
Possible	> 0 - 33%	54,936	10.58%	1	0.39%
Likely	> 33 - 66%	357,135	68.78%	234	90.70%
Very Likely	> 66 - 100%	30,322	5.84%	22	8.53%
		519,226	100.00%	258	100.00%
No minefields fail					

Although the %mf in VL was about 1% lower than in model run #1, the %LA in VL was about 2% lower than in model run #1, giving an MLS PR of 1.46. The USGS slope data was more detailed than the VITD slope data. The VITD slope data was most likely derived from DTED Level 1 data.

A further model run was needed to examine the effects on the Trafficability Layer by using USGS slope data as input into DTSS. Unfortunately, the DTSS Slope Generator could not use the USGS elevation data to create a slope feature class that could then be used to create trafficability estimates. It was assumed that the DTSS software is configured to use only DTED elevation data. Therefore, this concluded the analysis of slope impact.

4.4.2 Raster Layer Weighting Schemes

The sensitivity analysis of the Fort Polk data mirrored the sensitivity analysis of the Fort Irwin data – it investigated the importance of the individual model input raster layers and the weighting of these input layers. The performance of the following model runs was compared to model run #2 where the model was created by these five raster input layers:

Output = ***Hydrography*** + ***Transportation*** + ***USGS Slope*** + ***Trafficability*** + ***Visibility***

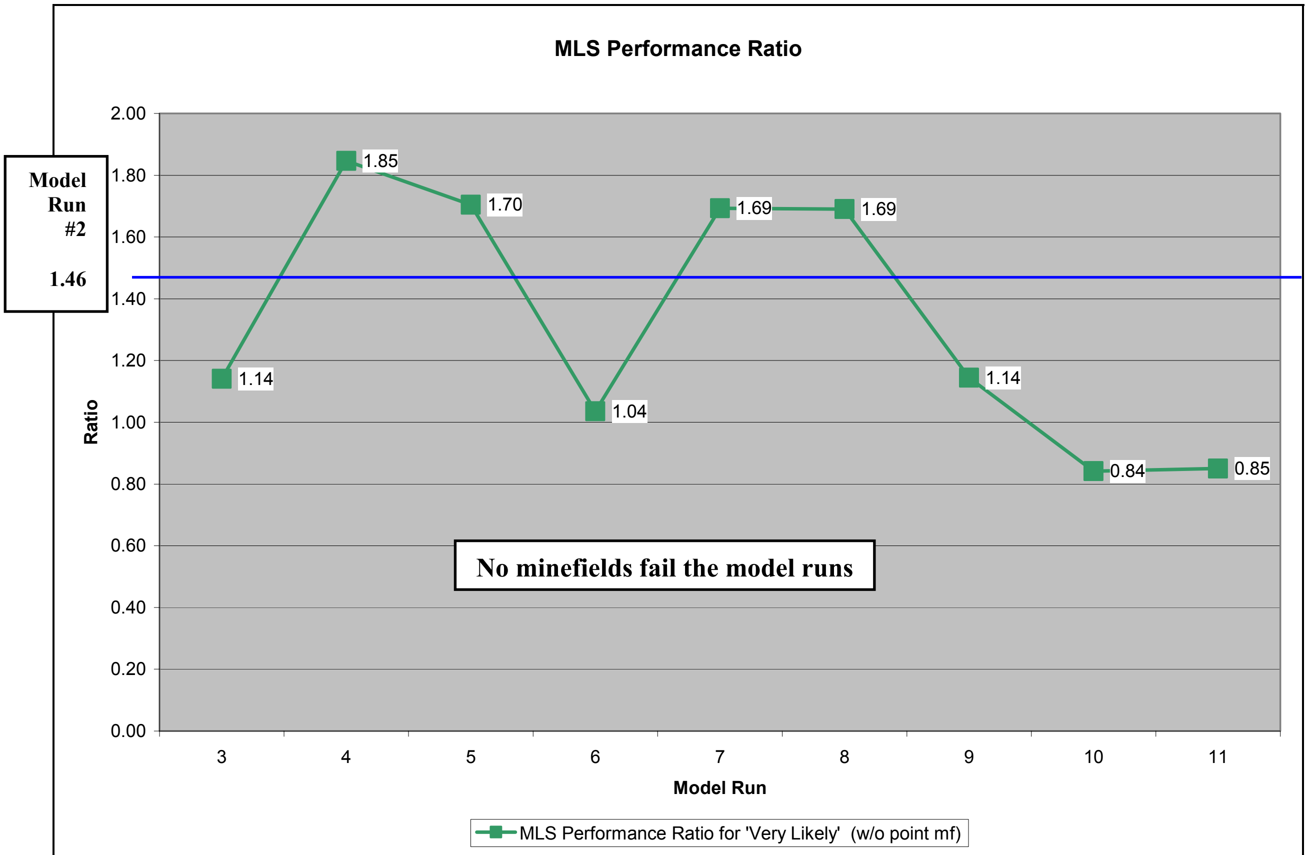
Again, the Trafficability Layer was created by using VITD slope data, not USGS, as input in order to make trafficability estimates.

The MLS PR from model run #2 of 1.46 was used to compare the performance ratios of model runs #3 - #11. Listed in Table 4.13 are each model run and what weighting scheme it investigated.

Table 4.13: GIS Model Layer Weighting Schemes for Fort Polk

Model Run #	Weighting Scheme	Description
#2	***Output*** *= 0.2*****Hydro*** *+0.2** ***Transpo*** *+ 0.2*****Slope*** *+ 0.2*****Traffic*** *+ 0.2*****Visibility***	The base model that all other models are compared to
#3	***Output*** *= 0*****Hydro*** *+ 0.25*****Transpo*** *+ 0.25*****Slope*** *+ 0.25*****Traffic*** *+ 0.25*****Visibility***	Removed the “Hydrography” layer from the model
#4	***Output*** *= 0.25*****Hydro*** *+ 0*****Transpo*** *+ 0.25*****Slope*** *+ 0.25*****Traffic*** *+ 0.25*****Visibility***	Removed the “Transportation” layer from the model
#5	***Output*** *= 0.25*****Hydro*** *+ 0.25*****Transpo*** *+ 0*****Slope*** *+ 0.25*****Traffic*** *+ 0.25*****Visibility***	Removed the “Slope” layer from the model
#6	***Output*** *= 0.25*****Hydro*** *+ 0.25*****Transpo*** *+ 0.25*****Slope*** *+ 0*****Traffic*** *+ 0.25*****Visibility***	Removed the “Trafficability” layer from the model
#7	***Output*** *= 0.25*****Hydro*** *+ 0.25*****Transpo*** *+ 0.25*****Slope*** *+ 0.25*****Traffic*** *+ 0*****Visibility***	Removed the “Visibility” layer from the model
#8	***Output*** *= 0.1*****Hydro*** *+ 0.6*****Transpo*** *+0.1*****Slope*** *+ 0.1*****Traffic*** *+ 0.1*****Visibility***	Weighted “Transportation”
#9	***Output*** *= 0.1*****Hydro*** *+ 0.3*****Transpo*** *+0.1*****Slope*** *+ 0.3*****Traffic*** *+ 0.1*****Visibility***	Weighted “Transportation” and “Trafficability”
#10	***Output*** *= 0.1*****Hydro*** *+ 0.4*****Transpo*** *+0.1*****Slope*** *+ 0.2*****Traffic*** *+ 0.1*****Visibility***	Weighted “Transportation” more than “Trafficability”
#11	***Output*** *= 0.1*****Hydro*** *+ 0.3*****Transpo*** *+0.3*****Slope*** *+ 0.1*****Traffic*** *+ 0.1*****Visibility***	Weighted “Transportation” and “Slope”

Each model run will be discussed in comparison to each run’s performance ratio. See Figure 4.8 for the MLS PRs for all of the model runs. The summary tables and accuracy assessment tables are included in Appendix D.

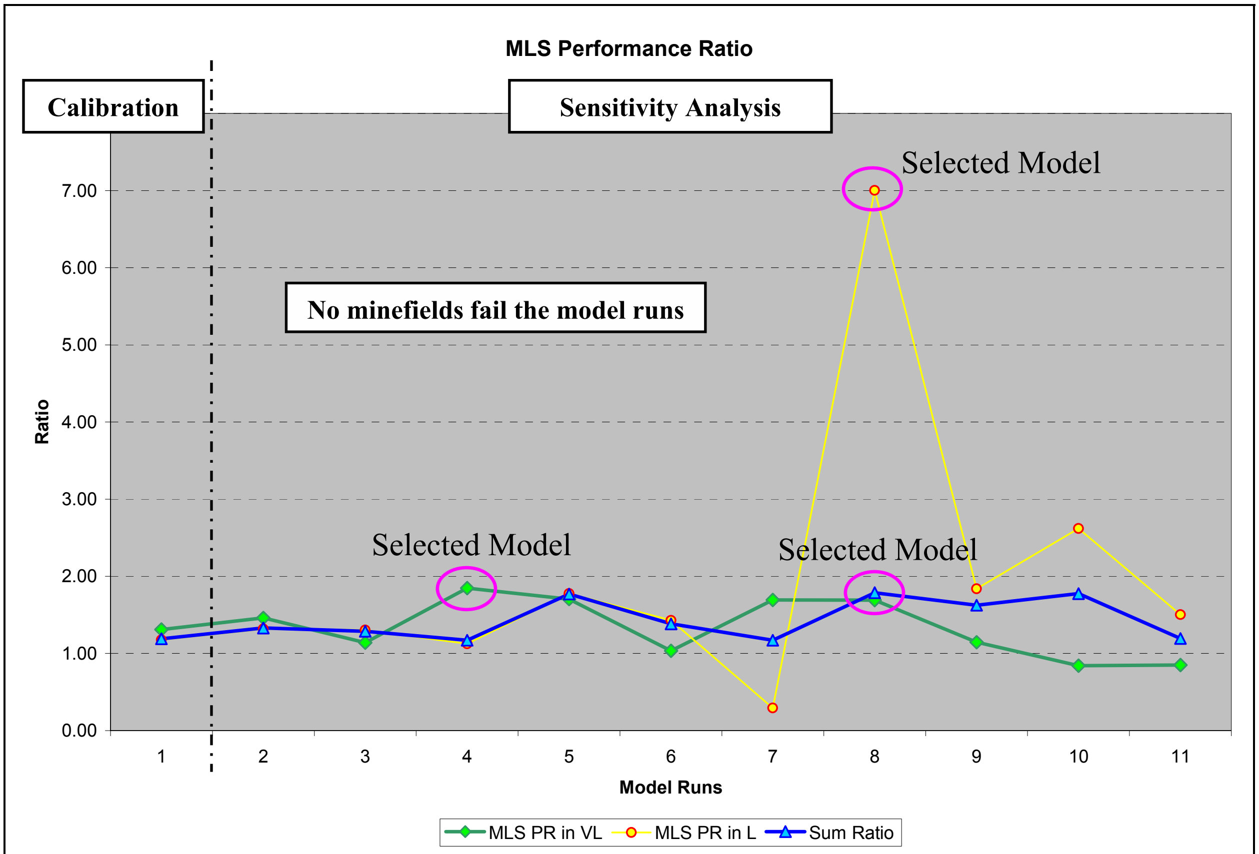


		3	4	5	6	7	8	9	10	11
VL	% LA	7.5%	5.2%	5.0%	8.6%	53.3%	53.4%	18.6%	26.2%	39.7%
	%mf	8.5%	9.7%	8.5%	8.9%	90.3%	90.3%	21.3%	22.1%	33.7%

Figure 4.8: Minefield Likelihood Surface Performance Ratio for Model Runs #3 - #11 for Fort Polk

Four of the model runs out performed model run #2. Model run #4 had the highest MLS PR of 1.85 but only classified 9.7% of %mf in VL. The ratio was so high because only 5.2% of the land area was classified. Model run #5 had an MLS PR of 1.7 but faced the same problems of model run #4. Model runs #7 and #8 had an MLS PR of 1.69. These runs classified over 90% of the minefields within the VL class but also classified over 53% of the land area in VL.

This results were difficult to interpret since the MLS PR indicates model run #4 was the best, yet it classified very few of the minefields within the VL class. The Sum Ratio indicated a better model run. See Figure 4.9 for a summary of the MLS PR values for the VL and L class and the Sum Ratio values.



		1	2	3	4	5	6	7	8	9	10	11
VL	% LA	7.7%	5.8%	7.5%	5.2%	5.0%	8.6%	53.3%	53.4%	18.6%	26.2%	39.7%
	%mf	10.1%	8.5%	8.5%	9.7%	8.5%	8.9%	90.3%	90.3%	21.3%	22.1%	33.7%
L	% LA	76.1%	68.8%	69.6%	79.8%	50.8%	63.4%	31.8%	1.0%	42.2%	29.0%	43.9%
	%mf	89.5%	90.7%	90.7%	89.9%	90.3%	90.7%	9.3%	7.0%	77.5%	76.0%	65.9%
	Model Run Description	Initial Input Layers	DTED2 Slope	No Hydrography Layer	No Transportation Layer	No Slope Layer	No Trafficability Layer	No Visibility Layer	Weight Transportation Layer	Weight Transportation & Trafficability Layer	Weight Transportation Layer more than Traffic Layer	Weight Transportation and Slope Layer

Figure 4.9: Minefield Likelihood Surface Performance Ratio for All Model Runs for Fort Polk

Based on the results from the Sum Ratio, model run #8 performed the best. By combining the VL and L class, model run #8 predicted the locations of 97.3% of the minefields while classifying 54.4% of the land area. This is a high percentage of land area but the even higher percentage of classified minefields is worth it. Model run #8 also had the highest MLS PR in the L class. Model run #4 had the best MLS PR in the VL class. A larger version of Figure 4.7 is contained in Appendix D. A separate minefield dataset for Fort Polk was not available in order to test the repeatability of the Fort Polk GIS model. See Chapter 5 for conclusions about these results.

4.5 Error & Uncertainty Analysis

Spatial uncertainty exists in all geospatial data and no GIS analysis is complete without addressing this problem. The input data layers have a specific spatial uncertainty which carries through the entire analysis and GIS model to the output. The impact of this is that Minefield Likelihood Surface cannot be used directly to map out individual minefields. It predicts the areas where minefields may exist with a certain degree of prediction accuracy and positional accuracy. For example, a model result may be that 20% of the land area has been classified as “Very Likely” to be mined with 60% of the known minefields classified in this region. This sample output may also vary spatially by 100m. The model verification data, or known minefield data, also has spatial uncertainty. Examining the effects of this uncertainty could be an entire research project in itself. However, the following paragraphs would describe the spatial uncertainty and approximate the model output uncertainty.

4.3.1 Input data Uncertainty

As reviewed in Section 3.1, each of the model inputs has a specific spatial uncertainty.

1. **DTED2 & USGS DEMs**: ± 50m horizontal and ± 30m vertical.
2. **VITD**: ± 0.01 arc-second or approximately 0.5m.
3. **Observer / Defensive Position Locations**: ± 100m.

The VITD spatial uncertainty is based on the horizontal precision as stated in the NIMA specification for this dataset. Through inspection of the individual dataset for Fort Irwin, some roads and trails were out of registration with rectified imagery by over 200m. Without further rectification of the VITD dataset, this alignment error forces the spatial uncertainty of the input VITD dataset closer to ± 200m than ± 0.5m. These errors did not seem to exist in the Fort Polk VITD dataset.

4.3.2 Model Output Spatial Uncertainty

In order to determine the specific spatial uncertainty of the model output, a separate sensitivity analysis would have to be performed by randomly varying the spatial locations of the input data within a range determined by each data layer’s uncertainty. Then by comparing the model outputs based on each variation, a comprehensive spatial uncertainty of the output could be determined. However, this is beyond the scope of this research and not one of the objectives.

The worst-case scenario is that the spatial uncertainty of the model output is equal to the worst spatial uncertainty of the input data layers. For Fort Irwin, the spatial uncertainty of the output is equal to the uncertainty of the VITD dataset which is ± 200m. For Fort Polk, the spatial uncertainty of the output is equal to the uncertainty of the observer / defensive position location dataset which is ± 100m.

4.3.3 Model Verification Data Spatial Uncertainty

The training minefield data has different levels of uncertainty based on the number of coordinates used to record the data. As discussed in Section 3.4.4.2, the uncertainty of a minefield recorded with 6-digit MGRS coordinates is ± 100m and the uncertainty of 8-digit MGRS coordinates is ±50m. Figure 4.10 depicts minefields with buffers of spatial uncertainty surrounding each minefield.

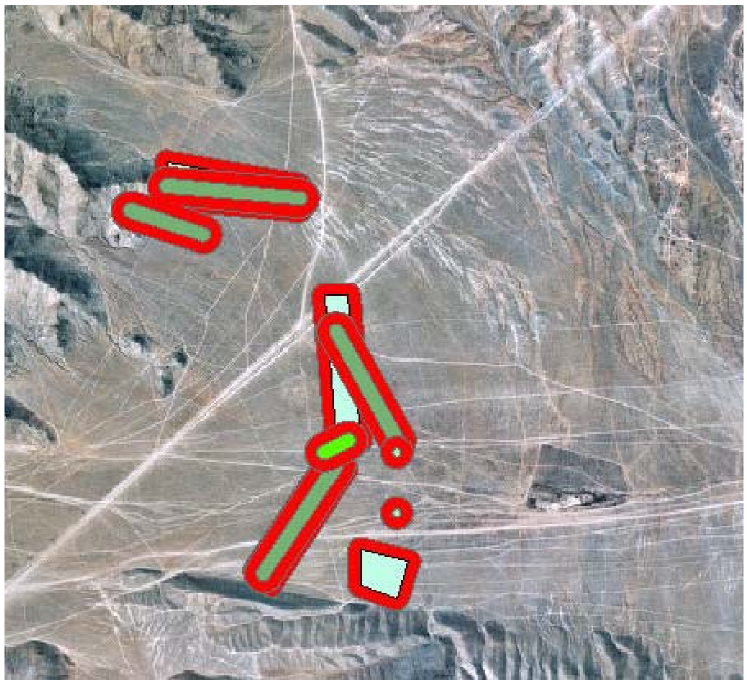


Figure 4.10: Spatial Uncertainty of Minefield Data

This uncertainty poses a real problem for point minefield data where the uncertainty region is larger that the actual minefield itself. Due to the spatial uncertainty of the model output and of the verification data, the interpretation of model performance on point minefields is extremely difficult. See Figure 4.11 for an example of this problem.

In this figure the model output has a grid resolution of 30m and the location of a point minefield, that is 70m in diameter, is represented by four pixels of the model output. Two of these pixels are in "Very Likely" and two are in "Likely". The minefield error buffer indicates that if the minefield was shifted 30m to the north all of the pixels would be classified as "Very Likely" and the performance of the prediction surface would improve by 50% for that point minefield.

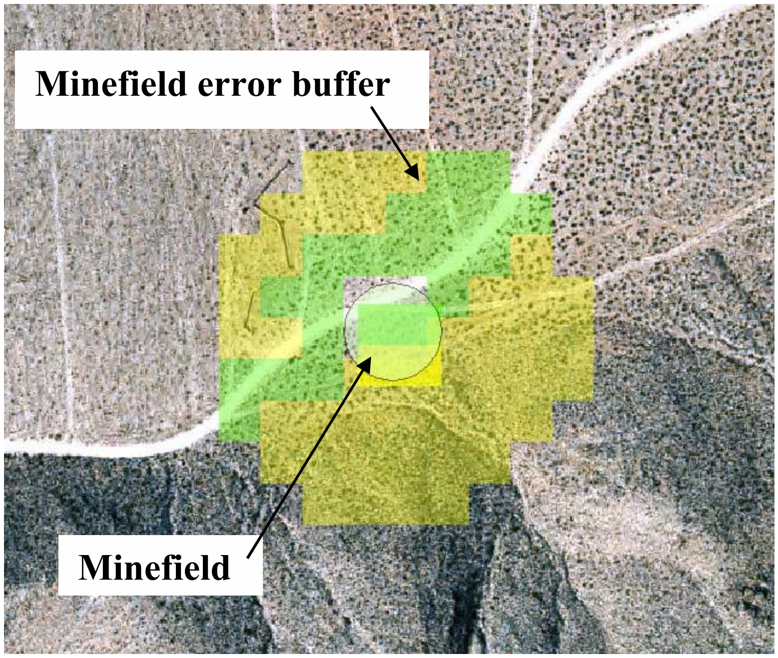


Figure 4.11: GIS Model Output for a Point Minefield

Therefore, the verification of the GIS model output based on point minefield data is extremely difficult since the shift of a few pixels can have a huge impact on the evaluation of the output. For these reasons, the evaluations of the model outputs in Sections 4.1 and 4.3 are much improved when minefield data without point minefields was used.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Chapter 4 revealed that the procedure and methodology developed in Chapter 3 can be customized for a specific area of interest and is successful in minefield prediction. There were some problems with point minefields versus rectangular minefields and with obtaining the minefield data. The following sections will discuss these issues and draw some conclusions.

5.1.1 Minefield Likelihood Procedure Conclusions

The Fort Irwin sensitivity analysis selected two different models based on the best Minefield Likelihood Surface Performance Ratio (MLS PR) and the Sum Ratio values. The optimal models were:

Model #6 *= 0.2****Hydro*** *+ 0.2****Transpo*** *+ 0.2****Slope*** *+ 0.2****Traffic*** *+ 0.2****Visibility***
Model #15 *= 0.35****Hydro*** *+ 0.35****Transpo*** *+ 0.1****Slope*** *+ 0.1****Traffic*** *+ 0.1****Visibility***

Both models used the same five input layers. The Slope Layer and the Visibility Layer were created by using DTED2 data. The Trafficability Layer was created by using the slope data derived from DTED2 data. Model #6 used equal weighting of the input layers. Model #15 weighted the Hydrography and Transportation Layer over the other layers. See Table 5.1 for a summary of the statistics for each model.

Table 5.1: Summary Statistics for Models #6 and #15 for Fort Irwin

Model Run #	**% Land Area in VL**	**% minefields in VL**	**% Land Area in L**	**% minefields in L**	**MLS PR for VL**	**MLS PR for L**	**Sum of %LA**	**Sum of %mf**	**Sum Ratio**
6	13.7%	48.5%	43.1%	43.2%	3.54	1.00	56.8%	91.7%	1.61
15	17.4%	47.5%	26.8%	38.7%	2.73	1.44	44.2%	86.2%	1.95

VL = Very Likely L = Likely LA = Land Area mf = minefield

The initial approach was to evaluate the model outputs based on the results from the "Very Likely" class. The MLS PR values showed that model #6 was the best model. However, the percentage of minefields classified by the model in the VL class was too low so the Sum Ratio was used to objectively evaluate the models by adding the statistics from the VL and L classes. This ratio showed that model #15 was the best. Although model #6 classified over 90% of the minefields, it also classified over 56% of the land area. Model #15 was more efficient at maximizing minefield classification and minimizing the land area classification. It used the best set of internal MLS scores and the best set of weighting coefficients used between each of the input layers. This model was used to create the final output prediction map for Fort Irwin found in Appendix D, Layout #3.

The Fort Polk analysis selected two different models as well. The models chosen were:

Model #4** = 0.25Hydro** + 0***Transpo** + 0.25***Slope** + 0.25***Traffic** + 0.25***Visibility***
Model #8** = 0.1**Hydro** + 0.6**Transpo** +0.1**Slope** + 0.1**Traffic** + 0.1**Visibility

The Slope Layer was derived from a USGS DEM since there was not full DTED2 coverage for the area of interest. The Trafficability Layer used VITD slope to generate trafficability estimates since DTSS would not accept the USGS DEM derived slope data. The Visibility Layer was created from observer locations and the USGS DEM. Model #4 consisted of only four input layers because the Transportation Layer was removed. Model #8 weighted the Transportation Layer over the other input layers. See Table 5.2 for summary statistics for these two models.

Table 5.2: Summary Statistics for Models #4 and #8 for Fort Polk

Model Run #	% Land Area in VL	% minefields in VL	% Land Area in L	% minefields in L	MLS PR for VL	MLS PR for L	Sum of %LA	Sum of %mf	Sum Ratio
4	5.3%	9.7%	79.8%	89.9%	1.85	1.13	85.1%	99.6%	1.17
8	53.4%	90.3%	1.0%	7.0%	1.69	7.00	54.4%	97.3%	1.79

Although the Fort Polk minefield data was mainly comprised of point minefields, the results were very similar to the Fort Irwin data. The MLS PR for the VL class show that model #4 was the best yet it only classified about 10% of the known minefields. The Sum Ratio showed that model #8 was the best model by adding the VL and L class statistics. Although the model classified 54% of the land area, over 97% of the minefields fell within the VL and L prediction classes! This is an extremely high prediction rate. Just as in the Fort Irwin model, model #8 for Fort Polk used the best set of internal MLS scores and the best set of weighting coefficients between each of the input layers. The model was used to create the final output for Fort Polk found in Appendix D, Layout #4.

The success of adding the statistics from the VL and L classes seems to indicate that the model output should be categorized into three classes instead of four – “Not Likely”, “Possible”, and “Likely”. It still seems desirable to keep the fourth class so to keep the %LA value around 10-15% but the current %mf values are too low to do this. In order to use the model output to create minefield search maps, the %LA has to be as low as possible in order to reduce the size of the search areas. However, the search teams would have very little confidence in using a map that has prediction accuracy less than 50% -- they would have better luck by flipping a coin. However, with more accurate input data and minefield verification data, the model parameters could be adjusted further to improve the model output accuracy. If the model could be improved enough so it would predict 95% of the known minefields within the “Very Likely” class, then it would be appropriate to use four minefield likelihood classes.

The weighting of the Transportation Layer seems to have a desirable effect on the model output. Both model #15 for Fort Irwin and model #8 for Fort Polk weighted the Transportation Layer. This outcome proves the value of performing the sensitivity analysis. However, for any new area of interest, the model should be calibrated first and then a sensitivity analysis should be performed. A model developed for one area of interest would not necessarily perform well in a different area of interest.

The model for Fort Irwin was proven to have repeatable results by using two different sets of minefield data in Section 4.2.3. This was an encouraging result and shows that with proper model calibration and sensitivity analysis, a model can successfully predict minefield areas.

5.1.2 Minefield Data Conclusions

There were two main issues with minefield data encountered during this analysis. The first issue was to acquire accurate minefield data and import the data into the GIS. The second was in evaluating the performance of the GIS model using different types of minefields.

The minefield training data was obtained from Fort Irwin and Fort Polk by collecting minefield log reports completed by both US Army training centers. These reports differed in formats and intended for internal use only. See Figure 5.1 for examples of both minefield log reports

52d MECH DIV Enemy/Friendly Min Obstacle Report (MINOBREP - E025)

Line #	Data	13C OBS 1	13B OBS 2	OBS 3	OBS 4	13C OBS 5	13A OBS 6
[illegible]	[illegible] DTG	091830/100200	100015/100300	092200/100001	100315/100500	—	100900/101100
[illegible]	MINE DTG	101323/101330	100745/[illegible]	101000/101130	100507/101[illegible]	100745/101030	
[illegible]	Unit	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[illegible]	TGT/OBS #	SV01	MD01	MD02	MD03	RH01	PIBMD01
[illegible]	Type Obstacle	48 VOL	MD	MD	MD	RC	MD
[illegible]	Corner Location 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Corner Location 2	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	Corner Location 3	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	Corner Location 4	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	Centerline Start Grid						
[illegible]	Centerline End Grid						
[illegible]	[illegible]						

		Obstacle Report B57 Team					
LINE	OC CALL SIGN	B57A	B57B	B57B	B57B	B57C	B57
1	Emplacing Unit	1/1/B/[illegible]	2/1/B/[illegible]	3/1/B/[illegible]	3/1/B/[illegible]	3/1/B/[illegible]	2/1/B/[illegible]
2	Obstacle Number	57TF01	57TF02	57TF03	57TF04	57TF05	57TF07
3	Obstacle Type	MQ/WT/SM	WR/MQ	WR/MQ	MQ	Nuis	WT/MQ/SM
4	Obstacle Intent	TURN	BLOCK	BLOCK	BLOCK	Block	TURN
5	Overwatching/Securing Unit	HHC/[illegible]	C/[illegible]	C/[illegible]	C/[illegible]	B/[illegible]	HHC/[illegible]
6	Start Time	180930	171500	171600	171645	171000	181330
7	Finish Time	181730	171940	171900	171735	171600	182100
8	From Grid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	To Grid	[illegible]					[illegible]
10	Total Meters of minefield frontage	90M	15M	18M	12M	20M	25M
11	# & Type of Buried AT mines	12XM15 24XM21				12xM21	24XM21 TR
12	# & Type of Surface AT mines		13XM15	15XM15	6XM15		
13	# MOPMS & Box #s	1ea, #16	Bx #8	Bx #2			1ea, #12
14	Total meters of wire (front) by type (TSC, Cattle, marking)	15M 11 ROW 90mTSC	15 M 11 ROW STD	10M 11 ROW STD		2x11Row 15m Front	300M TSC
15	# Rolls Concertina	48	11	13		22	69
16	# Long/ Short Pickets	76L	52L/11S	41L/22S		61L/ 10S	115L/8S
17	# Rolls Barbed Wire	1	.5	.25		1	2
18	Lanes Grid						

Figure 5.1: Example Minefield Log Reports from Fort Irwin and Fort Polk

Both minefield log reports contained a lot of information to include minefield coordinates, time and date, and unit that emplaced the minefield (some this information had to be protected in this figure). However, inputting this information and interpreting the log reports took a lot of time and data manipulation (see Section 3.4.4.3). It is quite clear that a minefield information database, like IMSMA, could greatly aid minefield data storage and sharing across the Army and other agencies. This process was the most tedious and time consuming out of all the tasks required to build the GIS model.

The second issue concerns the interpretation of minefield data and how to use the data to evaluate the performance of the minefield prediction model. In the evaluations of the prediction models for Fort Irwin, the models were more successful in predicting rectangular minefield locations than point minefields. Some of the point minefields have different employment strategies than other minefields. The artillery delivered scatterable minefields, or ADAM/RAAM minefields, can occupy areas of 160,000m^2 and are usually used to block choke points in the terrain or seal gaps in a defensive network of obstacles. Since these minefields can occupy such a vast area, only a portion of these minefields may fall within "likely" terrain as predicted by a minefield prediction model. Although these minefields are effective, the model will fail in predicting their locations due to this effect. See Figure 5.2 for an example of one of these minefields.

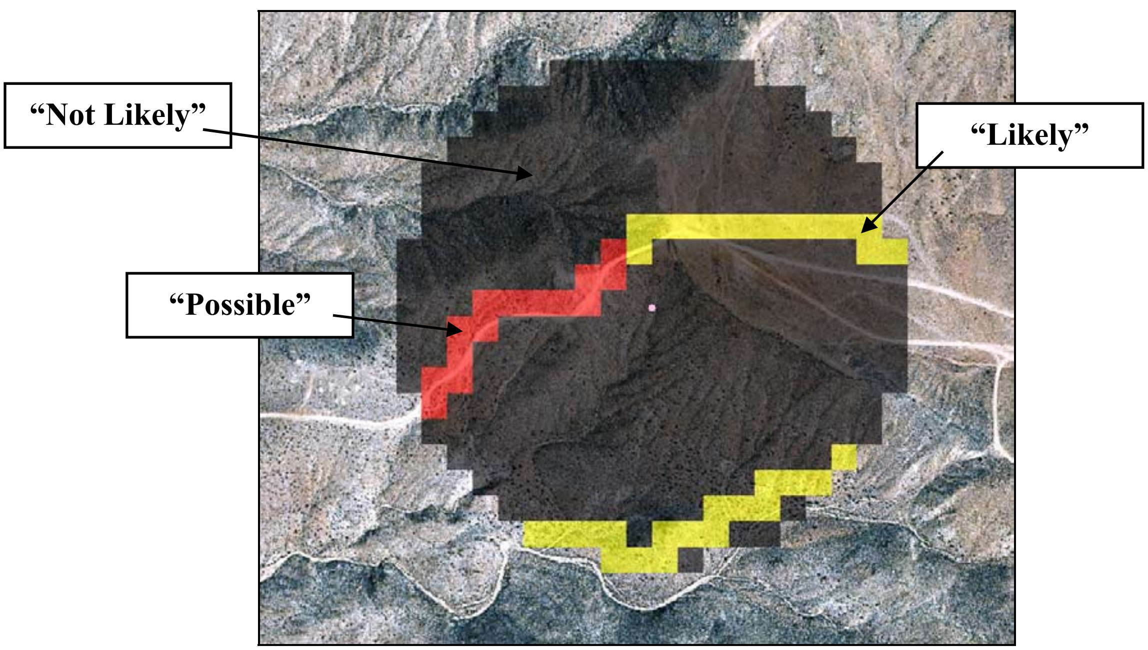


Figure 5.2: Example of an ADAM/RAAM minefield

This minefield was intended to cut off a narrow road in a mountain pass. However, many of the mines fall within untrafficable terrain where the model predicts "Not Likely" for minefields. Since the number of "Not Likely" pixels far outweighs the "Possible" and "Likely" pixels, the model failed to predict this minefield accurately. In conduct of this analysis, ADAM/RAAM minefields were removed from the training minefield dataset in order to evaluate the model output due to this problem. A separate model may be necessary to predict ADAM/RAAM minefield locations in the future.

There were also problems using the other point minefields to evaluate the model performance. Due to the spatial uncertainty of the point minefield data and the 30m spatial resolution of the GIS model, it was very difficult to evaluate the model performance using point minefields. The performance of the Fort Irwin models greatly improved after removing the point minefields from the minefield dataset (see discussion in Section 4.1.1). The analysis was unable to show this same improvement with the Fort Polk models since the vast majority of the minefields in the dataset were point minefields. If the GIS model used elevation data of finer spatial resolution (i.e. 5m or 10m), then the model output resolution could also be reduced. The spatial uncertainty of the point minefields would also have to be reduced. This could be done by using 8-digit MGRS coordinates instead of 6-digit coordinates and by using GPS units with higher precision and accuracy to record the point minefield locations. If these two improvements were made, the model performance for point minefields would improve.

Six different failures of the initial Minefield Likelihood Surface were explored in Section 4.1.1. These were problems that were encountered in both Fort Irwin and Fort Polk. This was not intended to be an all inclusive list of potential prediction surface failures. By applying this methodology to different areas of interest, new failures may be discovered that are caused by either the input data or with the minefield datasets. By examining each individual failure during the model calibration process, these failures will become apparent to the model user and can be corrected by adjusting either the internal MLS scores or the layer weighting scheme.

5.2 Recommendations for Model Improvements and Future Work

There are several directions in which this research could go and there are some possible improvements that could be made to enhance the model predictive capability.

5.2.1 Use of Reflective Surface DEMs

There are two different types of DEMs: bare-earth and reflective surface. The bare-earth DEMs are the most appropriate to use when determining ground slope information. The Trafficability Layer and the Slope Layer both use bare-earth DEMs. The DTED2 and USGS DEMs are both bare-earth DEMs. Reflective surface DEMs can be created through the use of radar imaging sensors and pulsed laser sensors. An Interferometric Synthetic Aperture Radar (IFSAR) sensor is an example of an imaging radar sensor. The elevation data derived from these sensors is called IFSARE. A pulsed laser sensor is called a Light Detection and Ranging (LIDAR) sensor. Both sensors can produce elevation data that represents the first returns to the sensor. These objects can be bare earth, the tops of trees, or the tops of buildings. In performing a viewshed analysis, the best DEM to use is a reflective surface DEM since it will show where vegetation and manmade features will affect visibility. This research was not able to obtain reflective surface DEMs for either area of interest. An improvement to the model would be to use one of these DEMs in the creation of the Visibility Layer.

Also, these reflective surface DEMs are normally available in finer spatial resolution than DTED2 – usually 10m resolution or less. If these DEMs were used in conjunction with bare-earth DEMs of equal spatial resolution, then the model output spatial resolution could be reduced from 30m to 10m. This improvement would enhance the predictive capabilities of the GIS model. A sensitivity analysis between 30m and 10m model output could determine this.

5.2.2 Description of a Menu-Driven Interface

The Minefield Likelihood Procedure would be greatly improved by automating the steps required to build the model and evaluate it. These steps were performed manually during the conduct of this research. This process took several days to create the initial model for Fort Irwin and Fort Polk. A menu-driven software interface could greatly speed up this process and simplify the decision-making process for the user. The GIS functions required to generate the model and evaluate its performance could be programmed in Visual Basic using ESRI's ArcObjects to create a simple menu-driven interface. The programming of this procedure is beyond the scope of this research but a discussion of what an interface would contain and do follows.

The interface would have to be given a catchy acronym like ***GM2AP ver 1.2*** (GIS Model for Minefield Area Prediction) or ***BIGMAP ver 2.0*** (Battlefield Integrated GIS for Minefield Area Prediction). It would consist of a set of 6 menus:

1. **Data Input Menu:** The user would be able to import vector and raster data. The user would also be able to specify an output projection, coordinate system, and horizontal datum.
    a. Vector: NIMA standard vector data to include ITD, VITD, FFD, and DTOP would serve as the primary source of vector data.
    b. Raster: Bare-earth DEMs, such as DTED Level 2 or USGS 30m and 10m, and reflective surface DEMs, such as LIDAR and IFSARE derived DEMs, would be specified ***separately***. Bare-earth DEMs would be used for slope calculation and reflective surface DEMs would be used for visibility or viewshed analysis.

2. **Trafficability Menu:** This menu would request trafficability data from either DTSS or from a user specified or provided trafficability model. If DTSS was selected, the computer would have to be DII/COE compliant. The menu would also ask if slope data is to be supplied from the vector dataset or from the bare-earth DEM for the purposes of trafficability estimates.

3. **Observer/Defensive Position Menu:** This menu would request a source of observer and/or defensive position locations. The data could exist in standard database or spreadsheet formats or come directly from ASAS (All Source Analysis System). The user could specify fields to include in the data but at a minimum the following would have to be included in the input data:
    a. Type of observer
    b. Maximum effective range of observer
    c. Observer height
    d. Target height
    e. Minimum observation range
    f. Project of output layer & type of output layer (shapefile or coverage)

The user would then specify which DEM, from the Data Input Menu, to use for a viewshed analysis. The user would also have to specify the output raster or grid resolution of the viewshed analysis.

4. **Minefield Data Menu:** The user would have the ability to import minefield data from a UN database, such as IMSMA, or from a generic database or spreadsheet or enter the data in a preformatted input form. The input minefield data would have to have the following information, at a minimum:
   a. Minefield Type (point, conventional, scatterable, etc. – pulldown menu)
   b. Minefield Start Point
   c. Minefield Intermediate Point (optional – user could enter several IPs)
   d. Minefield End Point
   e. Minefield Depth (optional). If only two coordinates are provided, the program would need to know the depth of the minefield from the minefield centerline. The program would have the capability of estimating the depth based on the minefield type specified. If four coordinates are provided, the program would assume this to be perimeter coordinates and the minefield depth would not be necessary.
   f. Coordinate system/Datum of source information
   g. Desired output coordinate system/datum
   h. Estimated horizontal positional accuracy of source data

   The menu would then query the user for a desired output layer displaying the minefield data (either shapefile or coverage). This data would be used later to assess the accuracy of the GIS model.

5. **Calibration and Sensitivity Analysis Menu:** In this menu, the user would specify MLS scores for each of the raster layers. There would be options to run the model, evaluate the model against data from the Minefield Data Menu, and edit the MLS scores to refine the calibration. There would also be sensitivity analysis options to allow the user to enter weights for the five raster layers that form the model. There would be default formulas like **Output** = **Hydro** + **Transpo** + **Slope** + **Traffic** + **Visibility** or **Output** = **Hydro** + **Transpo** + 2***Slope** + 2.5***Traffic** + 0.5***Visibility**. The user would also be able to specify their own specific weights or remove a raster layer with a weight of zero. The model output raster resolution would depend on the raster resolution of the input elevation data

6. **MLS Performance Menu:** This menu would present summary statistics about the Minefield Likelihood Surface in relationship to known minefield data (input in the Minefield Data Menu). The statistics would be those found in Chapter 4. The menu would output the following tables and graphs:

   a. Model Accuracy Assessment by Minefield. The number of minefield likelihood class pixels would be totaled by minefield. Table 4.1a in Section 4.1 is an example of this.

b. Model Summary Statistics. This table would list overall percentage of land area classified in each class, percentage of minefields classified in each class, and MLS PR and Sum Ratio values.
c. Graphs of MLS PR and Sum Ratio.

The interface would create the Minefield Likelihood Surface in the desired raster resolution with tables and graphs showing the accuracy of the results if known minefield data is given.

5.2.3 An Exhaustive Sensitivity Analysis

This research tested about 27 different models for the Fort Irwin and Fort Polk areas of interest. Additional model improvements could be identified if an exhaustive sensitivity analysis was performed by modifying intralayer MLS scores and interlayer weighting schemes. This analysis would perform hundreds of different combinations of MLS scores and model weights. It would require an automated process to build the model (as discussed in Section 5.3.2) and to test each iteration of the sensitivity analysis. The researcher would have to have a background in software programming in order to perform this analysis successfully.

5.2.4 Further Testing of the GIS Model

The GIS model should also be "field" tested as a future improvement. These field tests could involve two different scenarios. One scenario would involve testing the performance of the GIS model during a National Training Center training rotation at Fort Irwin. The GIS model, in an automated form, would be directly integrated in DTSS and would make an initial prediction for minefields at the beginning of the training exercise. Then the model would constantly update the minefield predictions based on information spot reports from MCS-Eng and other ABCS subsystems. These spot reports would include enemy defensive and observation locations, and friendly and enemy minefield locations. The Visibility Layer could be updated based on the defensive and observer locations. The model prediction success could be evaluated constantly based on the known minefield locations. Minefield information could be stored and shared by MCS-Eng or by IMSMA. The model output could be provided to those operational planners preparing for offensive attack to help them plan movement routes for their forces.

Another scenario would involve testing the model based on live minefield data from an area of interest such as Bosnia, Kosovo, or Afghanistan. This analysis could be performed just the research in this project was performed. An automated process would not be necessary. This would prove or disprove the validity of the model when predicting non-US minefield locations based on non-US minefield doctrine and tactics.

5.2.5 Develop Minefield Search Maps

Lastly, a research project could be designed that would develop the model output into search zones for remote minefield detection sensors – such as COBRA and LAMD. The researcher would have to have knowledge about the specifications of the individual sensor and how it is used in order to develop a methodology to translate the GIS model output to a useable search map. This research would have to be performed within the DoD and probably in cooperation with the US Army Night Vision Laboratory.

5.2.6 Integration of Expert System

The methodology that has been discussed so far has required the user to manually select input datasets, set internal MLS scores, and set weighting coefficients between each of the input model layers. This process could be further improved by incorporating an expert system that could initially set these MLS scores and weighting coefficients for the user by performing a calibration process and sensitivity analysis automatically. An additional step would be to incorporate artificial intelligence algorithms to enable the expert system to learn from past experiences and model implementations. Over time the expert system could collect parameters from past successful prediction models from areas of similar topography and hydrographic features and estimate parameters for a new area of interest. In order to start this research, the model would have to be performed numerous times over several different areas of interest to populate a database of prediction surfaces results.

5.3 Achievement of Objectives

All of the objectives for this research were achieved during the conduct of the literature review, methodology and model design, and during the model evaluation. A discussion of how these objectives were achieved follows:

1. **Investigate the current state of the art models in use for minefield area prediction.** An extensive literature and topical review was presented in Chapter 1. One previous prediction model was found that incorporated a GIS and an expert system. It was developed in the late 1980s by Par Government Systems Corporation for TEC. The ideas from this model were incorporated in the Minefield Likelihood Procedure and were expanded upon.

2. **Explore the data layers commonly used by the Department of Defense (DoD).** The GIS data layers commonly used outside of the DoD differ greatly from those used within the DoD. Chapter 2 and 3 described these data layers through the NIMA Foundation Data concept discussion and through the discussion of the individual data inputs for the GIS model.

3. **Design and implement an optimal site suitability type GIS model integrating common NIMA and/or USGS datasets and the best commercially available software.** The Minefield Likelihood Procedure has proved to be customizable for two different areas of interest that have completely different terrain characteristics. Current NIMA and USGS datasets were used in conjunction with ESRI's ArcGIS 8.2 software. The GIS model consists of five raster input layers. Each layer was formed by assigning specific MLS scores to specific attributes. These scores can be changed to improve model performance for a specific area of interest. Chapter 3 details the methodology used to create the GIS model.

4. **Evaluate the performance, accuracy, and sensitivity of the model using training minefield data.** The performance of the GIS model was evaluated by using training minefield datasets from Fort Irwin and Fort Polk. A series of models were created for each area of interest in order to calibrate the models and perform a sensitivity analysis. The accuracy of the models were evaluated by attempting to maximize the percentage of minefields classified in the "Very Likely" and "Likely" minefield likelihood classes while attempting to minimize the percentage of land area classified in these same classes. Two ratios were developed in order to quantitatively distinguish between the different models – the Minefield Likelihood Surface Performance Ratio and the Sum Ratio. The Sum Ratio values ultimately led to the discovery that model performance improved by combining the results from the "Very Likely" and "Likely" classes. Chapter 4 covers this in more detail.

5. **Suggest future performance enhancements and research directions.** Chapter 5 presents some conclusions about the GIS model performance and suggests future improvements and applications for the model.

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APPENDIX B: Glossary of Acronyms

ABCS	Army Battle Command System
ADAM/RAAM	Artillery Delivered Anti-personnel Mines / Remote Anti-Armor Mines
AFATDS	Advanced Field Artillery Tactical Data System
AHD	Anti-handling Device
AMDPCS	Air-Missile Defense Planning and Control System
AP	Anti-personnel
ASAS	All Source Analysis System
ASHTO	Association of State Highway and Transportation Officials
ASTAMIDS	Airborne Standoff Minefield Detection System
AT	Anti-tank
ATCCS	The Army Tactical Command and Control System
ATD	Advanced Technology Demonstration
BOS	Battlefield Operating Systems
BTRA	Battlespace Terrain Reasoning and Awareness
C3I	Command, Control, Communications, and Intelligence
CAMMS	Condensed Army Mobility Model System
CD-ROM	Compact Disc-Read Only Memory
CIB5	Controlled Image Base – 5 meter
COBRA	COastal Battlefield Reconnaissance and Analysis
CSSCS	Combat Service Support Control System
DEM	Digital Elevation Model
DGIWG	Digital Geographic Information Working Group
DIGEST	Digital Geographic Information Exchange Standard
DII/COE	Defense Information Infrastructure / Common Operating Environment
DIMS	Demining Information Management System
DMA	Defense Mapping Agency (now National Imagery and Mapping Agency [NIMA])
DoD	Department of Defense
DoDISS	Department of Defense Index of Specifications and Standards
DTOP	Digital Topographic Data
DTSS	Digital Topographic Support System
EO	Electro-optical
FACC	Feature and Attribute Coding Catalogue
FBCB2	Force XXI Battle Command Brigade and Below
FD	Foundation Data
FFD	Foundation Feature Data
FM	Field Manual
GCCS	Global Command and Control System
GIS	Geographic Information System
GOB	Ground Obstacles (coverage name)
HYDRO	Hydrography (coverage name)
ID	Identifier
IFSAR	Interferometric Synthetic Aperture Radar
IFSARE	Interferometric Synthetic Aperture Radar - Elevation

IMETS	Integrated Meteorological System
IMSMA	Information Management System for Mine Action
IND	Industry (coverage name)
IR	Infrared
ISO	International Organization for Standardization
ITD	Interim Terrain Data
LAMD	Light Airborne Mine Detection System
LIDAR	Light Detection and Ranging
MC&G	Mapping, Charting, and Geodesy
MCGT	Mapping, Charting, and Geodesy Technology
MCOO	Modified Combined Obstacle Overlay
MCS	Maneuver Control System
MCS	Maneuver Control System
MCS-Eng	Maneuver Control System – Engineer
MGRS	Military Grid Reference System
MOPMS	Modular Pack Mine System
MSDS	Mission Specific Data Set
MSL	Mean Sea Level
NATO	North Atlantic Treaty Organization
NIMA	National Imagery and Mapping Agency (formerly Defense Mapping Agency - DMA)
NRMM	NATO Reference Mobility Model
OBS	Obstacles (coverage name)
PHY	Physiography (coverage name)
POP	Population (coverage name)
SDR	Surface Drainage (coverage name)
SLP	Slope/Surface Configuration (coverage name)
SMC	Soil/Surface Materials (coverage name)
STANAG NATO	Standardization Agreement
TDA	Tactical Decision Aid
TEC	Topographic Engineering Center
TLM	Topographic Line Map
TRADOC	US Army Training and Doctrine Command
TRANS	Transportation (coverage name)
TTADB	Tactical Terrain Analysis Data Base
TUAV	Tactical Unmanned Aerial Vehicle
UAV	Unmanned Aerial Vehicle
US	United States
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USIGS	United States Imagery and Geospatial Information System
UTIL	Utilities (coverage name)
UXO	UneXploded Ordnance
VEG	Vegetation (coverage name)

VITD	Vector Product Interim Terrain Data (VITD product name)
VMap	Vector Smart Map
VPF	Vector Product Format
WGS	World Geodetic System

If an acronym is missing, try finding it here:
http://www.ulib.iupui.edu/subjectareas/gov/military.html

APPENDIX C: Background Material

The following sections contain background material that is referenced in Chapters 2 and 3.

Anti-Tank and Anti-Personnel Mines

The key characteristics of an AT or AP mine are shown in Figure C-1:

- Firing mechanism or other device (sets off the detonator or igniter charge).
- Detonator or igniter (sets off the booster charge).
- Booster charge (may be attached to the fuse or the igniter or be part of the main charge).
- Main charge (in a container; usually forms the body of the mine).
- Casing (contains all the above parts).

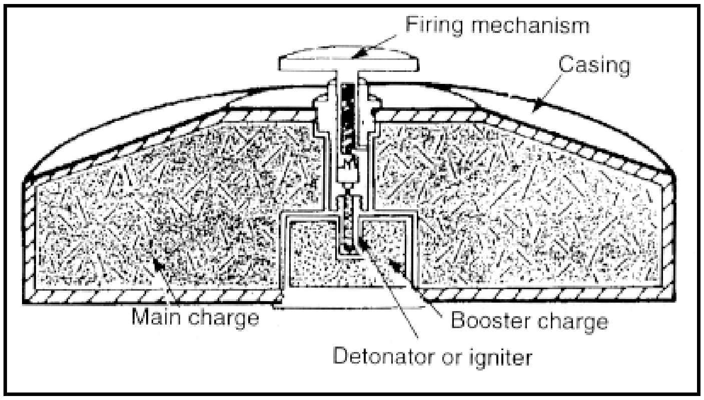


Figure C-1: Diagram of Mine Components [29]

Anti-tank mines are designed to incapacitate combat vehicles and/or kill the crew. They use three main types of fuses:

- Track-width fuse: Designed to disable a vehicle by removing the tracked wheels (i.e. on a tank) or remove one of the tires on wheeled vehicles. The fuse normally uses vehicle pressure to detonate the mine. This fuse is termed a "mobility kill." The mine must be on the surface or buried along a route or an avenue of approach.
- Full-width fuse: Designed to kill the crew of a combat vehicle and/or disable the prime weapon system on the vehicle. These fuses can employ a variety of technologies including acoustic, magnetic, vibration, radio frequency, and infrared sensors. This fuse is termed a "catastrophic kill." The mine must be on the surface or buried along a route or an avenue of approach but does not necessarily need to be driven over to initiate. They can also be command detonated (manually fired).
- Off-route fuse: Designed to incapacitate vehicles, weapon systems, and/or crew by striking the side or top of vehicles. These fuses normally employ the same technology found in full-width fuses but also can be command detonated. These fuses can produce mobility or catastrophic kills. Typical locations for these fused mines are in cut slopes along roads, in trees overhanging roads, and in buildings lining a road.

[29] FM 20-32 (2001)

Minefield Placement Considerations

Items 1 thru 5 in Figure C-2 show a battlefield example of minefield placement and intended purpose.

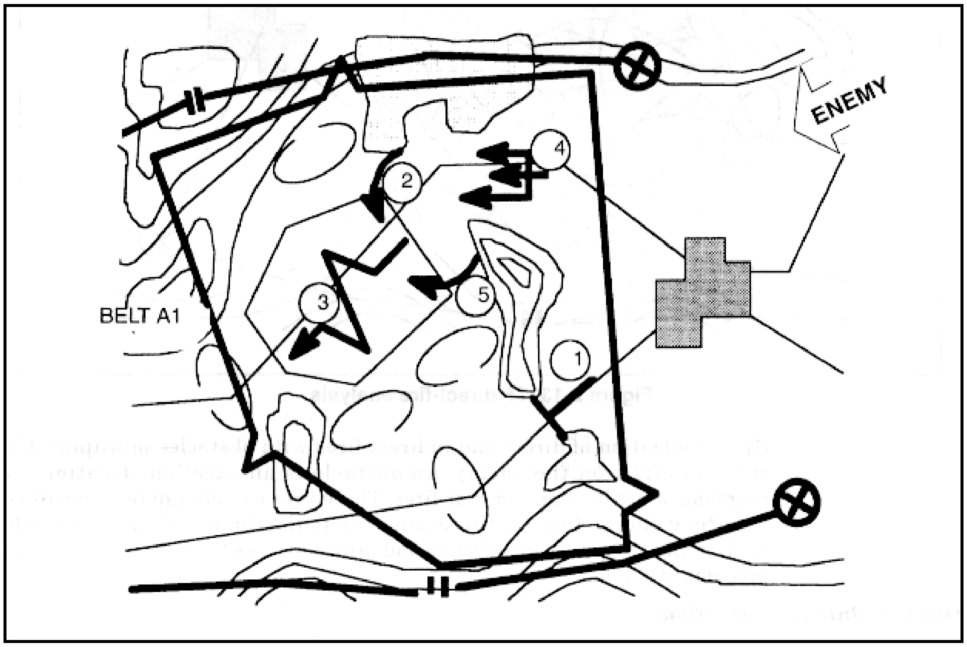
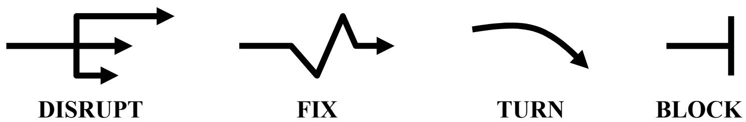


Figure C-2: Scheme of Obstacles Overlay[30]



[30] FM 20-32 (2001)

Digital Topographic Data (DTOP) Overview

Digital Topographic Data (DTOP) files are equivalent to a combination of the feature, attribute, and value content of the 1:50,000 and 1:100,000 scale standard topographic hardcopy maps. All DTOP product features, attributes, and values are individually organized into a data library of single subject thematic layers or coverages. Since most of the data used in DTOP is vector, the Vector Product Format (VPF) standards are used. VPF is a standard format, structure, and organization for large geographic databases. Figure C-3 shows the VPF structure[31]:

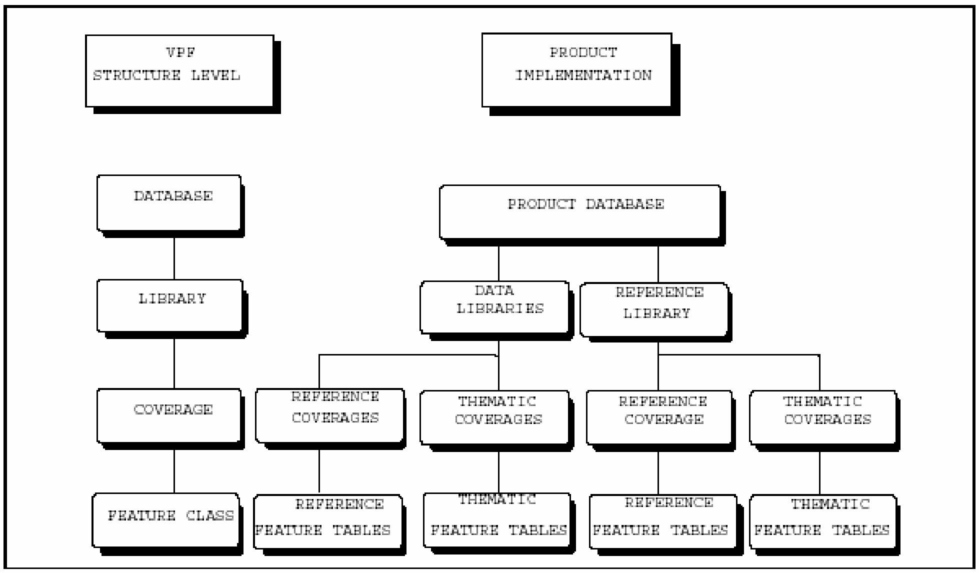


Figure C-3: Vector Product Format File Structure

Some of these thematic layers are Hydrography, Slope/Surface Configuration, Soil/Surface Materials, Surface Drainage, Transportation, Utilities, and Vegetation. These DTOP thematic layers follow the VPF file structure specifications. DTOP features, attributes, and values are mostly consistent with associated hardcopy Topographic Line Map (TLM) and Tactical Terrain Analysis Data Base (TTADB) products, as defined below:

> ***TTADB:*** *A 1:50,000 scale geographic information system type data base consisting of a set of selected single subject thematic terrain information overlays used to satisfy tactical military requirements. Data on the physical, biological, and cultural features of the Earth's surface is presented in a hard copy cartographic format.*

> ***TLM:*** *The standard worldwide topographic hardcopy map produced by NIMA and its coproducers for ground use by the armed services. It shows basic natural and man-made land use cover, cultural features of importance, including most transportation features and buildings and urban areas. Relief and terrain form is represented by the use of contour lines and spot heights. Any other natural or man-made feature considered to be of landmark importance is also included.*[32]

[31] VPF metric, MIL-PRF-0089049 (1998)
[32] DTOP metric, MIL-PRF-0089037 (1999)

Mission Specific Datasets (MSDS) Organized into DTOP Levels

Foundation Data is organized into the VPF data structure and packaged into different DTOP priority levels for specific civil and military uses. There are two categories of MSDS in development: one set of MSDS to satisfy map background and terrain visualization needs and another set of MSDS to satisfy the terrain analysis analytical applications, along with map background and terrain visualization requirements. The even numbered DTOP levels, DTOP Level 2 and DTOP Level 4, are designed for map background requirements. The odd numbered DTOP Levels, DTOP Level 1, DTOP Level 3, and DTOP Level 5, are designed for both map background and terrain analysis requirements. See Figure C-4 for an overview of these MSDS DTOP levels. All of the DTOP levels are upwardly compatible with and direct subsets of DTOP Level 5.

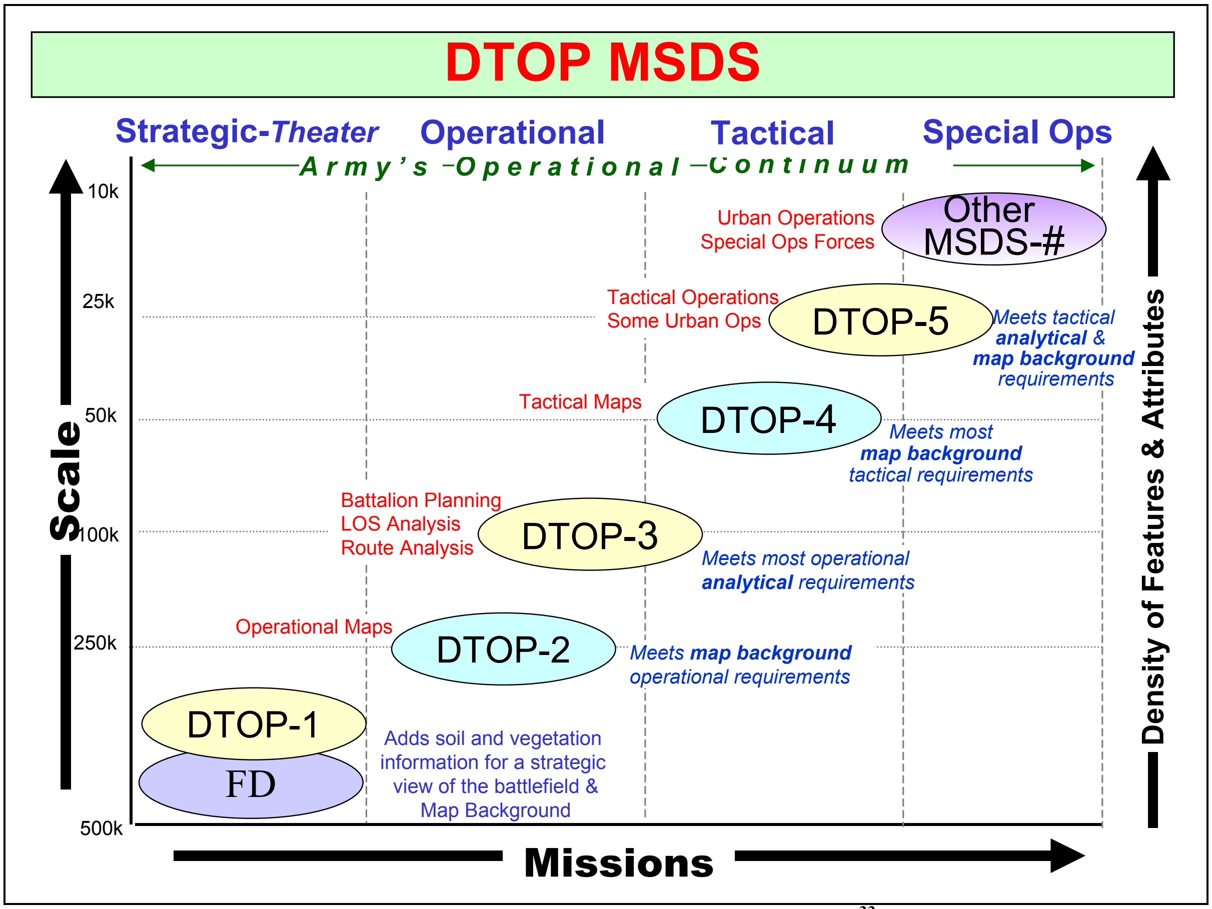


Figure C-4: MSDS DTOP Level Overview[33]

These proposed DTOP levels were described by Debra Kabinier in "Digital Topographic Data (DTOP) - Framework of Mission Specific Data Sets (MSDS)" published by the U.S. Army Topographic Engineering Center (TEC). The following DTOP level description was adapted from this document:

[33] Kabiner (2000)

<u>DTOP Level 1:</u> The intended use of DTOP 1 is for strategic level planning, initial operations, and crisis response. As such, DTOP 1 has the feature density of FFD with added detail to permit basic terrain analysis. Road, rail, and stream networks are derived from FFD. In addition, linear obstacles will be collected along transportation features. The soil/surface material coverage contains wet soil trafficability groups at a scale equivalent to 1:250,000. The vegetation coverage consists of the FFD information with additional feature classes such as rice paddies and orchards.

<u>DTOP Level 2:</u> DTOP 2 is designed for various situational awareness and map background displays at an equivalent scale of 1:250 – 1:100K. Surface Drainage and Transportation features are densified and key cultural and natural features such as industry, utilities, and population are included. There is limited ability to conduct analysis.

<u>DTOP Level 3:</u> DTOP 3 is a robust data set designed to support automated decision making, terrain analysis, battlefield visualization, and most tactical decision aids (TDAs). DTOP 3 also has the data content necessary to support customizable map background displays in command and control systems at an equivalent scale of 1:100 K. DTOP Level 3 generally has the features and attributes that have been provided in Interim Terrain Data (ITD) and a 1:100 K Topographic Line Map (TLM). To lower production costs, the slope coverage is not provided. Instead, DTED Level 2, part of FD, can be used to derive customer-specified slope coverages. The soil coverage consists of delineations based on wet soil trafficability groups rather than individual soil classes. The density of the road networks is greater than FFD and DTOP Level 1 but not as dense as DTOP Level 4 or 5, which are equivalent to the density of a 1:50 K TLM.

<u>DTOP Level 4:</u> DTOP 4 is designed for various large-scale situational awareness, map background displays and hard copy map production. It contains all of the 1:50,000 TLM line features found in DTOP Level 5 and limited features and attributes for terrain analysis.

<u>DTOP Level 5:</u> DTOP 5 is a full-up data set developed to support full-scale, joint, combined warfighting operations. It consists of the feature and attribute content of a TLM and terrain analysis information at a scale equivalent to 1:50,000. The data content supports some urban and Special Operation Forces requirements. Since DTOP 5 is very resource intensive, only small areas should be requested.[34]

[34] Kabinier (2000)

NRMM II Submodule Schematics

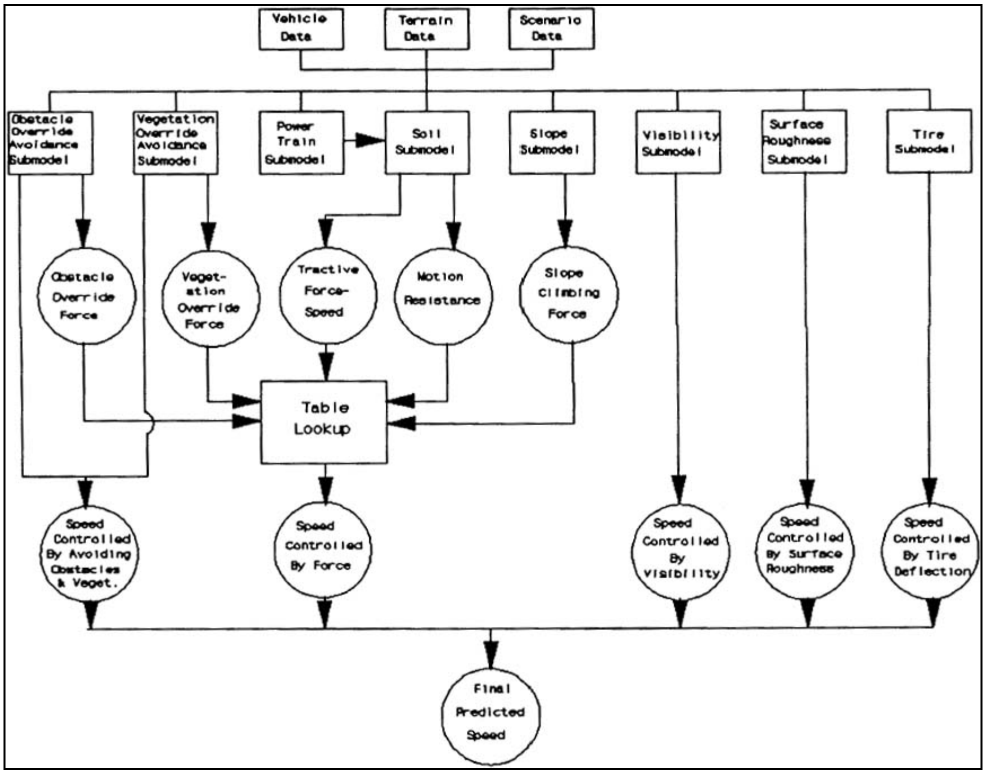


Figure C-5: NRMM II Cross-Country Prediction Submodule Schematic

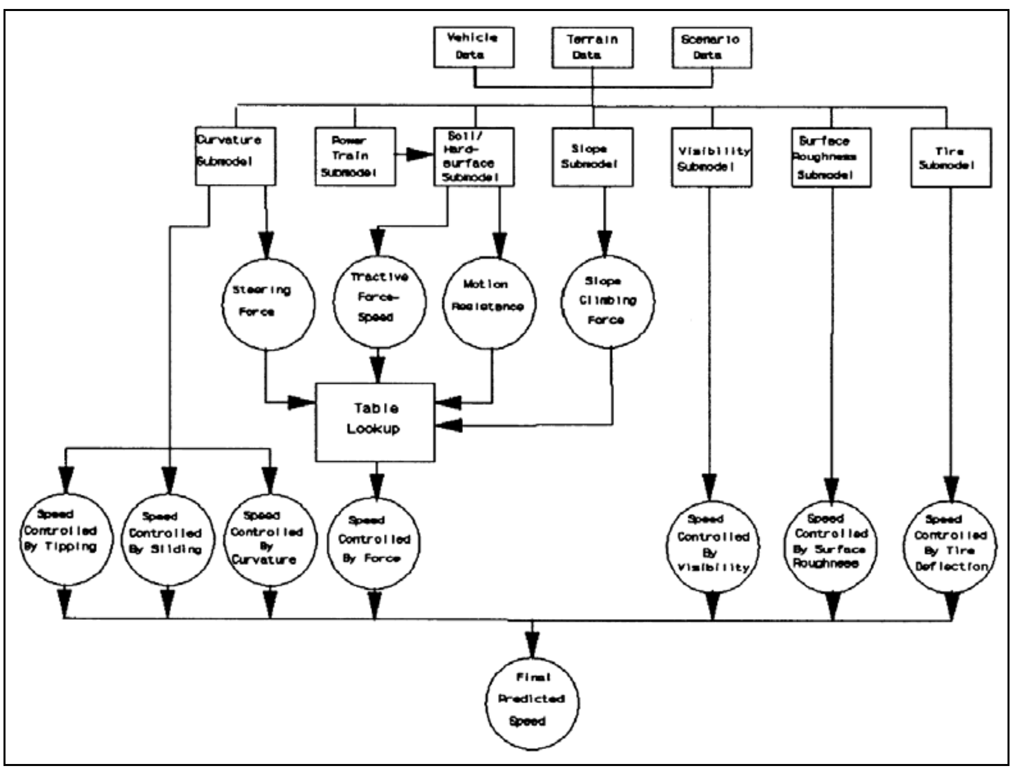


Figure C-6: NRMM II On-Road Prediction Submodule Schematic

Army Battle Command System (ABCS)

The following brief overview has been adapted from "Army Battle Command Systems (ABCS) Smart Book, Overview, Version 6.2.x" written by the Warrior-T Division of TRADOC. See Figure C-7 for the interrelation of the different ABCS components.

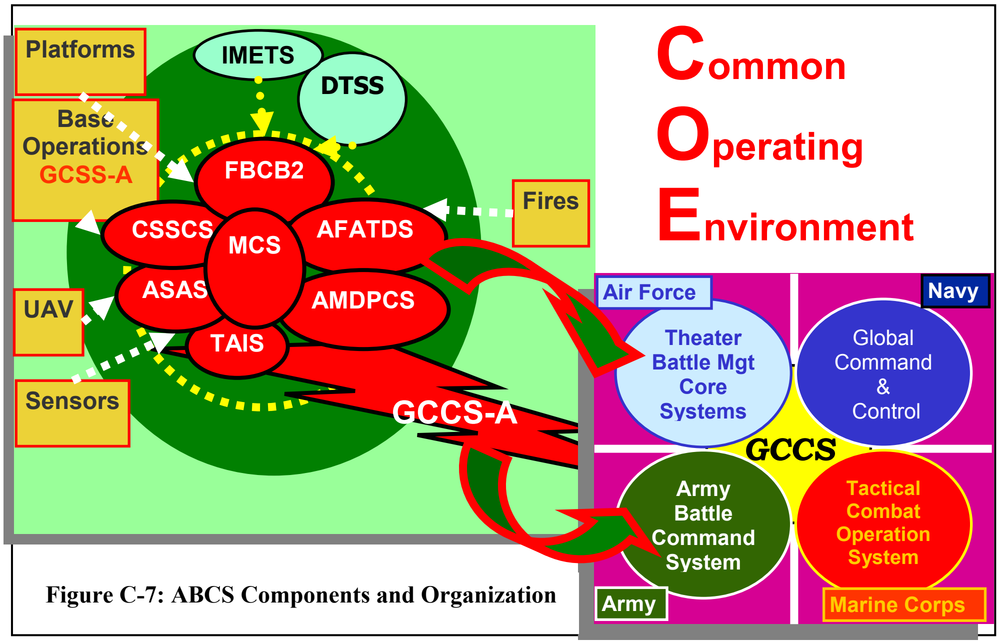


Figure C-7: ABCS Components and Organization

The ABCS is intended to: 1) provide and disseminate digital information, 2) make estimates, 3) make recommendations, 4) prepare operations plans and orders, and 5) supervise execution of decisions.

The ABCS has several informational components:

1. *GCCS-A is the Army component of the Global Command and Control System (GCCS) and supports warfighter information and understanding at the theater level, including the joint environment*

2. *The Army Tactical Command and Control System (ATCCS) is the integration of five primary functional area control systems providing situational information and decision support to the battlefield operating systems (BOS) from corps to battalion echelons. These five systems are:*
   - **a.** *Maneuver Control System (MCS)*
   - **b.** *Advanced Field Artillery Tactical Data System (AFATDS)*
   - **c.** *Air-Missile Defense Planning and Control System (AMDPCS)*
   - **d.** *All Source Analysis System (ASAS)*
   - **e.** *Combat Service Support Control System (CSSCS)*

3. *Force XXI Battle Command Brigade and Below (FBCB2) provides access from brigade to the individual platform.*

4. *Other ABCS Systems including the Digital Topographic Support System (DTSS) providing geospatial data analysis, the Integrated Meteorological System (IMETS) providing weather data and the Tactical Airspace Integration System providing airspace planning and management tools.*[35]

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[35] Warrior-T (TRADOC) (2001)

NIMA Dataset Coverage

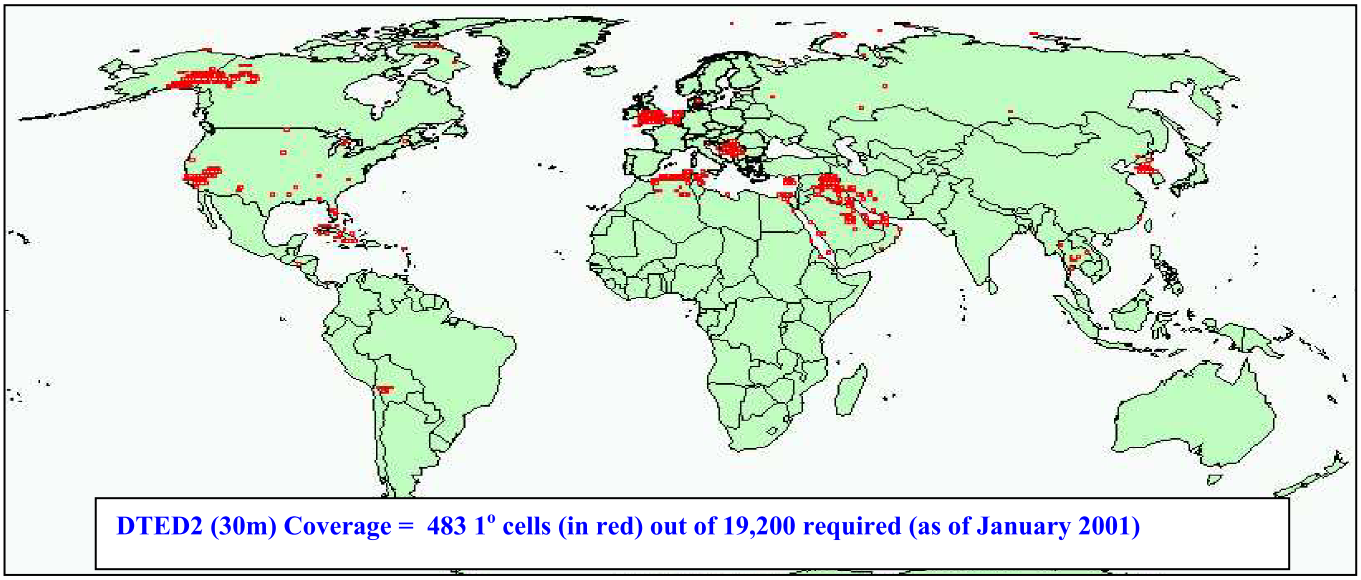


Figure C-8: DTED Level 2 coverage map

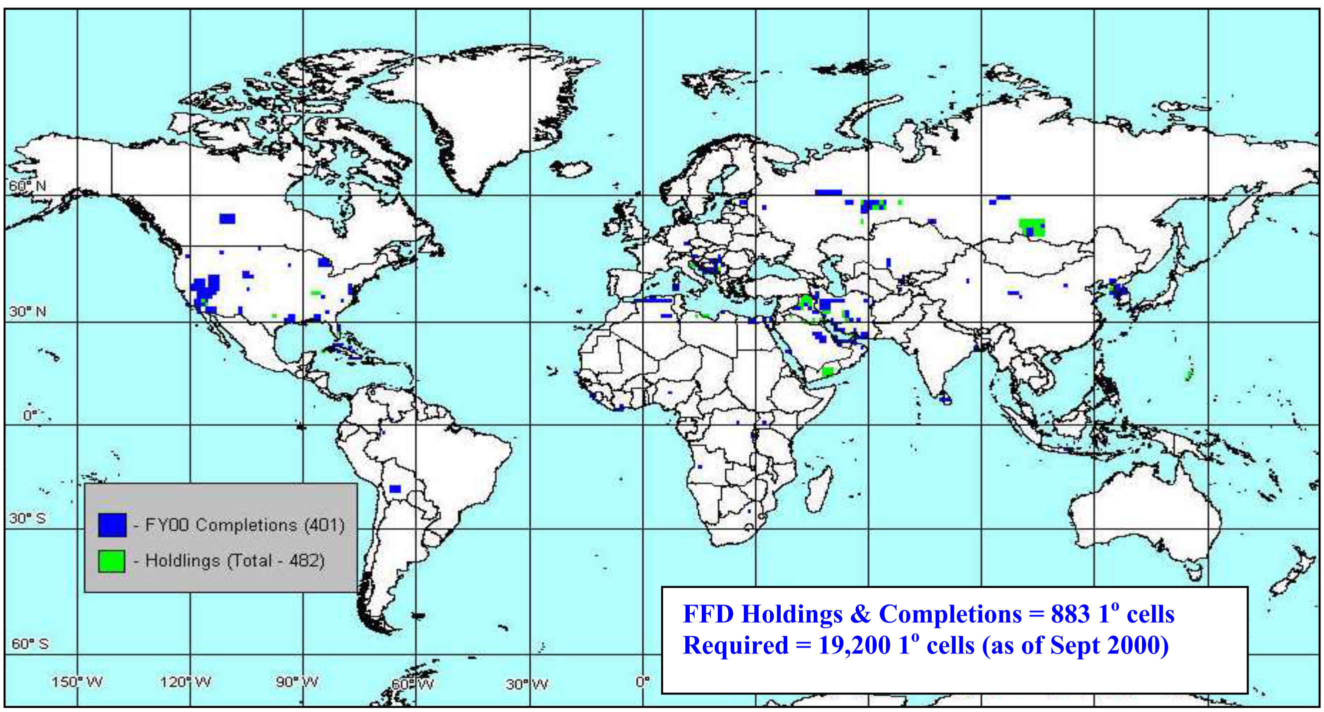


Figure C-9: FFD Coverage map

Rapid Terrain Visualization Program

The RTV program is part of the Joint Precision Strike Demonstration (JPSD) Project Office under the US Army Program Executive Office for Intelligence and Electronic Warfare & Sensors (PEO-IEW&S)

The RTV program objective is to collect highly detailed elevation data and to create standard NIMA vector datasets, in a short amount of time, in order to support tactical needs in crisis situations. The program can create LIDAR (LIght Detection And Ranging) derived DEMs, IFSAR derived DEMs – called IFSARE, and can extract vector features from imagery and create standard NIMA vector datasets such as VITD (discussed in next section), FFD and DTOP. These modules are referred to as the RTV Multispectral Imagery Feature Extraction Module (RTV MSI FE) and the RTV Feature Integration and Attribution Module.[36]

The Army Training and Doctrine Command (TRADOC) has identified an operational requirement to generate and distribute digital geospatial products rapidly. The requirement is data coverage for a 20x20 km square area within 18 hours, 90x90 km square area within 72 hours, and 300x300 km square area within 12 days.[37]

[36] Turner, et al (2000)
[37] https://peoiews.monmouth.army.mil/jpsd/rtv.htm

Vector Interim Terrain Data (VITD)

VITD is divided into six thematic layers, or coverages. There are separate feature classes within each thematic layer. Table C-1 lists these thematic layers and some common feature classes within each thematic layer. This is not an all inclusive list – some thematic layers may have more or less feature classes.[38]

Table C-1: VITD Thematic Layers and Feature Classes

Thematic Layer	Feature Classes within each Thematic Layer	VPF COVERAGE NAME / VPF feature class name
Obstacles		OBS
	Obstacles Area	obsarea
	Obstacles Line	obsline
	Obstacles Node	obsnode
Slope/Surface Configuration		SLP
	Slope Area	slparea
	Slope Water Area	slwarea
Soil/Surface Materials		SMC
	Surface Materials Area	smcarea
	Surface Materials Water Area	smwarea
Surface Drainage		SDR
	Surface Drainage Area	sdrarea
	Surface Drainage Channel Area	sdcarea
	Surface Drainage Channel Line	sdcline
	Surface Drainage Node	sdrnode
	Surface Drainage Line	sdrline
Transportation		TRN
	Transportation Bridge Line	trbline
	Transportation Bridge Node	trbdgnd
	Transportation Line	trnline
	Transportation Node	Trnnode
	Transportation Railroad Line	Trrline
	Transportation Road Line	Trdline
	Transportation Area	Trnarea
Vegetation		VEG
	Vegetation Area	Vegarea
	Vegetation Forested Area	Vgfarea
	Vegetation Water Area	Vgwarea

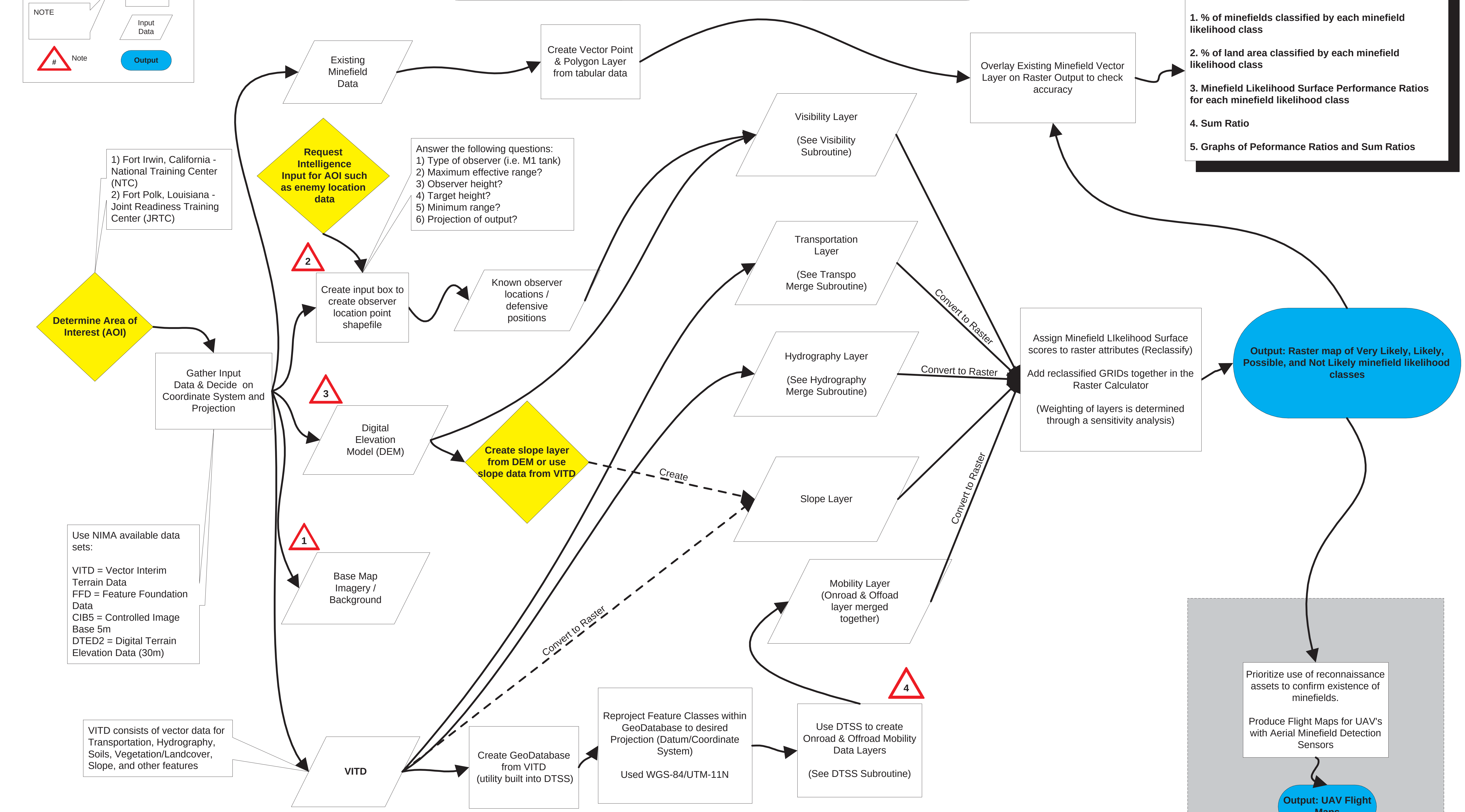
[38] VITD metric, MIL-PER-89040 (1995)

APPENDIX D: Layouts of Figures and Results

The following sections contain schematics and layouts that are referenced throughout the text of this document.

GIS Model for Minefield Area Prediction

26 November 2002 | Schematic Page D-2 | CPT Ed Chamberlayne



1 Collected aerial and satellite imagery for both NTC & JRTC. A Hillshade created from the DTED2 combined with the imagery is used a background map

2 Observer locations and defensive positions were taken from NTC & JRTC tactical situation slides.

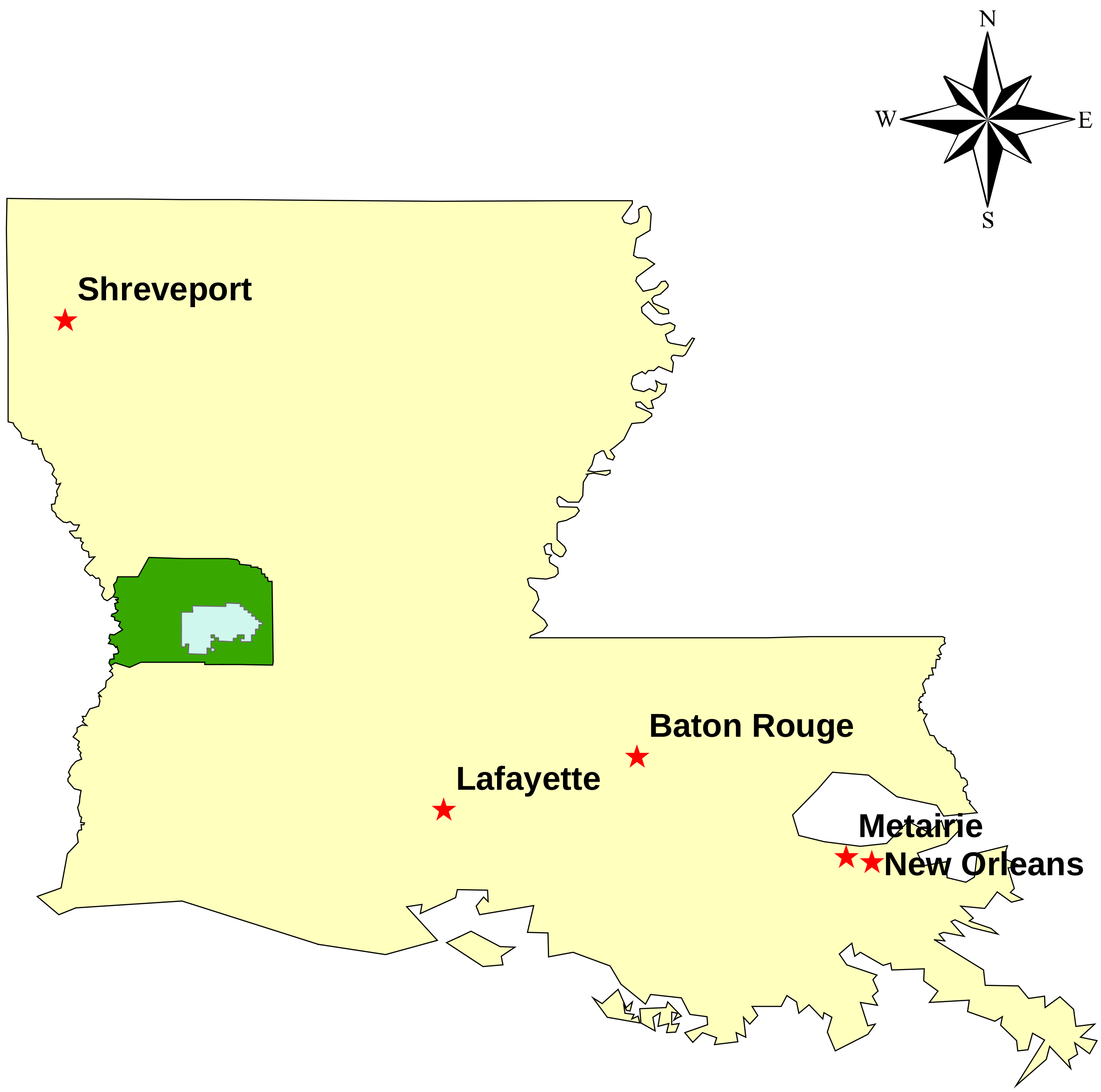
3 Collected DTED2 for NTC & JRTC. DTED2 data must be converted from .dt2 format to GRID to use in ArcGIS. In order to speed up the GIS model, clip the input DEM using the Arc command of GRIDCLIP.

4 Digital Topographic Support System (DTSS) was used to create the trafficability/mobility output. DTSS was created by TASC Inc. for the Combat Terrain Information Systems (CTIS) program. It is customized extension within ArcGIS (ArcMap).

Layout 1

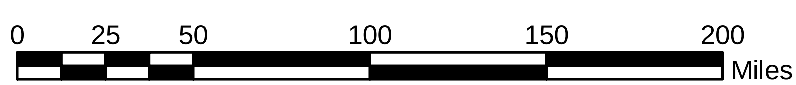

N
W
E
S
San Francisco
San Jose
Los Angeles
San Diego
Area of Interest - Fort Irwin, California
National Training Center
San Bernandino County
State of California
Major Cities
0
45
90
180
270
360
Miles

Layout 2



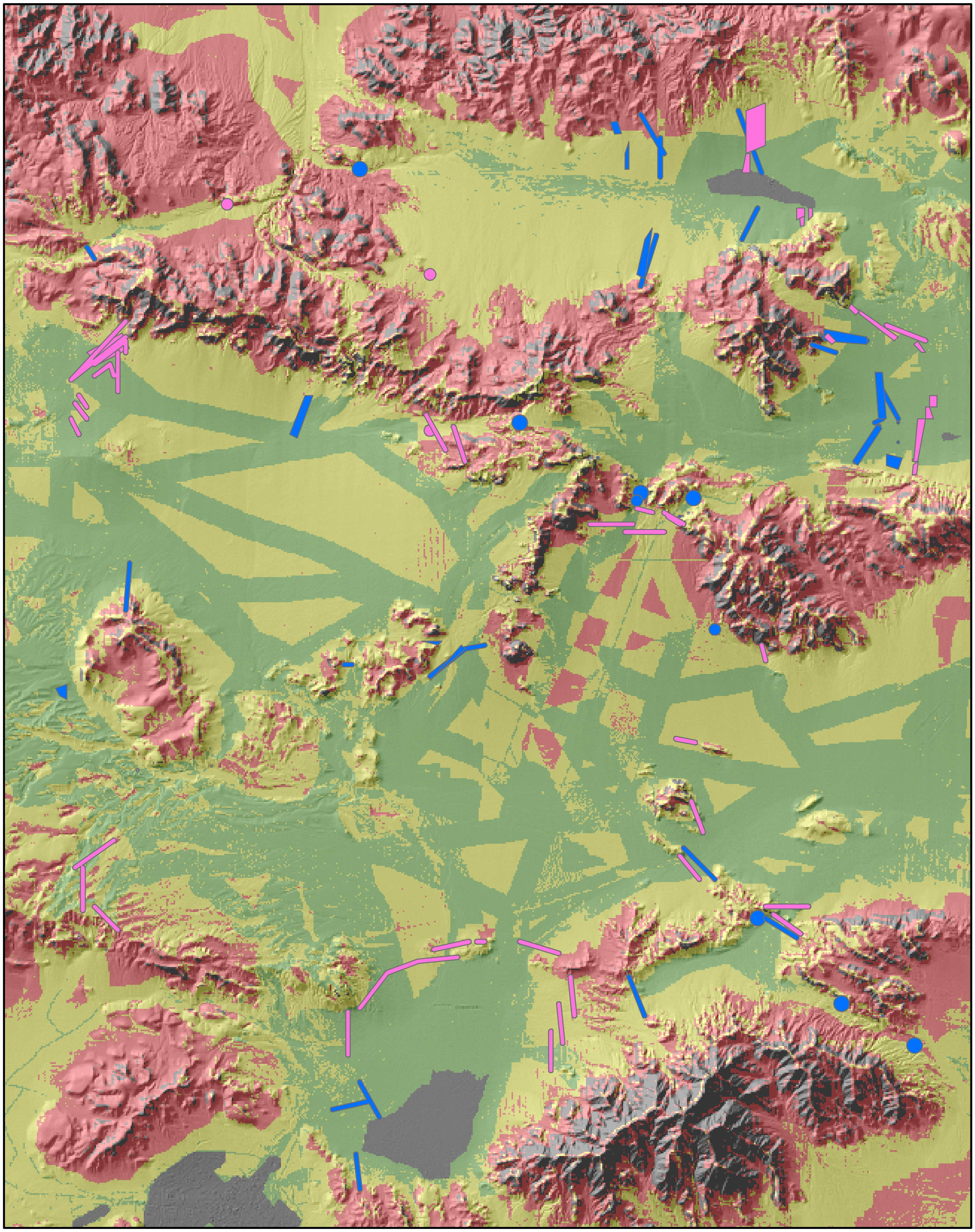
Area of Interest - Fort Polk, Louisiana

State of Louisiana
Vernon Parish
Fort Polk (South) Training Area
Major Cities



Minefield Likelihood Surface for Fort Irwin, CA

With Training Minefield Overlays



Legend

VALUE

- "Not Likely" Minefield Likelihood Class
- "Possible" Minefield Likelihood Class
- "Likely" Minefield Likelihood Class
- "Very Likely" Minefield Likelihood Class
- Training Minefield Dataset #1
- Training Minefield Dataset #2

Spatial Uncertainty = 200 meters

N W E S

LAYOUT 3

4 2 0 4 8 12 Kilometers

Minefield Likelihood Surface for Fort Polk, LA

With Training Minefield Overlay

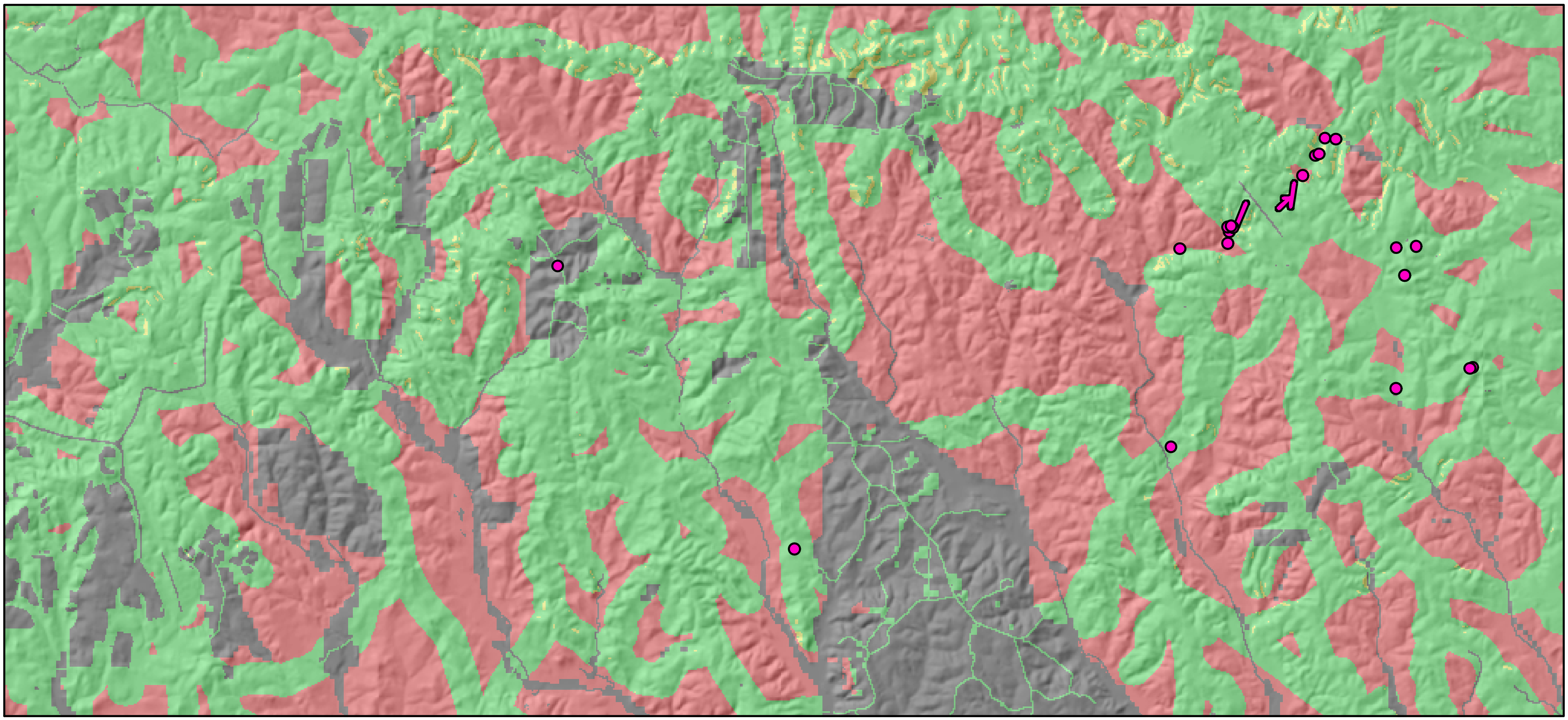
Legend

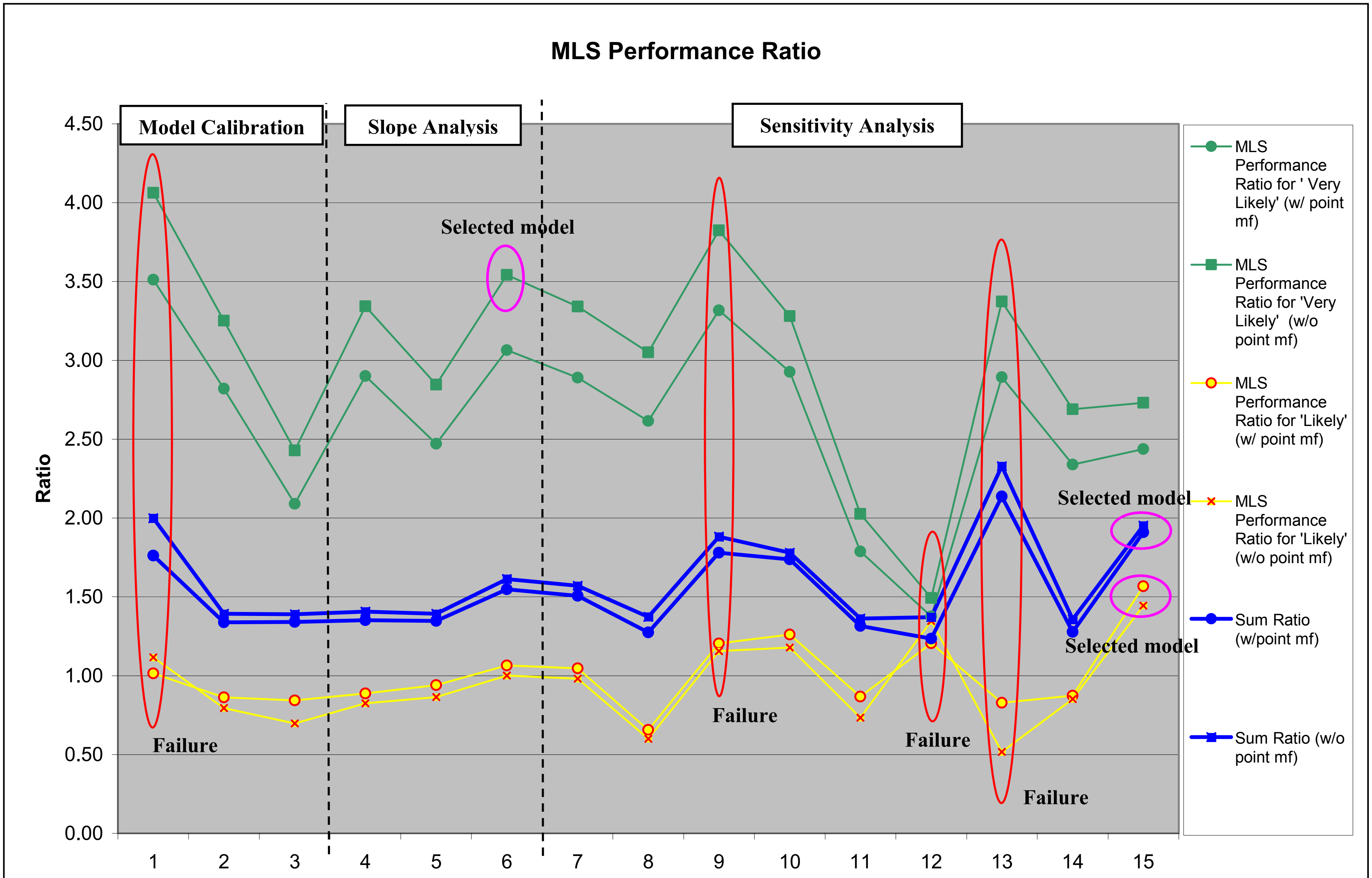
VALUE

- "Not Likely" Minefield Likelihood Class
- "Possible" Minefield Likelihood Class
- "Likely" Minefield Likelihood Class
- "Very Likely" Minefield Likelihood Class
- Training Minefield Data

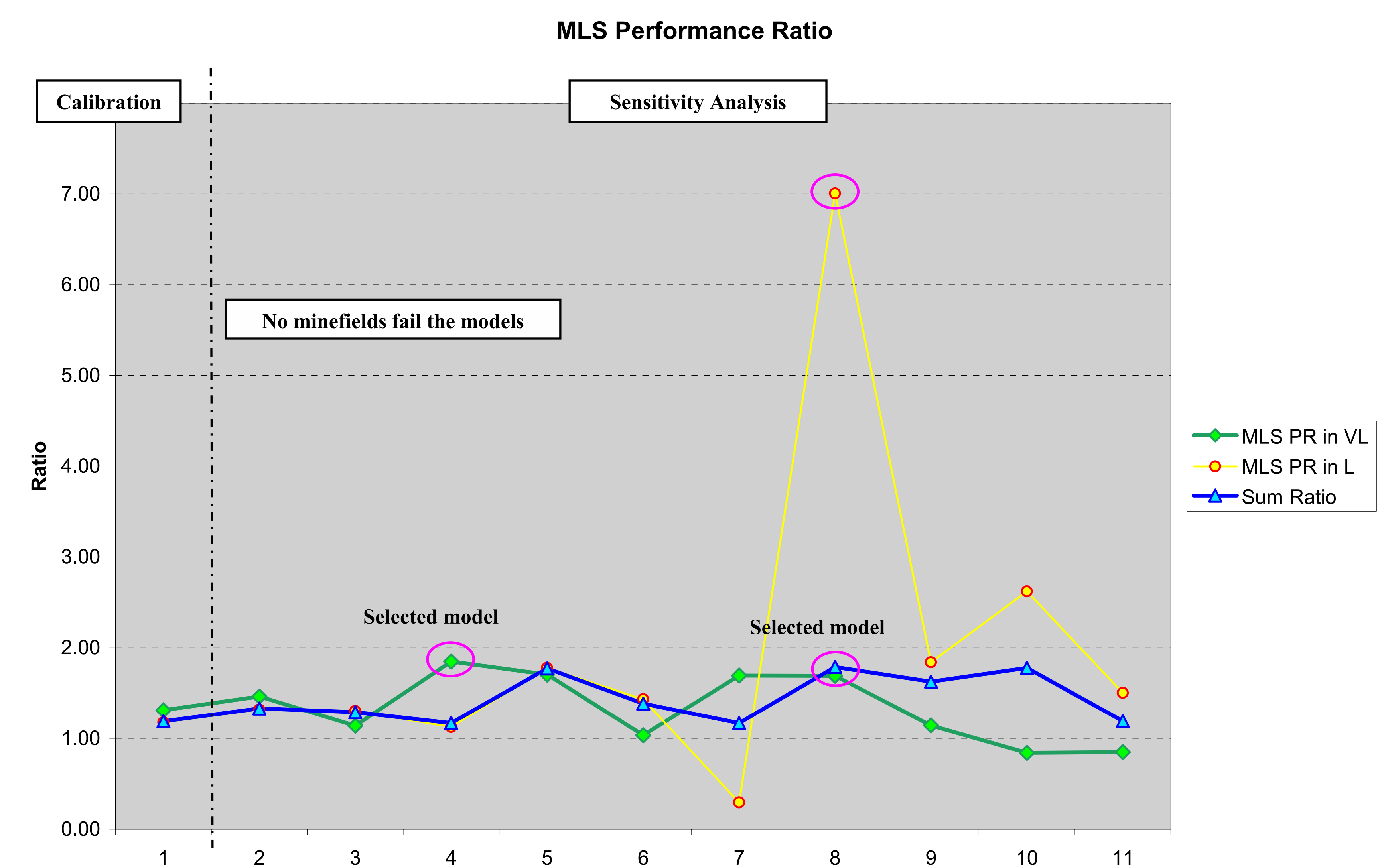
Layout 4

3 1.5 0 3 6 9 12 Kilometers





		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
VL	% LA	12.2%	16.0%	26.3%	15.1%	17.4%	13.7%	14.5%	20.9%	12.6%	14.9%	32.3%	10.6%	18.8%	18.2%	17.4%
	%mf w/pointmf	42.9%	45.0%	54.9%	43.8%	43.0%	42.0%	41.9%	54.6%	41.9%	43.5%	57.8%	14.6%	54.4%	42.6%	42.4%
	%mf w/o pointmf	49.6%	51.9%	63.8%	50.5%	49.6%	48.5%	48.5%	63.6%	48.3%	48.8%	65.5%	15.8%	63.4%	49.0%	47.5%
L	% LA	28.6%	49.7%	39.5%	50.3%	48.0%	43.1%	43.6%	45.3%	33.8%	37.1%	34.1%	52.9%	10.9%	48.0%	26.8%
	%mf w/pointmf	29.1%	42.8%	33.2%	44.6%	45.1%	46.0%	45.7%	29.7%	40.7%	46.8%	29.6%	63.8%	9.0%	41.9%	42.0%
	%mf w/o pointmf	31.9%	39.5%	27.5%	41.4%	41.5%	43.2%	42.8%	27.1%	39.1%	43.8%	25.1%	71.3%	5.6%	40.9%	38.7%
	Model Run Description	Initial Input Layers	Modified Transpo, Traffic, & Vis Layers	Remodified Visibility Layer	DTED2 Slope	New Trafficability Layer	DTED2 Slope & New Trafficability	No Hydrography Layer	No Transportation Layer	No Slope Layer	No Trafficability Layer	No Visibility Layer	Only Trafficability Layer	No Transpo & Slope Layers	Weighted Slope & Traffic Layers	Weighted Hydro & Transpo Layers



		1	2	3	4	5	6	7	8	9	10	11
VL	% LA	7.7%	5.8%	7.5%	5.2%	5.0%	8.6%	53.3%	53.4%	18.6%	26.2%	39.7%
	%mf	10.1%	8.5%	8.5%	9.7%	8.5%	8.9%	90.3%	90.3%	21.3%	22.1%	33.7%
L	% LA	76.1%	68.8%	69.6%	79.8%	50.8%	63.4%	31.8%	1.0%	42.2%	29.0%	43.9%
	%mf	89.5%	90.7%	90.7%	89.9%	90.3%	90.7%	9.3%	7.0%	77.5%	76.0%	65.9%
	Model Run Description	Initial Input Layers	DTED2 Slope	No Hydrography Layer	No Transportation Layer	No Slope Layer	No Trafficability Layer	No Visibility Layer	Weight Transportation Layer	Weight Transportation & Trafficability Layer	Weight Transportation Layer more than Traffic	Weight Transportation and Slope Layer

Model Run Statistics for Fort Irwin

Model Run #1
Fort Irwin
Minefields Data Set with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL	Reason for failure
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%	
1	A2CMD01	Conventional	38	0	0	0	38	100.00%	0.00%	0.00%	0.00%	Minefield cuts off trail. However, VITD trail is shifted 200m to the east (wrong location) and trafficability layer eliminates the area from consideration
2	A1SM01	Conventional	55	0	5	0	60	91.67%	0.00%	8.33%	0.00%	Minefield successfully cut off trail but the rest of the minefield was in untrafficable terrain "Obstacle Clearance Interference"; Vis layer add -5
3	ACASF04	Point - ADAM/RAAM	50	46	43	1	140	35.71%	32.86%	30.71%	0.71%	
4	ACASF05	Point - ADAM/RAAM	123	9	8	0	140	87.86%	6.43%	5.71%	0.00%	Minefield cuts off trail but the rest is untrafficable terrain; vis layer adds -5. ADAM/RAAM is artillery emplaced and has different employment considerations.
5	ACASF06	Point - ADAM/RAAM	67	0	17	56	140	47.86%	0.00%	12.14%	40.00%	
6	G1*SF03	Point - ADAM/RAAM	140	0	0	0	140	100.00%	0.00%	0.00%	0.00%	Minefield cuts off trail. However, VITD trail is shifted 200m to the north (wrong location) and trafficability layer eliminates the area from consideration; Vis layer adds -5
7	F2BSF01	Point - ADAM/RAAM	70	0	2	68	140	50.00%	0.00%	1.43%	48.57%	
8	F2ASF02	Point - ADAM/RAAM	65	28	48	0	141	46.10%	19.86%	34.04%	0.00%	
9	L*SF01	Point- ADAM/RAAM	120	20	0	0	140	85.71%	14.29%	0.00%	0.00%	Perfectly positioned minefield intended to cut off trail; Trail not in VITD therefore trafficability layer excluded feature; vis layer added -5
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%	
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%	
12	L1SM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%	Perfectly positioned minefield intended to cut off trail; Trail not in VITD therefore trafficability layer excluded feature; vis layer added -5
13	F1BSM01	Point - MOPMS	4	0	0	0	4	100.00%	0.00%	0.00%	0.00%	MOPMS minefield poorly positioned or wrong coordinate - ontop of mountain and not in nearby moutain pass.
14	F1BSM03	Point - MOPMS	2	0	2	0	4	50.00%	0.00%	50.00%	0.00%	
15	F2ASM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%	MOPMS minefield cuts off trail not in VITD; trafficability layer adds -99; vis adds -5
16	A1AHH01	Point - Hornet	36	3	40	0	79	45.57%	3.80%	50.63%	0.00%	
17	ACASF04	Point - ADAM/RAAM	11	27	41	0	79	13.92%	34.18%	51.90%	0.00%	
18	A1SV02	Volcano	47	0	32	55	134	35.07%	0.00%	23.88%	41.04%	
19	A1SV01	Volcano	90	0	2	81	173	52.02%	0.00%	1.16%	46.82%	Over 50% of minefield was in untrafficable terrain
20	A2ASV02	Volcano	12	0	101	133	246	4.88%	0.00%	41.06%	54.07%	
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%	
22	G1ESV01	Volcano	104	19	167	0	290	35.86%	6.55%	57.59%	0.00%	
23	G1ASV01	Volcano	38	24	135	0	197	19.29%	12.18%	68.53%	0.00%	
24	G1ASV02	Volcano	28	0	65	0	93	30.11%	0.00%	69.89%	0.00%	
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%	
26	G2CSV01	Volcano	16	0	77	66	159	10.06%	0.00%	48.43%	41.51%	
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%	
28	G2*SV03	Volcano	29	14	110	0	153	18.95%	9.15%	71.90%	0.00%	
29	G2ASV01	Volcano	33	0	2	137	172	19.19%	0.00%	1.16%	79.65%	
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%	
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%	
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%	
33	L2BSV01	Volcano	7	0	35	243	285	2.46%	0.00%	12.28%	85.26%	
34	L2CSV01	Volcano	0	0	116	122	238	0.00%	0.00%	48.74%	51.26%	
35	L2ASV01	Volcano	47	0	32	0	79	59.49%	0.00%	40.51%	0.00%	Volcano centered over VITD trail. Edges of minefield fall with untrafficable terrain since some of the existing trails are not contained in VITD; vis layer adds -5
36	??	Volcano	32	1	30	76	139	23.02%	0.72%	21.58%	54.68%	
37	A2BSV01	Volcano	26	1	45	116	188	13.83%	0.53%	23.94%	61.70%	
38	G1AMF01	Conventional	66	0	0	0	66	100.00%	0.00%	0.00%	0.00%	Minefield cuts off trail network; Trail not in VITD therefore trafficability layer adds -99; vis layer adds -5
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%	
40	G2CMT02	Conventional	0	0	8	116	124	0.00%	0.00%	6.45%	93.55%	
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%	
42	A2AMD01	Conventional	4	3	7	7	21	19.05%	14.29%	33.33%	33.33%	
43	G1BSV05	Volcano	0	28	194	0	222	0.00%	12.61%	87.39%	0.00%	
44	G1ASV05	Volcano	0	3	51	0	54	0.00%	5.56%	94.44%	0.00%	
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%	
46	G2ASV01	Volcano	13	2	178	106	299	4.35%	0.67%	59.53%	35.45%	
47	M2ASV01	Volcano	0	0	85	169	254	0.00%	0.00%	33.46%	66.54%	
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%	
			1379	386	1829	2701	6295					
		Overall Accuracy =	**21.91%**	**6.13%**	**29.05%**	**42.91%**						

Model Run #1
Fort Irwin

Minefields Data Set without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL	Reason for failure
1	A2CMD01	Conventional	38	0	0	0	38	100.00%	0.00%	0.00%	0.00%	Minefield cuts off trail. However, VITD trail is shifted 200m to the east (wrong location) and trafficability layer eliminates the area from consideration
2	A1SM01	Conventional	55	0	5	0	60	91.67%	0.00%	8.33%	0.00%	Minefield successfully cut off trail but the rest of the minefield was in untrafficable terrain "Obstacle Clearance Interference"; Vis layer add -5
18	A1SV02	Volcano	47	0	32	55	134	35.07%	0.00%	23.88%	41.04%	
19	A1SV01	Volcano	90	0	2	81	173	52.02%	0.00%	1.16%	46.82%	Over 50% of minefield was in untrafficable terrain
20	A2ASV02	Volcano	12	0	101	133	246	4.88%	0.00%	41.06%	54.07%	
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%	
22	G1ESV01	Volcano	104	19	167	0	290	35.86%	6.55%	57.59%	0.00%	
23	G1ASV01	Volcano	38	24	135	0	197	19.29%	12.18%	68.53%	0.00%	
24	G1ASV02	Volcano	28	0	65	0	93	30.11%	0.00%	69.89%	0.00%	
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%	
26	G2CSV01	Volcano	16	0	77	66	159	10.06%	0.00%	48.43%	41.51%	
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%	
28	G2*SV03	Volcano	29	14	110	0	153	18.95%	9.15%	71.90%	0.00%	
29	G2ASV01	Volcano	33	0	2	137	172	19.19%	0.00%	1.16%	79.65%	
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%	
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%	
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%	
33	L2BSV01	Volcano	7	0	35	243	285	2.46%	0.00%	12.28%	85.26%	
34	L2CSV01	Volcano	0	0	116	122	238	0.00%	0.00%	48.74%	51.26%	
35	L2ASV01	Volcano	47	0	32	0	79	59.49%	0.00%	40.51%	0.00%	Volcano centered over VITD trail. Edges of minefield fall with untrafficable terrain since some of the existing trails are not contained in VITD; vis layer adds -5
36	??	Volcano	32	1	30	76	139	23.02%	0.72%	21.58%	54.68%	
37	A2BSV01	Volcano	26	1	45	116	188	13.83%	0.53%	23.94%	61.70%	
38	G1AMF01	Conventional	66	0	0	0	66	100.00%	0.00%	0.00%	0.00%	Minefield cuts off trail network; Trail not in VITD therefore trafficability layer adds -99; vis layer adds -5
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%	
40	G2CMT02	Conventional	0	0	8	116	124	0.00%	0.00%	6.45%	93.55%	
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%	
42	A2AMD01	Conventional	4	3	7	7	21	19.05%	14.29%	33.33%	33.33%	
43	G1BSV05	Volcano	0	28	194	0	222	0.00%	12.61%	87.39%	0.00%	
44	G1ASV05	Volcano	0	3	51	0	54	0.00%	5.56%	94.44%	0.00%	
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%	
46	G2ASV01	Volcano	13	2	178	106	299	4.35%	0.67%	59.53%	35.45%	
47	M2ASV01	Volcano	0	0	85	169	254	0.00%	0.00%	33.46%	66.54%	
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%	
			685	253	1628	2530	5096					
		Overall Accuracy =	**13.44%**	**4.96%**	**31.95%**	**49.65%**						

Model Run #2
Fort Irwin

Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL	Reason for failure
0	G2*SM02	Point - MOPMS	0	0	0	41	41	0.00%	0.00%	0.00%	100.00%	
1	A2CMD01	Conventional	0	5	35	0	40	0.00%	12.50%	87.50%	0.00%	
2	A1SM01	Conventional	0	27	33	0	60	0.00%	45.00%	55.00%	0.00%	
3	ACASF04	Point - ADAM/RAAM	0	17	124	0	141	0.00%	12.06%	87.94%	0.00%	
4	ACASF05	Point - ADAM/RAAM	0	78	59	0	137	0.00%	56.93%	43.07%	0.00%	
5	ACASF06	Point - ADAM/RAAM	0	48	29	64	141	0.00%	34.04%	20.57%	45.39%	
6	G1*SF03	Point - ADAM/RAAM	0	31	110	0	141	0.00%	21.99%	78.01%	0.00%	
7	F2BSF01	Point - ADAM/RAAM	0	6	60	75	141	0.00%	4.26%	42.55%	53.19%	
8	F2ASF02	Point - ADAM/RAAM	44	20	73	0	137	32.12%	14.60%	53.28%	0.00%	
9	L*SF01	Point- ADAM/RAAM	0	66	75	0	141	0.00%	46.81%	53.19%	0.00%	
10	G2CSM01	Point - MOPMS	0	0	0	6	6	0.00%	0.00%	0.00%	100.00%	
11	G2BSM01	Point - MOPMS	0	0	0	5	5	0.00%	0.00%	0.00%	100.00%	
12	L1SM01	Point - MOPMS	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%	
13	F1BSM01	Point - MOPMS	4	0	0	0	4	100.00%	0.00%	0.00%	0.00%	Poorly positioned or bad grid
14	F1BSM03	Point - MOPMS	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%	
15	F2ASM01	Point - MOPMS	0	4	0	0	4	0.00%	100.00%	0.00%	0.00%	
16	A1AHH01	Point - Hornet	0	9	70	0	79	0.00%	11.39%	88.61%	0.00%	
17	ACASF04	Point - ADAM/RAAM	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%	
18	A1SV02	Volcano	0	29	50	53	132	0.00%	21.97%	37.88%	40.15%	
19	A1SV01	Volcano	0	66	26	80	172	0.00%	38.37%	15.12%	46.51%	
20	A2ASV02	Volcano	10	0	104	137	251	3.98%	0.00%	41.43%	54.58%	
21	G1DSV01	Volcano	0	0	6	127	133	0.00%	0.00%	4.51%	95.49%	
22	G1ESV01	Volcano	0	101	149	42	292	0.00%	34.59%	51.03%	14.38%	
23	G1ASV01	Volcano	0	39	157	0	196	0.00%	19.90%	80.10%	0.00%	
24	G1ASV02	Volcano	0	15	84	0	99	0.00%	15.15%	84.85%	0.00%	
25	G1BSV01	Volcano	0	0	0	149	149	0.00%	0.00%	0.00%	100.00%	
26	G2CSV01	Volcano	0	10	82	68	160	0.00%	6.25%	51.25%	42.50%	
27	G2ASV02	Volcano	0	0	0	153	153	0.00%	0.00%	0.00%	100.00%	
28	G2*SV03	Volcano	0	21	137	1	159	0.00%	13.21%	86.16%	0.63%	
29	G2ASV01	Volcano	0	0	32	140	172	0.00%	0.00%	18.60%	81.40%	
30	G2CSV06	Volcano	0	0	0	84	84	0.00%	0.00%	0.00%	100.00%	
31	L1SV02	Volcano	0	0	157	0	157	0.00%	0.00%	100.00%	0.00%	
32	L1SV03	Volcano	0	0	78	0	78	0.00%	0.00%	100.00%	0.00%	
33	L2BSV01	Volcano	11	0	19	255	285	3.86%	0.00%	6.67%	89.47%	
34	L2CSV01	Volcano	0	0	94	138	232	0.00%	0.00%	40.52%	59.48%	
35	L2ASV01	Volcano	0	0	57	21	78	0.00%	0.00%	73.08%	26.92%	
36	??	Volcano	0	3	61	75	139	0.00%	2.16%	43.88%	53.96%	
37	A2BSV01	Volcano	0	26	44	114	184	0.00%	14.13%	23.91%	61.96%	
38	G1AMF01	Conventional	0	66	0	0	66	0.00%	100.00%	0.00%	0.00%	
39	G2BMN01	Conventional	0	0	0	264	264	0.00%	0.00%	0.00%	100.00%	
40	G2CMT02	Conventional	0	0	10	115	125	0.00%	0.00%	8.00%	92.00%	
41	M3ASV01	Volcano	0	0	0	78	78	0.00%	0.00%	0.00%	100.00%	
42	A2AMD01	Conventional	0	0	20	7	27	0.00%	0.00%	74.07%	25.93%	
43	G1BSV05	Volcano	0	1	220	0	221	0.00%	0.45%	99.55%	0.00%	
44	G1ASV05	Volcano	0	0	48	6	54	0.00%	0.00%	88.89%	11.11%	
45	G2CSV05	Volcano	0	0	0	210	210	0.00%	0.00%	0.00%	100.00%	
46	G2ASV01	Volcano	0	7	186	113	306	0.00%	2.29%	60.78%	36.93%	
47	M2ASV01	Volcano	0	0	76	181	257	0.00%	0.00%	29.57%	70.43%	
48	A2BSV01	Volcano	0	0	50	38	88	0.00%	0.00%	56.82%	43.18%	
			69	695	2702	2840	6306					
			1.09%	**11.02%**	**42.85%**	**45.04%**						

Model Run #2
Fort Irwin

Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL	Reason not in VL
1	A2CMD01	Conventional	0	5	35	0	40	0.00%	12.50%	87.50%	0.00%	VITD road shifted to east by 200m -- needs to be rectified; not visible
2	A1SM01	Conventional	0	27	33	0	60	0.00%	45.00%	55.00%	0.00%	not visible; extends into untrafficable terrain
18	A1SV02	Volcano	0	29	50	53	132	0.00%	21.97%	37.88%	40.15%	
19	A1SV01	Volcano	0	66	26	80	172	0.00%	38.37%	15.12%	46.51%	
20	A2ASV02	Volcano	10	0	104	137	251	3.98%	0.00%	41.43%	54.58%	
21	G1DSV01	Volcano	0	0	6	127	133	0.00%	0.00%	4.51%	95.49%	
22	G1ESV01	Volcano	0	101	149	42	292	0.00%	34.59%	51.03%	14.38%	
23	G1ASV01	Volcano	0	39	157	0	196	0.00%	19.90%	80.10%	0.00%	not visible; extends into untrafficable terrain
24	G1ASV02	Volcano	0	15	84	0	99	0.00%	15.15%	84.85%	0.00%	cuts off trails not in VITD
25	G1BSV01	Volcano	0	0	0	149	149	0.00%	0.00%	0.00%	100.00%	
26	G2CSV01	Volcano	0	10	82	68	160	0.00%	6.25%	51.25%	42.50%	
27	G2ASV02	Volcano	0	0	0	153	153	0.00%	0.00%	0.00%	100.00%	
28	G2*SV03	Volcano	0	21	137	1	159	0.00%	13.21%	86.16%	0.63%	cuts off trails not in VITD
29	G2ASV01	Volcano	0	0	32	140	172	0.00%	0.00%	18.60%	81.40%	
30	G2CSV06	Volcano	0	0	0	84	84	0.00%	0.00%	0.00%	100.00%	
31	L1SV02	Volcano	0	0	157	0	157	0.00%	0.00%	100.00%	0.00%	cuts off trails not in VITD; not visible
32	L1SV03	Volcano	0	0	78	0	78	0.00%	0.00%	100.00%	0.00%	not visible
33	L2BSV01	Volcano	11	0	19	255	285	3.86%	0.00%	6.67%	89.47%	
34	L2CSV01	Volcano	0	0	94	138	232	0.00%	0.00%	40.52%	59.48%	
35	L2ASV01	Volcano	0	0	57	21	78	0.00%	0.00%	73.08%	26.92%	
36	??	Volcano	0	3	61	75	139	0.00%	2.16%	43.88%	53.96%	
37	A2BSV01	Volcano	0	26	44	114	184	0.00%	14.13%	23.91%	61.96%	
38	G1AMF01	Conventional	0	66	0	0	66	0.00%	100.00%	0.00%	0.00%	cuts off trails not in VITD; not visible
39	G2BMN01	Conventional	0	0	0	264	264	0.00%	0.00%	0.00%	100.00%	
40	G2CMT02	Conventional	0	0	10	115	125	0.00%	0.00%	8.00%	92.00%	
41	M3ASV01	Volcano	0	0	0	78	78	0.00%	0.00%	0.00%	100.00%	
42	A2AMD01	Conventional	0	0	20	7	27	0.00%	0.00%	74.07%	25.93%	
43	G1BSV05	Volcano	0	1	220	0	221	0.00%	0.45%	99.55%	0.00%	not visible
44	G1ASV05	Volcano	0	0	48	6	54	0.00%	0.00%	88.89%	11.11%	
45	G2CSV05	Volcano	0	0	0	210	210	0.00%	0.00%	0.00%	100.00%	
46	G2ASV01	Volcano	0	7	186	113	306	0.00%	2.29%	60.78%	36.93%	
47	M2ASV01	Volcano	0	0	76	181	257	0.00%	0.00%	29.57%	70.43%	
48	A2BSV01	Volcano	0	0	50	38	88	0.00%	0.00%	56.82%	43.18%	
			21	416	2015	2649	5101					
		Overall Accuracy =	**0.41%**	**8.16%**	**39.50%**	**51.93%**						

Model Run #3
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL	Reason for failure
0	G2*SM02	Point - MOPMS				38	38	0.00%	0.00%	0.00%	100.00%	
1	A2CMD01	Conventional		3	35		38	0.00%	7.89%	92.11%	0.00%	
2	A1SM01	Conventional		6	48	6	60	0.00%	10.00%	80.00%	10.00%	
3	ACASF04	Point - ADAM/RAAM			137	3	140	0.00%	0.00%	97.86%	2.14%	
4	ACASF05	Point - ADAM/RAAM			140		140	0.00%	0.00%	100.00%	0.00%	
5	ACASF06	Point - ADAM/RAAM		44	30	66	140	0.00%	31.43%	21.43%	47.14%	
6	G1*SF03	Point - ADAM/RAAM		27	113		140	0.00%	19.29%	80.71%	0.00%	
7	F2BSF01	Point - ADAM/RAAM		13	49	78	140	0.00%	9.29%	35.00%	55.71%	
8	F2ASF02	Point - ADAM/RAAM	48	11	73	9	141	34.04%	7.80%	51.77%	6.38%	
9	L*SF01	Point- ADAM/RAAM		113	27		140	0.00%	80.71%	19.29%	0.00%	
10	G2CSM01	Point - MOPMS				4	4	0.00%	0.00%	0.00%	100.00%	
11	G2BSM01	Point - MOPMS				4	4	0.00%	0.00%	0.00%	100.00%	
12	L1SM01	Point - MOPMS			3		3	0.00%	0.00%	100.00%	0.00%	
13	F1BSM01	Point - MOPMS	4				4	100.00%	0.00%	0.00%	0.00%	Poorly positioned or bad grid
14	F1BSM03	Point - MOPMS			2	2	4	0.00%	0.00%	50.00%	50.00%	
15	F2ASM01	Point - MOPMS		3			3	0.00%	100.00%	0.00%	0.00%	
16	A1AHH01	Point - Hornet		40	39		79	0.00%	50.63%	49.37%	0.00%	
17	ACASF04	Point - ADAM/RAAM			79		79	0.00%	0.00%	100.00%	0.00%	
18	A1SV02	Volcano		28	26	80	134	0.00%	20.90%	19.40%	59.70%	
19	A1SV01	Volcano		71	27	75	173	0.00%	41.04%	15.61%	43.35%	
20	A2ASV02	Volcano	9		103	134	246	3.66%	0.00%	41.87%	54.47%	
21	G1DSV01	Volcano				132	132	0.00%	0.00%	0.00%	100.00%	
22	G1ESV01	Volcano		98	30	162	290	0.00%	33.79%	10.34%	55.86%	
23	G1ASV01	Volcano		28	51	118	197	0.00%	14.21%	25.89%	59.90%	
24	G1ASV02	Volcano		25	68		93	0.00%	26.88%	73.12%	0.00%	
25	G1BSV01	Volcano				150	150	0.00%	0.00%	0.00%	100.00%	
26	G2CSV01	Volcano		12	77	70	159	0.00%	7.55%	48.43%	44.03%	
27	G2ASV02	Volcano				161	161	0.00%	0.00%	0.00%	100.00%	
28	G2*SV03	Volcano		31	118	4	153	0.00%	20.26%	77.12%	2.61%	
29	G2ASV01	Volcano		29	12	131	172	0.00%	16.86%	6.98%	76.16%	
30	G2CSV06	Volcano				85	85	0.00%	0.00%	0.00%	100.00%	
31	L1SV02	Volcano			158		158	0.00%	0.00%	100.00%	0.00%	
32	L1SV03	Volcano			66	13	79	0.00%	0.00%	83.54%	16.46%	
33	L2BSV01	Volcano	9		6	270	285	3.16%	0.00%	2.11%	94.74%	
34	L2CSV01	Volcano			40	198	238	0.00%	0.00%	16.81%	83.19%	
35	L2ASV01	Volcano			44	35	79	0.00%	0.00%	55.70%	44.30%	
36	??	Volcano		10	57	72	139	0.00%	7.19%	41.01%	51.80%	
37	A2BSV01	Volcano		14	59	115	188	0.00%	7.45%	31.38%	61.17%	
38	G1AMF01	Conventional		65	1		66	0.00%	98.48%	1.52%	0.00%	
39	G2BMN01	Conventional				268	268	0.00%	0.00%	0.00%	100.00%	
40	G2CMT02	Conventional			20	104	124	0.00%	0.00%	16.13%	83.87%	
41	M3ASV01	Volcano				81	81	0.00%	0.00%	0.00%	100.00%	
42	A2AMD01	Conventional			14	7	21	0.00%	0.00%	66.67%	33.33%	
43	G1BSV05	Volcano			75	147	222	0.00%	0.00%	33.78%	66.22%	
44	G1ASV05	Volcano			9	45	54	0.00%	0.00%	16.67%	83.33%	
45	G2CSV05	Volcano				208	208	0.00%	0.00%	0.00%	100.00%	
46	G2ASV01	Volcano		6	179	114	299	0.00%	2.01%	59.87%	38.13%	
47	M2ASV01	Volcano			70	184	254	0.00%	0.00%	27.56%	72.44%	
48	A2BSV01	Volcano			8	82	90	0.00%	0.00%	8.89%	91.11%	
			70	677	2093	3455	6295					
		Overall Accuracy =	**1.11%**	**10.75%**	**33.25%**	**54.88%**						

Model Run #3
Fort Irwin

Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
1	A2CMD01	Conventional		3	35		38	0.00%	7.89%	92.11%	0.00%
2	A1SM01	Conventional		6	48	6	60	0.00%	10.00%	80.00%	10.00%
18	A1SV02	Volcano		28	26	80	134	0.00%	20.90%	19.40%	59.70%
19	A1SV01	Volcano		71	27	75	173	0.00%	41.04%	15.61%	43.35%
20	A2ASV02	Volcano	9		103	134	246	3.66%	0.00%	41.87%	54.47%
21	G1DSV01	Volcano				132	132	0.00%	0.00%	0.00%	100.00%
22	G1ESV01	Volcano		98	30	162	290	0.00%	33.79%	10.34%	55.86%
23	G1ASV01	Volcano		28	51	118	197	0.00%	14.21%	25.89%	59.90%
24	G1ASV02	Volcano		25	68		93	0.00%	26.88%	73.12%	0.00%
25	G1BSV01	Volcano				150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano		12	77	70	159	0.00%	7.55%	48.43%	44.03%
27	G2ASV02	Volcano				161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano		31	118	4	153	0.00%	20.26%	77.12%	2.61%
29	G2ASV01	Volcano		29	12	131	172	0.00%	16.86%	6.98%	76.16%
30	G2CSV06	Volcano				85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano			158		158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano			66	13	79	0.00%	0.00%	83.54%	16.46%
33	L2BSV01	Volcano	9		6	270	285	3.16%	0.00%	2.11%	94.74%
34	L2CSV01	Volcano			40	198	238	0.00%	0.00%	16.81%	83.19%
35	L2ASV01	Volcano			44	35	79	0.00%	0.00%	55.70%	44.30%
36	??	Volcano		10	57	72	139	0.00%	7.19%	41.01%	51.80%
37	A2BSV01	Volcano		14	59	115	188	0.00%	7.45%	31.38%	61.17%
38	G1AMF01	Conventional		65	1		66	0.00%	98.48%	1.52%	0.00%
39	G2BMN01	Conventional				268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional			20	104	124	0.00%	0.00%	16.13%	83.87%
41	M3ASV01	Volcano				81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional			14	7	21	0.00%	0.00%	66.67%	33.33%
43	G1BSV05	Volcano			75	147	222	0.00%	0.00%	33.78%	66.22%
44	G1ASV05	Volcano			9	45	54	0.00%	0.00%	16.67%	83.33%
45	G2CSV05	Volcano				208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano		6	179	114	299	0.00%	2.01%	59.87%	38.13%
47	M2ASV01	Volcano			70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano			8	82	90	0.00%	0.00%	8.89%	91.11%
			18	426	1401	3251	5096				
		Overall Accuracy =	**0.35%**	**8.36%**	**27.49%**	**63.80%**					

3-merged_mf_nopoint

Model Run #4
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	0	3	35	0	38	0.00%	7.89%	92.11%	0.00%
2	A1SM01	Conventional	0	35	25	0	60	0.00%	58.33%	41.67%	0.00%
3	ACASF04	Point - ADAM/RAAM	1	27	109	3	140	0.71%	19.29%	77.86%	2.14%
4	ACASF05	Point - ADAM/RAAM	1	80	59	0	140	0.71%	57.14%	42.14%	0.00%
5	ACASF06	Point - ADAM/RAAM	3	14	64	59	140	2.14%	10.00%	45.71%	42.14%
6	G1*SF03	Point - ADAM/RAAM	0	58	82	0	140	0.00%	41.43%	58.57%	0.00%
7	F2BSF01	Point - ADAM/RAAM	0	11	53	76	140	0.00%	7.86%	37.86%	54.29%
8	F2ASF02	Point - ADAM/RAAM	29	20	92	0	141	20.57%	14.18%	65.25%	0.00%
9	L*SF01	Point- ADAM/RAAM	0	59	81	0	140	0.00%	42.14%	57.86%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	0	1	2	0	3	0.00%	33.33%	66.67%	0.00%
13	F1BSM01	Point - MOPMS	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
14	F1BSM03	Point - MOPMS	0	1	3	0	4	0.00%	25.00%	75.00%	0.00%
15	F2ASM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	0	11	68	0	79	0.00%	13.92%	86.08%	0.00%
17	ACASF04	Point - ADAM/RAAM	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
18	A1SV02	Volcano	0	28	52	54	134	0.00%	20.90%	38.81%	40.30%
19	A1SV01	Volcano	0	32	63	78	173	0.00%	18.50%	36.42%	45.09%
20	A2ASV02	Volcano	9	0	101	136	246	3.66%	0.00%	41.06%	55.28%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	0	98	192	0	290	0.00%	33.79%	66.21%	0.00%
23	G1ASV01	Volcano	4	35	158	0	197	2.03%	17.77%	80.20%	0.00%
24	G1ASV02	Volcano	11	5	77	0	93	11.83%	5.38%	82.80%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	7	5	77	70	159	4.40%	3.14%	48.43%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	21	125	7	153	0.00%	13.73%	81.70%	4.58%
29	G2ASV01	Volcano	1	9	29	133	172	0.58%	5.23%	16.86%	77.33%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	21	255	285	3.16%	0.00%	7.37%	89.47%
34	L2CSV01	Volcano	0	0	121	117	238	0.00%	0.00%	50.84%	49.16%
35	L2ASV01	Volcano	0	10	51	18	79	0.00%	12.66%	64.56%	22.78%
36	??	Volcano	0	3	64	72	139	0.00%	2.16%	46.04%	51.80%
37	A2BSV01	Volcano	0	14	59	115	188	0.00%	7.45%	31.38%	61.17%
38	G1AMF01	Conventional	0	65	1	0	66	0.00%	98.48%	1.52%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	14	110	124	0.00%	0.00%	11.29%	88.71%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	0	13	8	21	0.00%	0.00%	61.90%	38.10%
43	G1BSV05	Volcano	0	0	222	0	222	0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	0	54	0	54	0.00%	0.00%	100.00%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	3	3	179	114	299	1.00%	1.00%	59.87%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%
			78	651	2808	2758	6295				
		Overall Accuracy =	**1.24%**	**10.34%**	**44.61%**	**43.81%**					

Model Run #4
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
1	A2CMD01	Conventional	0	3	35	0	38	0.00%	7.89%	92.11%	0.00%
2	A1SM01	Conventional	0	35	25	0	60	0.00%	58.33%	41.67%	0.00%
18	A1SV02	Volcano	0	28	52	54	134	0.00%	20.90%	38.81%	40.30%
19	A1SV01	Volcano	0	32	63	78	173	0.00%	18.50%	36.42%	45.09%
20	A2ASV02	Volcano	9	0	101	136	246	3.66%	0.00%	41.06%	55.28%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	0	98	192	0	290	0.00%	33.79%	66.21%	0.00%
23	G1ASV01	Volcano	4	35	158	0	197	2.03%	17.77%	80.20%	0.00%
24	G1ASV02	Volcano	11	5	77	0	93	11.83%	5.38%	82.80%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	7	5	77	70	159	4.40%	3.14%	48.43%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	21	125	7	153	0.00%	13.73%	81.70%	4.58%
29	G2ASV01	Volcano	1	9	29	133	172	0.58%	5.23%	16.86%	77.33%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	21	255	285	3.16%	0.00%	7.37%	89.47%
34	L2CSV01	Volcano	0	0	121	117	238	0.00%	0.00%	50.84%	49.16%
35	L2ASV01	Volcano	0	10	51	18	79	0.00%	12.66%	64.56%	22.78%
36	??	Volcano	0	3	64	72	139	0.00%	2.16%	46.04%	51.80%
37	A2BSV01	Volcano	0	14	59	115	188	0.00%	7.45%	31.38%	61.17%
38	G1AMF01	Conventional	0	65	1	0	66	0.00%	98.48%	1.52%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	14	110	124	0.00%	0.00%	11.29%	88.71%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	0	13	8	21	0.00%	0.00%	61.90%	38.10%
43	G1BSV05	Volcano	0	0	222	0	222	0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	0	54	0	54	0.00%	0.00%	100.00%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	3	3	179	114	299	1.00%	1.00%	59.87%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%
			44	366	2112	2574	5096				
		Overall Accuracy =	**0.86%**	**7.18%**	**41.44%**	**50.51%**					

Model Run #5
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL	Reason for failure
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%	
1	A2CMD01	Conventional	0	3	35	0	38	0.00%	7.89%	92.11%	0.00%	
2	A1SM01	Conventional	0	6	54	0	60	0.00%	10.00%	90.00%	0.00%	
3	ACASF04	Point - ADAM/RAAM	0	0	139	1	140	0.00%	0.00%	99.29%	0.71%	
4	ACASF05	Point - ADAM/RAAM	0	0	140	0	140	0.00%	0.00%	100.00%	0.00%	
5	ACASF06	Point - ADAM/RAAM	0	40	41	59	140	0.00%	28.57%	29.29%	42.14%	
6	G1*SF03	Point - ADAM/RAAM	0	27	113	0	140	0.00%	19.29%	80.71%	0.00%	
7	F2BSF01	Point - ADAM/RAAM	0	13	62	65	140	0.00%	9.29%	44.29%	46.43%	
8	F2ASF02	Point - ADAM/RAAM	48	3	80	10	141	34.04%	2.13%	56.74%	7.09%	
9	L*SF01	Point- ADAM/RAAM	0	117	23	0	140	0.00%	83.57%	16.43%	0.00%	
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%	
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%	
12	L1SM01	Point - MOPMS	0	0	3	0	3	0.00%	0.00%	100.00%	0.00%	
13	F1BSM01	Point - MOPMS	4	0	0	0	4	100.00%	0.00%	0.00%	0.00%	Poorly positioned or bad grid
14	F1BSM03	Point - MOPMS	0	0	3	1	4	0.00%	0.00%	75.00%	25.00%	
15	F2ASM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%	
16	A1AHH01	Point - Hornet	0	37	42	0	79	0.00%	46.84%	53.16%	0.00%	
17	ACASF04	Point - ADAM/RAAM	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%	
18	A1SV02	Volcano	0	28	48	58	134	0.00%	20.90%	35.82%	43.28%	
19	A1SV01	Volcano	0	71	27	75	173	0.00%	41.04%	15.61%	43.35%	
20	A2ASV02	Volcano	9	0	103	134	246	3.66%	0.00%	41.87%	54.47%	
21	G1DSV01	Volcano	0	0	3	129	132	0.00%	0.00%	2.27%	97.73%	
22	G1ESV01	Volcano	0	100	140	50	290	0.00%	34.48%	48.28%	17.24%	
23	G1ASV01	Volcano	0	28	169	0	197	0.00%	14.21%	85.79%	0.00%	
24	G1ASV02	Volcano	0	28	65	0	93	0.00%	30.11%	69.89%	0.00%	
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%	
26	G2CSV01	Volcano	0	16	73	70	159	0.00%	10.06%	45.91%	44.03%	
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%	
28	G2*SV03	Volcano	0	34	115	4	153	0.00%	22.22%	75.16%	2.61%	
29	G2ASV01	Volcano	0	28	11	133	172	0.00%	16.28%	6.40%	77.33%	
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%	
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%	
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%	
33	L2BSV01	Volcano	9	0	20	256	285	3.16%	0.00%	7.02%	89.82%	
34	L2CSV01	Volcano	0	0	120	118	238	0.00%	0.00%	50.42%	49.58%	
35	L2ASV01	Volcano	0	0	59	20	79	0.00%	0.00%	74.68%	25.32%	
36	??	Volcano	0	10	57	72	139	0.00%	7.19%	41.01%	51.80%	
37	A2BSV01	Volcano	0	14	59	115	188	0.00%	7.45%	31.38%	61.17%	
38	G1AMF01	Conventional	0	53	13	0	66	0.00%	80.30%	19.70%	0.00%	
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%	
40	G2CMT02	Conventional	0	0	114	10	124	0.00%	0.00%	91.94%	8.06%	
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%	
42	A2AMD01	Conventional	0	2	19	0	21	0.00%	9.52%	90.48%	0.00%	
43	G1BSV05	Volcano	0	0	222	0	222	0.00%	0.00%	100.00%	0.00%	
44	G1ASV05	Volcano	0	0	48	6	54	0.00%	0.00%	88.89%	11.11%	
45	G2CSV05	Volcano	0	0	3	205	208	0.00%	0.00%	1.44%	98.56%	
46	G2ASV01	Volcano	0	16	169	114	299	0.00%	5.35%	56.52%	38.13%	
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%	
48	A2BSV01	Volcano	0	0	61	29	90	0.00%	0.00%	67.78%	32.22%	
			70	677	2839	2709	6295					
		Overall Accuracy =	**1.11%**	**10.75%**	**45.10%**	**43.03%**						

Model Run #5
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
1	A2CMD01	Conventional	0	3	35	0	38
2	A1SM01	Conventional	0	6	54	0	60
18	A1SV02	Volcano	0	28	48	58	134
19	A1SV01	Volcano	0	71	27	75	173
20	A2ASV02	Volcano	9	0	103	134	246
21	G1DSV01	Volcano	0	0	3	129	132
22	G1ESV01	Volcano	0	100	140	50	290
23	G1ASV01	Volcano	0	28	169	0	197
24	G1ASV02	Volcano	0	28	65	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	0	16	73	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	34	115	4	153
29	G2ASV01	Volcano	0	28	11	133	172
30	G2CSV06	Volcano	0	0	0	85	85
31	L1SV02	Volcano	0	0	158	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	0	20	256	285
34	L2CSV01	Volcano	0	0	120	118	238
35	L2ASV01	Volcano	0	0	59	20	79
36	??	Volcano	0	10	57	72	139
37	A2BSV01	Volcano	0	14	59	115	188
38	G1AMF01	Conventional	0	53	13	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	114	10	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	2	19	0	21
43	G1BSV05	Volcano	0	0	222	0	222
44	G1ASV05	Volcano	0	0	48	6	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	0	16	169	114	299
47	M2ASV01	Volcano	0	0	70	184	254
48	A2BSV01	Volcano	0	0	61	29	90
			18	437	2114	2527	5096
		Overall Accuracy =	**0.35%**	**8.58%**	**41.48%**	**49.59%**	

% NL	% P	% L	% VL
0.00%	7.89%	92.11%	0.00%
0.00%	10.00%	90.00%	0.00%
0.00%	20.90%	35.82%	43.28%
0.00%	41.04%	15.61%	43.35%
3.66%	0.00%	41.87%	54.47%
0.00%	0.00%	2.27%	97.73%
0.00%	34.48%	48.28%	17.24%
0.00%	14.21%	85.79%	0.00%
0.00%	30.11%	69.89%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	10.06%	45.91%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	22.22%	75.16%	2.61%
0.00%	16.28%	6.40%	77.33%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.00%	7.02%	89.82%
0.00%	0.00%	50.42%	49.58%
0.00%	0.00%	74.68%	25.32%
0.00%	7.19%	41.01%	51.80%
0.00%	7.45%	31.38%	61.17%
0.00%	80.30%	19.70%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	91.94%	8.06%
0.00%	0.00%	0.00%	100.00%
0.00%	9.52%	90.48%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	88.89%	11.11%
0.00%	0.00%	1.44%	98.56%
0.00%	5.35%	56.52%	38.13%
0.00%	0.00%	27.56%	72.44%
0.00%	0.00%	67.78%	32.22%

Model Run #6
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	G2*SM02	Point - MOPMS	0	0	0	38	38
1	A2CMD01	Conventional	0	3	35	0	38
2	A1SM01	Conventional	0	33	27	0	60
3	ACASF04	Point - ADAM/RAAM	1	32	106	1	140
4	ACASF05	Point - ADAM/RAAM	1	81	58	0	140
5	ACASF06	Point - ADAM/RAAM	3	14	65	58	140
6	G1*SF03	Point - ADAM/RAAM	0	58	82	0	140
7	F2BSF01	Point - ADAM/RAAM	0	11	64	65	140
8	F2ASF02	Point - ADAM/RAAM	29	7	104	1	141
9	L*SF01	Point- ADAM/RAAM	0	76	64	0	140
10	G2CSM01	Point - MOPMS	0	0	0	4	4
11	G2BSM01	Point - MOPMS	0	0	0	4	4
12	L1SM01	Point - MOPMS	0	1	2	0	3
13	F1BSM01	Point - MOPMS	0	0	4	0	4
14	F1BSM03	Point - MOPMS	0	1	3	0	4
15	F2ASM01	Point - MOPMS	0	3	0	0	3
16	A1AHH01	Point - Hornet	0	12	67	0	79
17	ACASF04	Point - ADAM/RAAM	0	6	73	0	79
18	A1SV02	Volcano	0	28	48	58	134
19	A1SV01	Volcano	0	32	60	81	173
20	A2ASV02	Volcano	9	0	103	134	246
21	G1DSV01	Volcano	0	0	6	126	132
22	G1ESV01	Volcano	0	100	190	0	290
23	G1ASV01	Volcano	4	32	161	0	197
24	G1ASV02	Volcano	11	5	77	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	7	6	76	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	18	122	13	153
29	G2ASV01	Volcano	1	9	26	136	172
30	G2CSV06	Volcano	0	0	0	85	85
31	L1SV02	Volcano	0	22	136	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	0	21	255	285
34	L2CSV01	Volcano	0	0	121	117	238
35	L2ASV01	Volcano	0	10	61	8	79
36	??	Volcano	0	3	64	72	139
37	A2BSV01	Volcano	0	14	59	115	188
38	G1AMF01	Conventional	0	53	13	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	114	10	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	4	13	4	21
43	G1BSV05	Volcano	0	0	222	0	222
44	G1ASV05	Volcano	0	0	54	0	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	3	8	174	114	299
47	M2ASV01	Volcano	0	0	70	184	254
48	A2BSV01	Volcano	0	0	66	24	90
			78	682	2893	2642	6295
		Overall Accuracy =	**1.24%**	**10.83%**	**45.96%**	**41.97%**	

% NL	% P	% L	% VL
0.00%	0.00%	0.00%	100.00%
0.00%	7.89%	92.11%	0.00%
0.00%	55.00%	45.00%	0.00%
0.71%	22.86%	75.71%	0.71%
0.71%	57.86%	41.43%	0.00%
2.14%	10.00%	46.43%	41.43%
0.00%	41.43%	58.57%	0.00%
0.00%	7.86%	45.71%	46.43%
20.57%	4.96%	73.76%	0.71%
0.00%	54.29%	45.71%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	33.33%	66.67%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	25.00%	75.00%	0.00%
0.00%	100.00%	0.00%	0.00%
0.00%	15.19%	84.81%	0.00%
0.00%	7.59%	92.41%	0.00%
0.00%	20.90%	35.82%	43.28%
0.00%	18.50%	34.68%	46.82%
3.66%	0.00%	41.87%	54.47%
0.00%	0.00%	4.55%	95.45%
0.00%	34.48%	65.52%	0.00%
2.03%	16.24%	81.73%	0.00%
11.83%	5.38%	82.80%	0.00%
0.00%	0.00%	0.00%	100.00%
4.40%	3.77%	47.80%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	11.76%	79.74%	8.50%
0.58%	5.23%	15.12%	79.07%
0.00%	0.00%	0.00%	100.00%
0.00%	13.92%	86.08%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.00%	7.37%	89.47%
0.00%	0.00%	50.84%	49.16%
0.00%	12.66%	77.22%	10.13%
0.00%	2.16%	46.04%	51.80%
0.00%	7.45%	31.38%	61.17%
0.00%	80.30%	19.70%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	91.94%	8.06%
0.00%	0.00%	0.00%	100.00%
0.00%	19.05%	61.90%	19.05%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	1.44%	98.56%
1.00%	2.68%	58.19%	38.13%
0.00%	0.00%	27.56%	72.44%
0.00%	0.00%	73.33%	26.67%

Model Run #6
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
1	A2CMD01	Conventional	0	3	35	0	38
2	A1SM01	Conventional	0	33	27	0	60
18	A1SV02	Volcano	0	28	48	58	134
19	A1SV01	Volcano	0	32	60	81	173
20	A2ASV02	Volcano	9	0	103	134	246
21	G1DSV01	Volcano	0	0	6	126	132
22	G1ESV01	Volcano	0	100	190	0	290
23	G1ASV01	Volcano	4	32	161	0	197
24	G1ASV02	Volcano	11	5	77	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	7	6	76	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	18	122	13	153
29	G2ASV01	Volcano	1	9	26	136	172
30	G2CSV06	Volcano	0	0	0	85	85
31	L1SV02	Volcano	0	22	136	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	0	21	255	285
34	L2CSV01	Volcano	0	0	121	117	238
35	L2ASV01	Volcano	0	10	61	8	79
36	??	Volcano	0	3	64	72	139
37	A2BSV01	Volcano	0	14	59	115	188
38	G1AMF01	Conventional	0	53	13	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	114	10	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	4	13	4	21
43	G1BSV05	Volcano	0	0	222	0	222
44	G1ASV05	Volcano	0	0	54	0	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	3	8	174	114	299
47	M2ASV01	Volcano	0	0	70	184	254
48	A2BSV01	Volcano	0	0	66	24	90
			44	380	2201	2471	5096
		Overall Accuracy =	**0.86%**	**7.46%**	**43.19%**	**48.49%**	

% NL	% P	% L	% VL
0.00%	7.89%	92.11%	0.00%
0.00%	55.00%	45.00%	0.00%
0.00%	20.90%	35.82%	43.28%
0.00%	18.50%	34.68%	46.82%
3.66%	0.00%	41.87%	54.47%
0.00%	0.00%	4.55%	95.45%
0.00%	34.48%	65.52%	0.00%
2.03%	16.24%	81.73%	0.00%
11.83%	5.38%	82.80%	0.00%
0.00%	0.00%	0.00%	100.00%
4.40%	3.77%	47.80%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	11.76%	79.74%	8.50%
0.58%	5.23%	15.12%	79.07%
0.00%	0.00%	0.00%	100.00%
0.00%	13.92%	86.08%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.00%	7.37%	89.47%
0.00%	0.00%	50.84%	49.16%
0.00%	12.66%	77.22%	10.13%
0.00%	2.16%	46.04%	51.80%
0.00%	7.45%	31.38%	61.17%
0.00%	80.30%	19.70%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	91.94%	8.06%
0.00%	0.00%	0.00%	100.00%
0.00%	19.05%	61.90%	19.05%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	1.44%	98.56%
1.00%	2.68%	58.19%	38.13%
0.00%	0.00%	27.56%	72.44%
0.00%	0.00%	73.33%	26.67%

Model Run #7
Fort Irwin

Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	G2*SM02	Point - MOPMS	0	0	0	38	38
1	A2CMD01	Conventional	0	6	31	1	38
2	A1SM01	Conventional	0	34	26	0	60
3	ACASF04	Point - ADAM/RAAM	1	30	108	1	140
4	ACASF05	Point - ADAM/RAAM	1	85	54	0	140
5	ACASF06	Point - ADAM/RAAM	4	13	66	57	140
6	G1*SF03	Point - ADAM/RAAM	0	59	81	0	140
7	F2BSF01	Point - ADAM/RAAM	0	11	65	64	140
8	F2ASF02	Point - ADAM/RAAM	28	3	109	1	141
9	L*SF01	Point- ADAM/RAAM	0	75	65	0	140
10	G2CSM01	Point - MOPMS	0	0	0	4	4
11	G2BSM01	Point - MOPMS	0	0	0	4	4
12	L1SM01	Point - MOPMS	0	0	3	0	3
13	F1BSM01	Point - MOPMS	0	0	4	0	4
14	F1BSM03	Point - MOPMS	0	1	3	0	4
15	F2ASM01	Point - MOPMS	0	3	0	0	3
16	A1AHH01	Point - Hornet	0	12	67	0	79
17	ACASF04	Point - ADAM/RAAM	0	11	68	0	79
18	A1SV02	Volcano	0	31	45	58	134
19	A1SV01	Volcano	0	33	59	81	173
20	A2ASV02	Volcano	0	0	102	144	246
21	G1DSV01	Volcano	0	0	6	126	132
22	G1ESV01	Volcano	0	100	190	0	290
23	G1ASV01	Volcano	3	34	160	0	197
24	G1ASV02	Volcano	12	8	73	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	11	6	76	66	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	22	122	9	153
29	G2ASV01	Volcano	2	9	26	135	172
30	G2CSV06	Volcano	0	0	0	85	85
31	L1SV02	Volcano	0	29	129	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	0	0	21	264	285
34	L2CSV01	Volcano	0	0	116	122	238
35	L2ASV01	Volcano	0	11	60	8	79
36	??	Volcano	0	3	60	76	139
37	A2BSV01	Volcano	0	14	58	116	188
38	G1AMF01	Conventional	0	53	13	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	113	11	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	5	13	3	21
43	G1BSV05	Volcano	0	1	221	0	222
44	G1ASV05	Volcano	0	0	54	0	54
45	G2CSV05	Volcano	0	0	2	206	208
46	G2ASV01	Volcano	5	12	176	106	299
47	M2ASV01	Volcano	0	0	85	169	254
48	A2BSV01	Volcano	0	0	66	24	90
			67	714	2875	2639	6295
		Overall Accuracy =	**1.06%**	**11.34%**	**45.67%**	**41.92%**	

% NL	% P	% L	% VL
0.00%	0.00%	0.00%	100.00%
0.00%	15.79%	81.58%	2.63%
0.00%	56.67%	43.33%	0.00%
0.71%	21.43%	77.14%	0.71%
0.71%	60.71%	38.57%	0.00%
2.86%	9.29%	47.14%	40.71%
0.00%	42.14%	57.86%	0.00%
0.00%	7.86%	46.43%	45.71%
19.86%	2.13%	77.30%	0.71%
0.00%	53.57%	46.43%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	25.00%	75.00%	0.00%
0.00%	100.00%	0.00%	0.00%
0.00%	15.19%	84.81%	0.00%
0.00%	13.92%	86.08%	0.00%
0.00%	23.13%	33.58%	43.28%
0.00%	19.08%	34.10%	46.82%
0.00%	0.00%	41.46%	58.54%
0.00%	0.00%	4.55%	95.45%
0.00%	34.48%	65.52%	0.00%
1.52%	17.26%	81.22%	0.00%
12.90%	8.60%	78.49%	0.00%
0.00%	0.00%	0.00%	100.00%
6.92%	3.77%	47.80%	41.51%
0.00%	0.00%	0.00%	100.00%
0.00%	14.38%	79.74%	5.88%
1.16%	5.23%	15.12%	78.49%
0.00%	0.00%	0.00%	100.00%
0.00%	18.35%	81.65%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	7.37%	92.63%
0.00%	0.00%	48.74%	51.26%
0.00%	13.92%	75.95%	10.13%
0.00%	2.16%	43.17%	54.68%
0.00%	7.45%	30.85%	61.70%
0.00%	80.30%	19.70%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	91.13%	8.87%
0.00%	0.00%	0.00%	100.00%
0.00%	23.81%	61.90%	14.29%
0.00%	0.45%	99.55%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.96%	99.04%
1.67%	4.01%	58.86%	35.45%
0.00%	0.00%	33.46%	66.54%
0.00%	0.00%	73.33%	26.67%

Model Run #7
Fort Irwin

Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
1	A2CMD01	Conventional	0	6	31	1	38	0.00%	15.79%	81.58%	2.63%
2	A1SM01	Conventional	0	34	26	0	60	0.00%	56.67%	43.33%	0.00%
18	A1SV02	Volcano	0	31	45	58	134	0.00%	23.13%	33.58%	43.28%
19	A1SV01	Volcano	0	33	59	81	173	0.00%	19.08%	34.10%	46.82%
20	A2ASV02	Volcano	0	0	102	144	246	0.00%	0.00%	41.46%	58.54%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	0	100	190	0	290	0.00%	34.48%	65.52%	0.00%
23	G1ASV01	Volcano	3	34	160	0	197	1.52%	17.26%	81.22%	0.00%
24	G1ASV02	Volcano	12	8	73	0	93	12.90%	8.60%	78.49%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	11	6	76	66	159	6.92%	3.77%	47.80%	41.51%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	22	122	9	153	0.00%	14.38%	79.74%	5.88%
29	G2ASV01	Volcano	2	9	26	135	172	1.16%	5.23%	15.12%	78.49%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	29	129	0	158	0.00%	18.35%	81.65%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	0	0	21	264	285	0.00%	0.00%	7.37%	92.63%
34	L2CSV01	Volcano	0	0	116	122	238	0.00%	0.00%	48.74%	51.26%
35	L2ASV01	Volcano	0	11	60	8	79	0.00%	13.92%	75.95%	10.13%
36	??	Volcano	0	3	60	76	139	0.00%	2.16%	43.17%	54.68%
37	A2BSV01	Volcano	0	14	58	116	188	0.00%	7.45%	30.85%	61.70%
38	G1AMF01	Conventional	0	53	13	0	66	0.00%	80.30%	19.70%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	113	11	124	0.00%	0.00%	91.13%	8.87%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	5	13	3	21	0.00%	23.81%	61.90%	14.29%
43	G1BSV05	Volcano	0	1	221	0	222	0.00%	0.45%	99.55%	0.00%
44	G1ASV05	Volcano	0	0	54	0	54	0.00%	0.00%	100.00%	0.00%
45	G2CSV05	Volcano	0	0	2	206	208	0.00%	0.00%	0.96%	99.04%
46	G2ASV01	Volcano	5	12	176	106	299	1.67%	4.01%	58.86%	35.45%
47	M2ASV01	Volcano	0	0	85	169	254	0.00%	0.00%	33.46%	66.54%
48	A2BSV01	Volcano	0	0	66	24	90	0.00%	0.00%	73.33%	26.67%
			33	411	2182	2470	5096				
		Overall Accuracy =	**0.65%**	**8.07%**	**42.82%**	**48.47%**					

7-merged_mf_nopoint

Model Run #8
Fort Irwin

Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	0	27	10	1	38	0.00%	71.05%	26.32%	2.63%
2	A1SM01	Conventional	0	54	6	0	60	0.00%	90.00%	10.00%	0.00%
3	ACASF04	Point - ADAM/RAAM	1	56	82	1	140	0.71%	40.00%	58.57%	0.71%
4	ACASF05	Point - ADAM/RAAM	1	124	13	2	140	0.71%	88.57%	9.29%	1.43%
5	ACASF06	Point - ADAM/RAAM	4	48	36	52	140	2.86%	34.29%	25.71%	37.14%
6	G1*SF03	Point - ADAM/RAAM	0	130	10	0	140	0.00%	92.86%	7.14%	0.00%
7	F2BSF01	Point - ADAM/RAAM	0	14	69	57	140	0.00%	10.00%	49.29%	40.71%
8	F2ASF02	Point - ADAM/RAAM	28	29	84	0	141	19.86%	20.57%	59.57%	0.00%
9	L*SF01	Point- ADAM/RAAM	0	51	89	0	140	0.00%	36.43%	63.57%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
13	F1BSM01	Point - MOPMS	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
14	F1BSM03	Point - MOPMS	0	0	3	1	4	0.00%	0.00%	75.00%	25.00%
15	F2ASM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	0	10	37	32	79	0.00%	12.66%	46.84%	40.51%
17	ACASF04	Point - ADAM/RAAM	0	18	61	0	79	0.00%	22.78%	77.22%	0.00%
18	A1SV02	Volcano	0	38	41	55	134	0.00%	28.36%	30.60%	41.04%
19	A1SV01	Volcano	0	2	87	84	173	0.00%	1.16%	50.29%	48.55%
20	A2ASV02	Volcano	9	0	4	233	246	3.66%	0.00%	1.63%	94.72%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	0	108	182	0	290	0.00%	37.24%	62.76%	0.00%
23	G1ASV01	Volcano	3	35	159	0	197	1.52%	17.77%	80.71%	0.00%
24	G1ASV02	Volcano	12	5	14	62	93	12.90%	5.38%	15.05%	66.67%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	11	0	8	140	159	6.92%	0.00%	5.03%	88.05%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	15	33	105	153	0.00%	9.80%	21.57%	68.63%
29	G2ASV01	Volcano	2	0	32	138	172	1.16%	0.00%	18.60%	80.23%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	23	253	285	3.16%	0.00%	8.07%	88.77%
34	L2CSV01	Volcano	0	0	92	146	238	0.00%	0.00%	38.66%	61.34%
35	L2ASV01	Volcano	0	41	34	4	79	0.00%	51.90%	43.04%	5.06%
36	??	Volcano	0	3	26	110	139	0.00%	2.16%	18.71%	79.14%
37	A2BSV01	Volcano	0	22	12	154	188	0.00%	11.70%	6.38%	81.91%
38	G1AMF01	Conventional	0	59	7	0	66	0.00%	89.39%	10.61%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	0	124	124	0.00%	0.00%	0.00%	100.00%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	5	12	4	21	0.00%	23.81%	57.14%	19.05%
43	G1BSV05	Volcano	0	4	218	0	222	0.00%	1.80%	98.20%	0.00%
44	G1ASV05	Volcano	0	0	54	0	54	0.00%	0.00%	100.00%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	5	1	22	271	299	1.67%	0.33%	7.36%	90.64%
47	M2ASV01	Volcano	0	0	0	254	254	0.00%	0.00%	0.00%	100.00%
48	A2BSV01	Volcano	0	0	64	26	90	0.00%	0.00%	71.11%	28.89%
			85	905	1871	3434	6295				
		Overall Accuracy =	**1.35%**	**14.38%**	**29.72%**	**54.55%**					

8-merged_mf_wpoint

Model Run #8
Fort Irwin

Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
1	A2CMD01	Conventional	0	27	10	1	38
2	A1SM01	Conventional	0	54	6	0	60
18	A1SV02	Volcano	0	38	41	55	134
19	A1SV01	Volcano	0	2	87	84	173
20	A2ASV02	Volcano	9	0	4	233	246
21	G1DSV01	Volcano	0	0	6	126	132
22	G1ESV01	Volcano	0	108	182	0	290
23	G1ASV01	Volcano	3	35	159	0	197
24	G1ASV02	Volcano	12	5	14	62	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	11	0	8	140	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	15	33	105	153
29	G2ASV01	Volcano	2	0	32	138	172
30	G2CSV06	Volcano	0	0	0	85	85
31	L1SV02	Volcano	0	0	158	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	0	23	253	285
34	L2CSV01	Volcano	0	0	92	146	238
35	L2ASV01	Volcano	0	41	34	4	79
36	??	Volcano	0	3	26	110	139
37	A2BSV01	Volcano	0	22	12	154	188
38	G1AMF01	Conventional	0	59	7	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	0	124	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	5	12	4	21
43	G1BSV05	Volcano	0	4	218	0	222
44	G1ASV05	Volcano	0	0	54	0	54
45	G2CSV05	Volcano	0	0	0	208	208
46	G2ASV01	Volcano	5	1	22	271	299
47	M2ASV01	Volcano	0	0	0	254	254
48	A2BSV01	Volcano	0	0	64	26	90
			51	419	1383	3243	5096
		Overall Accuracy =	**1.00%**	**8.22%**	**27.14%**	**63.64%**	

% NL	% P	% L	% VL
0.00%	71.05%	26.32%	2.63%
0.00%	90.00%	10.00%	0.00%
0.00%	28.36%	30.60%	41.04%
0.00%	1.16%	50.29%	48.55%
3.66%	0.00%	1.63%	94.72%
0.00%	0.00%	4.55%	95.45%
0.00%	37.24%	62.76%	0.00%
1.52%	17.77%	80.71%	0.00%
12.90%	5.38%	15.05%	66.67%
0.00%	0.00%	0.00%	100.00%
6.92%	0.00%	5.03%	88.05%
0.00%	0.00%	0.00%	100.00%
0.00%	9.80%	21.57%	68.63%
1.16%	0.00%	18.60%	80.23%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.00%	8.07%	88.77%
0.00%	0.00%	38.66%	61.34%
0.00%	51.90%	43.04%	5.06%
0.00%	2.16%	18.71%	79.14%
0.00%	11.70%	6.38%	81.91%
0.00%	89.39%	10.61%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	23.81%	57.14%	19.05%
0.00%	1.80%	98.20%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
1.67%	0.33%	7.36%	90.64%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	71.11%	28.89%

Model Run #9
Fort Irwin

Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	3	25	10	0	38	7.89%	65.79%	26.32%	0.00%
2	A1SM01	Conventional	6	49	5	0	60	10.00%	81.67%	8.33%	0.00%
3	ACASF04	Point - ADAM/RAAM	0	38	101	1	140	0.00%	27.14%	72.14%	0.71%
4	ACASF05	Point - ADAM/RAAM	0	119	21	0	140	0.00%	85.00%	15.00%	0.00%
5	ACASF06	Point - ADAM/RAAM	0	5	74	61	140	0.00%	3.57%	52.86%	43.57%
6	G1*SF03	Point - ADAM/RAAM	27	113	0	0	140	19.29%	80.71%	0.00%	0.00%
7	F2BSF01	Point - ADAM/RAAM	1	11	63	65	140	0.71%	7.86%	45.00%	46.43%
8	F2ASF02	Point - ADAM/RAAM	0	20	118	3	141	0.00%	14.18%	83.69%	2.13%
9	L*SF01	Point- ADAM/RAAM	63	23	54	0	140	45.00%	16.43%	38.57%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
13	F1BSM01	Point - MOPMS	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
14	F1BSM03	Point - MOPMS	0	1	3	0	4	0.00%	25.00%	75.00%	0.00%
15	F2ASM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	8	4	67	0	79	10.13%	5.06%	84.81%	0.00%
17	ACASF04	Point - ADAM/RAAM	0	13	66	0	79	0.00%	16.46%	83.54%	0.00%
18	A1SV02	Volcano	28	14	34	58	134	20.90%	10.45%	25.37%	43.28%
19	A1SV01	Volcano	2	1	89	81	173	1.16%	0.58%	51.45%	46.82%
20	A2ASV02	Volcano	9	0	103	134	246	3.66%	0.00%	41.87%	54.47%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	100	29	161	0	290	34.48%	10.00%	55.52%	0.00%
23	G1ASV01	Volcano	17	17	163	0	197	8.63%	8.63%	82.74%	0.00%
24	G1ASV02	Volcano	14	0	79	0	93	15.05%	0.00%	84.95%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	0	0	89	70	159	0.00%	0.00%	55.97%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	12	17	108	16	153	7.84%	11.11%	70.59%	10.46%
29	G2ASV01	Volcano	0	0	36	136	172	0.00%	0.00%	20.93%	79.07%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	35	241	285	3.16%	0.00%	12.28%	84.56%
34	L2CSV01	Volcano	0	2	119	117	238	0.00%	0.84%	50.00%	49.16%
35	L2ASV01	Volcano	0	20	51	8	79	0.00%	25.32%	64.56%	10.13%
36	??	Volcano	3	1	63	72	139	2.16%	0.72%	45.32%	51.80%
37	A2BSV01	Volcano	0	26	47	115	188	0.00%	13.83%	25.00%	61.17%
38	G1AMF01	Conventional	53	13	0	0	66	80.30%	19.70%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	114	10	124	0.00%	0.00%	91.94%	8.06%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	5	12	4	21	0.00%	23.81%	57.14%	19.05%
43	G1BSV05	Volcano	0	0	222	0	222	0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	9	45	0	54	0.00%	16.67%	83.33%	0.00%
45	G2CSV05	Volcano	0	0	3	205	208	0.00%	0.00%	1.44%	98.56%
46	G2ASV01	Volcano	2	0	183	114	299	0.67%	0.00%	61.20%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	2	64	24	90	0.00%	2.22%	71.11%	26.67%
			360	738	2561	2636	6295				
		Overall Accuracy =	**5.72%**	**11.72%**	**40.68%**	**41.87%**					

Model Run #9
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total		% NL	% P	% L	% VL
1	A2CMD01	Conventional	3	25	10	0	38		7.89%	65.79%	26.32%	0.00%
2	A1SM01	Conventional	6	49	5	0	60		10.00%	81.67%	8.33%	0.00%
18	A1SV02	Volcano	28	14	34	58	134		20.90%	10.45%	25.37%	43.28%
19	A1SV01	Volcano	2	1	89	81	173		1.16%	0.58%	51.45%	46.82%
20	A2ASV02	Volcano	9	0	103	134	246		3.66%	0.00%	41.87%	54.47%
21	G1DSV01	Volcano	0	0	6	126	132		0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	100	29	161	0	290		34.48%	10.00%	55.52%	0.00%
23	G1ASV01	Volcano	17	17	163	0	197		8.63%	8.63%	82.74%	0.00%
24	G1ASV02	Volcano	14	0	79	0	93		15.05%	0.00%	84.95%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150		0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	0	0	89	70	159		0.00%	0.00%	55.97%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161		0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	12	17	108	16	153		7.84%	11.11%	70.59%	10.46%
29	G2ASV01	Volcano	0	0	36	136	172		0.00%	0.00%	20.93%	79.07%
30	G2CSV06	Volcano	0	0	0	85	85		0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	158	0	0	158		0.00%	100.00%	0.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79		0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	35	241	285		3.16%	0.00%	12.28%	84.56%
34	L2CSV01	Volcano	0	2	119	117	238		0.00%	0.84%	50.00%	49.16%
35	L2ASV01	Volcano	0	20	51	8	79		0.00%	25.32%	64.56%	10.13%
36	??	Volcano	3	1	63	72	139		2.16%	0.72%	45.32%	51.80%
37	A2BSV01	Volcano	0	26	47	115	188		0.00%	13.83%	25.00%	61.17%
38	G1AMF01	Conventional	53	13	0	0	66		80.30%	19.70%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268		0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	114	10	124		0.00%	0.00%	91.94%	8.06%
41	M3ASV01	Volcano	0	0	0	81	81		0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	5	12	4	21		0.00%	23.81%	57.14%	19.05%
43	G1BSV05	Volcano	0	0	222	0	222		0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	9	45	0	54		0.00%	16.67%	83.33%	0.00%
45	G2CSV05	Volcano	0	0	3	205	208		0.00%	0.00%	1.44%	98.56%
46	G2ASV01	Volcano	2	0	183	114	299		0.67%	0.00%	61.20%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254		0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	2	64	24	90		0.00%	2.22%	71.11%	26.67%
			258	388	1990	2460	5096					
		Overall Accuracy =	**5.06%**	**7.61%**	**39.05%**	**48.27%**						

9-merged_mf_nopoint

Model Run #10
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	0	3	25	10	38	0.00%	7.89%	65.79%	26.32%
2	A1SM01	Conventional	0	8	52	0	60	0.00%	13.33%	86.67%	0.00%
3	ACASF04	Point - ADAM/RAAM	1	18	100	21	140	0.71%	12.86%	71.43%	15.00%
4	ACASF05	Point - ADAM/RAAM	1	37	98	4	140	0.71%	26.43%	70.00%	2.86%
5	ACASF06	Point - ADAM/RAAM	3	1	64	72	140	2.14%	0.71%	45.71%	51.43%
6	G1*SF03	Point - ADAM/RAAM	0	27	113	0	140	0.00%	19.29%	80.71%	0.00%
7	F2BSF01	Point - ADAM/RAAM	0	2	37	101	140	0.00%	1.43%	26.43%	72.14%
8	F2ASF02	Point - ADAM/RAAM	29	14	94	4	141	20.57%	9.93%	66.67%	2.84%
9	L*SF01	Point- ADAM/RAAM	0	84	56	0	140	0.00%	60.00%	40.00%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	0	0	3	0	3	0.00%	0.00%	100.00%	0.00%
13	F1BSM01	Point - MOPMS	0	0	3	1	4	0.00%	0.00%	75.00%	25.00%
14	F1BSM03	Point - MOPMS	0	0	3	1	4	0.00%	0.00%	75.00%	25.00%
15	F2ASM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	0	11	68	0	79	0.00%	13.92%	86.08%	0.00%
17	ACASF04	Point - ADAM/RAAM	0	0	76	3	79	0.00%	0.00%	96.20%	3.80%
18	A1SV02	Volcano	0	28	51	55	134	0.00%	20.90%	38.06%	41.04%
19	A1SV01	Volcano	0	2	72	99	173	0.00%	1.16%	41.62%	57.23%
20	A2ASV02	Volcano	9	0	101	136	246	3.66%	0.00%	41.06%	55.28%
21	G1DSV01	Volcano	0	0	6	126	132	0.00%	0.00%	4.55%	95.45%
22	G1ESV01	Volcano	0	124	166	0	290	0.00%	42.76%	57.24%	0.00%
23	G1ASV01	Volcano	4	25	168	0	197	2.03%	12.69%	85.28%	0.00%
24	G1ASV02	Volcano	11	5	77	0	93	11.83%	5.38%	82.80%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	7	0	82	70	159	4.40%	0.00%	51.57%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	26	120	7	153	0.00%	16.99%	78.43%	4.58%
29	G2ASV01	Volcano	1	0	31	140	172	0.58%	0.00%	18.02%	81.40%
30	G2CSV06	Volcano	0	0	6	79	85	0.00%	0.00%	7.06%	92.94%
31	L1SV02	Volcano	0	22	136	0	158	0.00%	13.92%	86.08%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	35	241	285	3.16%	0.00%	12.28%	84.56%
34	L2CSV01	Volcano	0	2	119	117	238	0.00%	0.84%	50.00%	49.16%
35	L2ASV01	Volcano	0	0	75	4	79	0.00%	0.00%	94.94%	5.06%
36	??	Volcano	0	4	63	72	139	0.00%	2.88%	45.32%	51.80%
37	A2BSV01	Volcano	0	6	55	127	188	0.00%	3.19%	29.26%	67.55%
38	G1AMF01	Conventional	0	66	0	0	66	0.00%	100.00%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	115	9	124	0.00%	0.00%	92.74%	7.26%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	0	2	12	7	21	0.00%	9.52%	57.14%	33.33%
43	G1BSV05	Volcano	0	0	222	0	222	0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	9	45	0	54	0.00%	16.67%	83.33%	0.00%
45	G2CSV05	Volcano	0	0	3	205	208	0.00%	0.00%	1.44%	98.56%
46	G2ASV01	Volcano	3	2	180	114	299	1.00%	0.67%	60.20%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	2	64	24	90	0.00%	2.22%	71.11%	26.67%
			78	533	2945	2739	6295				
		Overall Accuracy =	**1.24%**	**8.47%**	**46.78%**	**43.51%**					

10-merged_mf_wpoint

Model Run #10
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
1	A2CMD01	Conventional	0	3	25	10	38
2	A1SM01	Conventional	0	8	52	0	60
18	A1SV02	Volcano	0	28	51	55	134
19	A1SV01	Volcano	0	2	72	99	173
20	A2ASV02	Volcano	9	0	101	136	246
21	G1DSV01	Volcano	0	0	6	126	132
22	G1ESV01	Volcano	0	124	166	0	290
23	G1ASV01	Volcano	4	25	168	0	197
24	G1ASV02	Volcano	11	5	77	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	7	0	82	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	26	120	7	153
29	G2ASV01	Volcano	1	0	31	140	172
30	G2CSV06	Volcano	0	0	6	79	85
31	L1SV02	Volcano	0	22	136	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	0	35	241	285
34	L2CSV01	Volcano	0	2	119	117	238
35	L2ASV01	Volcano	0	0	75	4	79
36	??	Volcano	0	4	63	72	139
37	A2BSV01	Volcano	0	6	55	127	188
38	G1AMF01	Conventional	0	66	0	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	115	9	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	2	12	7	21
43	G1BSV05	Volcano	0	0	222	0	222
44	G1ASV05	Volcano	0	9	45	0	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	3	2	180	114	299
47	M2ASV01	Volcano	0	0	70	184	254
48	A2BSV01	Volcano	0	2	64	24	90
			44	336	2230	2486	5096
		Overall Accuracy =	**0.86%**	**6.59%**	**43.76%**	**48.78%**	

% NL	% P	% L	% VL
0.00%	7.89%	65.79%	26.32%
0.00%	13.33%	86.67%	0.00%
0.00%	20.90%	38.06%	41.04%
0.00%	1.16%	41.62%	57.23%
3.66%	0.00%	41.06%	55.28%
0.00%	0.00%	4.55%	95.45%
0.00%	42.76%	57.24%	0.00%
2.03%	12.69%	85.28%	0.00%
11.83%	5.38%	82.80%	0.00%
0.00%	0.00%	0.00%	100.00%
4.40%	0.00%	51.57%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	16.99%	78.43%	4.58%
0.58%	0.00%	18.02%	81.40%
0.00%	0.00%	7.06%	92.94%
0.00%	13.92%	86.08%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.00%	12.28%	84.56%
0.00%	0.84%	50.00%	49.16%
0.00%	0.00%	94.94%	5.06%
0.00%	2.88%	45.32%	51.80%
0.00%	3.19%	29.26%	67.55%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	92.74%	7.26%
0.00%	0.00%	0.00%	100.00%
0.00%	9.52%	57.14%	33.33%
0.00%	0.00%	100.00%	0.00%
0.00%	16.67%	83.33%	0.00%
0.00%	0.00%	1.44%	98.56%
1.00%	0.67%	60.20%	38.13%
0.00%	0.00%	27.56%	72.44%
0.00%	2.22%	71.11%	26.67%

Model Run #11
Fort Irwin

Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	0	3	35	0	38	0.00%	7.89%	92.11%	0.00%
2	A1SM01	Conventional	0	8	49	3	60	0.00%	13.33%	81.67%	5.00%
3	ACASF04	Point - ADAM/RAAM	1	18	87	34	140	0.71%	12.86%	62.14%	24.29%
4	ACASF05	Point - ADAM/RAAM	1	33	100	6	140	0.71%	23.57%	71.43%	4.29%
5	ACASF06	Point - ADAM/RAAM	3	1	64	72	140	2.14%	0.71%	45.71%	51.43%
6	G1*SF03	Point - ADAM/RAAM	0	27	113	0	140	0.00%	19.29%	80.71%	0.00%
7	F2BSF01	Point - ADAM/RAAM	0	27	50	63	140	0.00%	19.29%	35.71%	45.00%
8	F2ASF02	Point - ADAM/RAAM	29	8	46	58	141	20.57%	5.67%	32.62%	41.13%
9	L*SF01	Point- ADAM/RAAM	0	115	25	0	140	0.00%	82.14%	17.86%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	0	0	3	0	3	0.00%	0.00%	100.00%	0.00%
13	F1BSM01	Point - MOPMS	0	3	1	0	4	0.00%	75.00%	25.00%	0.00%
14	F1BSM03	Point - MOPMS	0	0	3	1	4	0.00%	0.00%	75.00%	25.00%
15	F2ASM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	0	39	40	0	79	0.00%	49.37%	50.63%	0.00%
17	ACASF04	Point - ADAM/RAAM	0	4	54	21	79	0.00%	5.06%	68.35%	26.58%
18	A1SV02	Volcano	0	28	14	92	134	0.00%	20.90%	10.45%	68.66%
19	A1SV01	Volcano	0	71	24	78	173	0.00%	41.04%	13.87%	45.09%
20	A2ASV02	Volcano	9	1	102	134	246	3.66%	0.41%	41.46%	54.47%
21	G1DSV01	Volcano	0	0	0	132	132	0.00%	0.00%	0.00%	100.00%
22	G1ESV01	Volcano	0	99	30	161	290	0.00%	34.14%	10.34%	55.52%
23	G1ASV01	Volcano	4	23	19	151	197	2.03%	11.68%	9.64%	76.65%
24	G1ASV02	Volcano	11	17	65	0	93	11.83%	18.28%	69.89%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	7	11	71	70	159	4.40%	6.92%	44.65%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	31	115	7	153	0.00%	20.26%	75.16%	4.58%
29	G2ASV01	Volcano	1	28	15	128	172	0.58%	16.28%	8.72%	74.42%
30	G2CSV06	Volcano	0	0	6	79	85	0.00%	0.00%	7.06%	92.94%
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	0	79	79	0.00%	0.00%	0.00%	100.00%
33	L2BSV01	Volcano	9	0	0	276	285	3.16%	0.00%	0.00%	96.84%
34	L2CSV01	Volcano	0	0	34	204	238	0.00%	0.00%	14.29%	85.71%
35	L2ASV01	Volcano	0	0	38	41	79	0.00%	0.00%	48.10%	51.90%
36	??	Volcano	0	29	42	68	139	0.00%	20.86%	30.22%	48.92%
37	A2BSV01	Volcano	0	6	59	123	188	0.00%	3.19%	31.38%	65.43%
38	G1AMF01	Conventional	0	53	13	0	66	0.00%	80.30%	19.70%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	116	8	124	0.00%	0.00%	93.55%	6.45%
41	M3ASV01	Volcano	0	0	6	75	81	0.00%	0.00%	7.41%	92.59%
42	A2AMD01	Conventional	0	6	10	5	21	0.00%	28.57%	47.62%	23.81%
43	G1BSV05	Volcano	0	0	12	210	222	0.00%	0.00%	5.41%	94.59%
44	G1ASV05	Volcano	0	0	9	45	54	0.00%	0.00%	16.67%	83.33%
45	G2CSV05	Volcano	0	0	3	205	208	0.00%	0.00%	1.44%	98.56%
46	G2ASV01	Volcano	3	24	158	114	299	1.00%	8.03%	52.84%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	0	4	86	90	0.00%	0.00%	4.44%	95.56%
			78	716	1863	3638	6295				
		Overall Accuracy =	**1.24%**	**11.37%**	**29.59%**	**57.79%**					

Model Run #11
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total		% NL	% P	% L	% VL
1	A2CMD01	Conventional	0	3	35	0	38		0.00%	7.89%	92.11%	0.00%
2	A1SM01	Conventional	0	8	49	3	60		0.00%	13.33%	81.67%	5.00%
18	A1SV02	Volcano	0	28	14	92	134		0.00%	20.90%	10.45%	68.66%
19	A1SV01	Volcano	0	71	24	78	173		0.00%	41.04%	13.87%	45.09%
20	A2ASV02	Volcano	9	1	102	134	246		3.66%	0.41%	41.46%	54.47%
21	G1DSV01	Volcano	0	0	0	132	132		0.00%	0.00%	0.00%	100.00%
22	G1ESV01	Volcano	0	99	30	161	290		0.00%	34.14%	10.34%	55.52%
23	G1ASV01	Volcano	4	23	19	151	197		2.03%	11.68%	9.64%	76.65%
24	G1ASV02	Volcano	11	17	65	0	93		11.83%	18.28%	69.89%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150		0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	7	11	71	70	159		4.40%	6.92%	44.65%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161		0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	31	115	7	153		0.00%	20.26%	75.16%	4.58%
29	G2ASV01	Volcano	1	28	15	128	172		0.58%	16.28%	8.72%	74.42%
30	G2CSV06	Volcano	0	0	6	79	85		0.00%	0.00%	7.06%	92.94%
31	L1SV02	Volcano	0	0	158	0	158		0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	0	79	79		0.00%	0.00%	0.00%	100.00%
33	L2BSV01	Volcano	9	0	0	276	285		3.16%	0.00%	0.00%	96.84%
34	L2CSV01	Volcano	0	0	34	204	238		0.00%	0.00%	14.29%	85.71%
35	L2ASV01	Volcano	0	0	38	41	79		0.00%	0.00%	48.10%	51.90%
36	??	Volcano	0	29	42	68	139		0.00%	20.86%	30.22%	48.92%
37	A2BSV01	Volcano	0	6	59	123	188		0.00%	3.19%	31.38%	65.43%
38	G1AMF01	Conventional	0	53	13	0	66		0.00%	80.30%	19.70%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268		0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	116	8	124		0.00%	0.00%	93.55%	6.45%
41	M3ASV01	Volcano	0	0	6	75	81		0.00%	0.00%	7.41%	92.59%
42	A2AMD01	Conventional	0	6	10	5	21		0.00%	28.57%	47.62%	23.81%
43	G1BSV05	Volcano	0	0	12	210	222		0.00%	0.00%	5.41%	94.59%
44	G1ASV05	Volcano	0	0	9	45	54		0.00%	0.00%	16.67%	83.33%
45	G2CSV05	Volcano	0	0	3	205	208		0.00%	0.00%	1.44%	98.56%
46	G2ASV01	Volcano	3	24	158	114	299		1.00%	8.03%	52.84%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254		0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	0	4	86	90		0.00%	0.00%	4.44%	95.56%
			44	438	1277	3337	5096					
		Overall Accuracy =	**0.86%**	**8.59%**	**25.06%**	**65.48%**						

Model Run #12
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	38	0	0	0	38	100.00%	0.00%	0.00%	0.00%
2	A1SM01	Conventional	55	0	5	0	60	91.67%	0.00%	8.33%	0.00%
3	ACASF04	Point - ADAM/RAAM	63	0	77	0	140	45.00%	0.00%	55.00%	0.00%
4	ACASF05	Point - ADAM/RAAM	123	0	17	0	140	87.86%	0.00%	12.14%	0.00%
5	ACASF06	Point - ADAM/RAAM	68	0	38	34	140	48.57%	0.00%	27.14%	24.29%
6	G1*SF03	Point - ADAM/RAAM	140	0	0	0	140	100.00%	0.00%	0.00%	0.00%
7	F2BSF01	Point - ADAM/RAAM	73	0	55	12	140	52.14%	0.00%	39.29%	8.57%
8	F2ASF02	Point - ADAM/RAAM	47	0	76	18	141	33.33%	0.00%	53.90%	12.77%
9	L*SF01	Point- ADAM/RAAM	117	0	23	0	140	83.57%	0.00%	16.43%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
13	F1BSM01	Point - MOPMS	4	0	0	0	4	100.00%	0.00%	0.00%	0.00%
14	F1BSM03	Point - MOPMS	2	0	1	1	4	50.00%	0.00%	25.00%	25.00%
15	F2ASM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	40	0	39	0	79	50.63%	0.00%	49.37%	0.00%
17	ACASF04	Point - ADAM/RAAM	20	0	59	0	79	25.32%	0.00%	74.68%	0.00%
18	A1SV02	Volcano	42	0	66	26	134	31.34%	0.00%	49.25%	19.40%
19	A1SV01	Volcano	90	0	68	15	173	52.02%	0.00%	39.31%	8.67%
20	A2ASV02	Volcano	1	0	200	45	246	0.41%	0.00%	81.30%	18.29%
21	G1DSV01	Volcano	0	0	109	23	132	0.00%	0.00%	82.58%	17.42%
22	G1ESV01	Volcano	104	0	178	8	290	35.86%	0.00%	61.38%	2.76%
23	G1ASV01	Volcano	34	0	163	0	197	17.26%	0.00%	82.74%	0.00%
24	G1ASV02	Volcano	28	0	65	0	93	30.11%	0.00%	69.89%	0.00%
25	G1BSV01	Volcano	0	0	57	93	150	0.00%	0.00%	38.00%	62.00%
26	G2CSV01	Volcano	16	0	143	0	159	10.06%	0.00%	89.94%	0.00%
27	G2ASV02	Volcano	0	0	85	76	161	0.00%	0.00%	52.80%	47.20%
28	G2*SV03	Volcano	31	0	110	12	153	20.26%	0.00%	71.90%	7.84%
29	G2ASV01	Volcano	33	0	122	17	172	19.19%	0.00%	70.93%	9.88%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	0	0	147	138	285	0.00%	0.00%	51.58%	48.42%
34	L2CSV01	Volcano	0	0	232	6	238	0.00%	0.00%	97.48%	2.52%
35	L2ASV01	Volcano	41	0	26	12	79	51.90%	0.00%	32.91%	15.19%
36	??	Volcano	29	0	87	23	139	20.86%	0.00%	62.59%	16.55%
37	A2BSV01	Volcano	26	0	153	9	188	13.83%	0.00%	81.38%	4.79%
38	G1AMF01	Conventional	53	0	13	0	66	80.30%	0.00%	19.70%	0.00%
39	G2BMN01	Conventional	0	0	170	98	268	0.00%	0.00%	63.43%	36.57%
40	G2CMT02	Conventional	0	0	116	8	124	0.00%	0.00%	93.55%	6.45%
41	M3ASV01	Volcano	0	0	80	1	81	0.00%	0.00%	98.77%	1.23%
42	A2AMD01	Conventional	12	0	9	0	21	57.14%	0.00%	42.86%	0.00%
43	G1BSV05	Volcano	0	0	222	0	222	0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	0	51	3	54	0.00%	0.00%	94.44%	5.56%
45	G2CSV05	Volcano	0	0	111	97	208	0.00%	0.00%	53.37%	46.63%
46	G2ASV01	Volcano	23	0	276	0	299	7.69%	0.00%	92.31%	0.00%
47	M2ASV01	Volcano	0	0	247	7	254	0.00%	0.00%	97.24%	2.76%
48	A2BSV01	Volcano	0	0	85	5	90	0.00%	0.00%	94.44%	5.56%
			1359	0	4018	918	6295				
		Overall Accuracy =	**21.59%**	**0.00%**	**63.83%**	**14.58%**					

Model Run #12
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total		% NL	% P	% L	% VL
1	A2CMD01	Conventional	38	0	0	0	38		100.00%	0.00%	0.00%	0.00%
2	A1SM01	Conventional	55	0	5	0	60		91.67%	0.00%	8.33%	0.00%
18	A1SV02	Volcano	42	0	66	26	134		31.34%	0.00%	49.25%	19.40%
19	A1SV01	Volcano	90	0	68	15	173		52.02%	0.00%	39.31%	8.67%
20	A2ASV02	Volcano	1	0	200	45	246		0.41%	0.00%	81.30%	18.29%
21	G1DSV01	Volcano	0	0	109	23	132		0.00%	0.00%	82.58%	17.42%
22	G1ESV01	Volcano	104	0	178	8	290		35.86%	0.00%	61.38%	2.76%
23	G1ASV01	Volcano	34	0	163	0	197		17.26%	0.00%	82.74%	0.00%
24	G1ASV02	Volcano	28	0	65	0	93		30.11%	0.00%	69.89%	0.00%
25	G1BSV01	Volcano	0	0	57	93	150		0.00%	0.00%	38.00%	62.00%
26	G2CSV01	Volcano	16	0	143	0	159		10.06%	0.00%	89.94%	0.00%
27	G2ASV02	Volcano	0	0	85	76	161		0.00%	0.00%	52.80%	47.20%
28	G2*SV03	Volcano	31	0	110	12	153		20.26%	0.00%	71.90%	7.84%
29	G2ASV01	Volcano	33	0	122	17	172		19.19%	0.00%	70.93%	9.88%
30	G2CSV06	Volcano	0	0	0	85	85		0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	158	0	158		0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79		0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	0	0	147	138	285		0.00%	0.00%	51.58%	48.42%
34	L2CSV01	Volcano	0	0	232	6	238		0.00%	0.00%	97.48%	2.52%
35	L2ASV01	Volcano	41	0	26	12	79		51.90%	0.00%	32.91%	15.19%
36	??	Volcano	29	0	87	23	139		20.86%	0.00%	62.59%	16.55%
37	A2BSV01	Volcano	26	0	153	9	188		13.83%	0.00%	81.38%	4.79%
38	G1AMF01	Conventional	53	0	13	0	66		80.30%	0.00%	19.70%	0.00%
39	G2BMN01	Conventional	0	0	170	98	268		0.00%	0.00%	63.43%	36.57%
40	G2CMT02	Conventional	0	0	116	8	124		0.00%	0.00%	93.55%	6.45%
41	M3ASV01	Volcano	0	0	80	1	81		0.00%	0.00%	98.77%	1.23%
42	A2AMD01	Conventional	12	0	9	0	21		57.14%	0.00%	42.86%	0.00%
43	G1BSV05	Volcano	0	0	222	0	222		0.00%	0.00%	100.00%	0.00%
44	G1ASV05	Volcano	0	0	51	3	54		0.00%	0.00%	94.44%	5.56%
45	G2CSV05	Volcano	0	0	111	97	208		0.00%	0.00%	53.37%	46.63%
46	G2ASV01	Volcano	23	0	276	0	299		7.69%	0.00%	92.31%	0.00%
47	M2ASV01	Volcano	0	0	247	7	254		0.00%	0.00%	97.24%	2.76%
48	A2BSV01	Volcano	0	0	85	5	90		0.00%	0.00%	94.44%	5.56%
			656	0	3633	807	5096					
		Overall Accuracy =	**12.87%**	**0.00%**	**71.29%**	**15.84%**						

Model Run #13
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	28	0	10	0	38	73.68%	0.00%	26.32%	0.00%
2	A1SM01	Conventional	55	5	0	0	60	91.67%	8.33%	0.00%	0.00%
3	ACASF04	Point - ADAM/RAAM	45	69	25	1	140	32.14%	49.29%	17.86%	0.71%
4	ACASF05	Point - ADAM/RAAM	121	15	2	2	140	86.43%	10.71%	1.43%	1.43%
5	ACASF06	Point - ADAM/RAAM	51	8	29	52	140	36.43%	5.71%	20.71%	37.14%
6	G1*SF03	Point - ADAM/RAAM	135	0	5	0	140	96.43%	0.00%	3.57%	0.00%
7	F2BSF01	Point - ADAM/RAAM	14	0	69	57	140	10.00%	0.00%	49.29%	40.71%
8	F2ASF02	Point - ADAM/RAAM	25	69	46	1	141	17.73%	48.94%	32.62%	0.71%
9	L*SF01	Point- ADAM/RAAM	53	33	54	0	140	37.86%	23.57%	38.57%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
13	F1BSM01	Point - MOPMS	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
14	F1BSM03	Point - MOPMS	0	0	3	1	4	0.00%	0.00%	75.00%	25.00%
15	F2ASM01	Point - MOPMS	3	0	0	0	3	100.00%	0.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	10	2	36	31	79	12.66%	2.53%	45.57%	39.24%
17	ACASF04	Point - ADAM/RAAM	17	55	7	0	79	21.52%	69.62%	8.86%	0.00%
18	A1SV02	Volcano	38	37	4	55	134	28.36%	27.61%	2.99%	41.04%
19	A1SV01	Volcano	2	3	84	84	173	1.16%	1.73%	48.55%	48.55%
20	A2ASV02	Volcano	9	0	4	233	246	3.66%	0.00%	1.63%	94.72%
21	G1DSV01	Volcano	0	5	1	126	132	0.00%	3.79%	0.76%	95.45%
22	G1ESV01	Volcano	109	174	7	0	290	37.59%	60.00%	2.41%	0.00%
23	G1ASV01	Volcano	30	167	0	0	197	15.23%	84.77%	0.00%	0.00%
24	G1ASV02	Volcano	14	0	17	62	93	15.05%	0.00%	18.28%	66.67%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	0	0	19	140	159	0.00%	0.00%	11.95%	88.05%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	15	14	19	105	153	9.80%	9.15%	12.42%	68.63%
29	G2ASV01	Volcano	0	0	32	140	172	0.00%	0.00%	18.60%	81.40%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%
32	L1SV03	Volcano	0	79	0	0	79	0.00%	100.00%	0.00%	0.00%
33	L2BSV01	Volcano	9	22	13	241	285	3.16%	7.72%	4.56%	84.56%
34	L2CSV01	Volcano	0	91	1	146	238	0.00%	38.24%	0.42%	61.34%
35	L2ASV01	Volcano	41	26	12	0	79	51.90%	32.91%	15.19%	0.00%
36	??	Volcano	3	1	25	110	139	2.16%	0.72%	17.99%	79.14%
37	A2BSV01	Volcano	22	12	0	154	188	11.70%	6.38%	0.00%	81.91%
38	G1AMF01	Conventional	59	7	0	0	66	89.39%	10.61%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	0	124	124	0.00%	0.00%	0.00%	100.00%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	2	6	8	5	21	9.52%	28.57%	38.10%	23.81%
43	G1BSV05	Volcano	0	222	0	0	222	0.00%	100.00%	0.00%	0.00%
44	G1ASV05	Volcano	0	51	3	0	54	0.00%	94.44%	5.56%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	1	1	23	274	299	0.33%	0.33%	7.69%	91.64%
47	M2ASV01	Volcano	0	0	0	254	254	0.00%	0.00%	0.00%	100.00%
48	A2BSV01	Volcano	0	60	4	26	90	0.00%	66.67%	4.44%	28.89%
			914	1392	566	3423	6295				
		Overall Accuracy =	**14.52%**	**22.11%**	**8.99%**	**54.38%**					

Model Run #13
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
1	A2CMD01	Conventional	28	0	10	0	38	73.68%	0.00%	26.32%	0.00%
2	A1SM01	Conventional	55	5	0	0	60	91.67%	8.33%	0.00%	0.00%
18	A1SV02	Volcano	38	37	4	55	134	28.36%	27.61%	2.99%	41.04%
19	A1SV01	Volcano	2	3	84	84	173	1.16%	1.73%	48.55%	48.55%
20	A2ASV02	Volcano	9	0	4	233	246	3.66%	0.00%	1.63%	94.72%
21	G1DSV01	Volcano	0	5	1	126	132	0.00%	3.79%	0.76%	95.45%
22	G1ESV01	Volcano	109	174	7	0	290	37.59%	60.00%	2.41%	0.00%
23	G1ASV01	Volcano	30	167	0	0	197	15.23%	84.77%	0.00%	0.00%
24	G1ASV02	Volcano	14	0	17	62	93	15.05%	0.00%	18.28%	66.67%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	0	0	19	140	159	0.00%	0.00%	11.95%	88.05%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	15	14	19	105	153	9.80%	9.15%	12.42%	68.63%
29	G2ASV01	Volcano	0	0	32	140	172	0.00%	0.00%	18.60%	81.40%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	158	0	0	158	0.00%	100.00%	0.00%	0.00%
32	L1SV03	Volcano	0	79	0	0	79	0.00%	100.00%	0.00%	0.00%
33	L2BSV01	Volcano	9	22	13	241	285	3.16%	7.72%	4.56%	84.56%
34	L2CSV01	Volcano	0	91	1	146	238	0.00%	38.24%	0.42%	61.34%
35	L2ASV01	Volcano	41	26	12	0	79	51.90%	32.91%	15.19%	0.00%
36	??	Volcano	3	1	25	110	139	2.16%	0.72%	17.99%	79.14%
37	A2BSV01	Volcano	22	12	0	154	188	11.70%	6.38%	0.00%	81.91%
38	G1AMF01	Conventional	59	7	0	0	66	89.39%	10.61%	0.00%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	0	124	124	0.00%	0.00%	0.00%	100.00%
41	M3ASV01	Volcano	0	0	0	81	81	0.00%	0.00%	0.00%	100.00%
42	A2AMD01	Conventional	2	6	8	5	21	9.52%	28.57%	38.10%	23.81%
43	G1BSV05	Volcano	0	222	0	0	222	0.00%	100.00%	0.00%	0.00%
44	G1ASV05	Volcano	0	51	3	0	54	0.00%	94.44%	5.56%	0.00%
45	G2CSV05	Volcano	0	0	0	208	208	0.00%	0.00%	0.00%	100.00%
46	G2ASV01	Volcano	1	1	23	274	299	0.33%	0.33%	7.69%	91.64%
47	M2ASV01	Volcano	0	0	0	254	254	0.00%	0.00%	0.00%	100.00%
48	A2BSV01	Volcano	0	60	4	26	90	0.00%	66.67%	4.44%	28.89%
			437	1141	286	3232	5096				
		Overall Accuracy =	**8.58%**	**22.39%**	**5.61%**	**63.42%**					

Model Run #14
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	G2*SM02	Point - MOPMS	0	0	0	38	38	0.00%	0.00%	0.00%	100.00%
1	A2CMD01	Conventional	0	13	25	0	38	0.00%	34.21%	65.79%	0.00%
2	A1SM01	Conventional	0	47	13	0	60	0.00%	78.33%	21.67%	0.00%
3	ACASF04	Point - ADAM/RAAM	1	46	92	1	140	0.71%	32.86%	65.71%	0.71%
4	ACASF05	Point - ADAM/RAAM	1	99	40	0	140	0.71%	70.71%	28.57%	0.00%
5	ACASF06	Point - ADAM/RAAM	3	25	52	60	140	2.14%	17.86%	37.14%	42.86%
6	G1*SF03	Point - ADAM/RAAM	0	105	35	0	140	0.00%	75.00%	25.00%	0.00%
7	F2BSF01	Point - ADAM/RAAM	0	34	45	61	140	0.00%	24.29%	32.14%	43.57%
8	F2ASF02	Point - ADAM/RAAM	29	16	80	16	141	20.57%	11.35%	56.74%	11.35%
9	L*SF01	Point- ADAM/RAAM	0	63	77	0	140	0.00%	45.00%	55.00%	0.00%
10	G2CSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
11	G2BSM01	Point - MOPMS	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
12	L1SM01	Point - MOPMS	0	1	2	0	3	0.00%	33.33%	66.67%	0.00%
13	F1BSM01	Point - MOPMS	0	3	1	0	4	0.00%	75.00%	25.00%	0.00%
14	F1BSM03	Point - MOPMS	0	1	2	1	4	0.00%	25.00%	50.00%	25.00%
15	F2ASM01	Point - MOPMS	0	3	0	0	3	0.00%	100.00%	0.00%	0.00%
16	A1AHH01	Point - Hornet	0	10	69	0	79	0.00%	12.66%	87.34%	0.00%
17	ACASF04	Point - ADAM/RAAM	0	17	62	0	79	0.00%	21.52%	78.48%	0.00%
18	A1SV02	Volcano	0	28	47	59	134	0.00%	20.90%	35.07%	44.03%
19	A1SV01	Volcano	0	65	32	76	173	0.00%	37.57%	18.50%	43.93%
20	A2ASV02	Volcano	9	0	101	136	246	3.66%	0.00%	41.06%	55.28%
21	G1DSV01	Volcano	0	0	3	129	132	0.00%	0.00%	2.27%	97.73%
22	G1ESV01	Volcano	0	99	183	8	290	0.00%	34.14%	63.10%	2.76%
23	G1ASV01	Volcano	4	32	160	1	197	2.03%	16.24%	81.22%	0.51%
24	G1ASV02	Volcano	11	12	70	0	93	11.83%	12.90%	75.27%	0.00%
25	G1BSV01	Volcano	0	0	0	150	150	0.00%	0.00%	0.00%	100.00%
26	G2CSV01	Volcano	7	7	75	70	159	4.40%	4.40%	47.17%	44.03%
27	G2ASV02	Volcano	0	0	0	161	161	0.00%	0.00%	0.00%	100.00%
28	G2*SV03	Volcano	0	22	115	16	153	0.00%	14.38%	75.16%	10.46%
29	G2ASV01	Volcano	1	23	20	128	172	0.58%	13.37%	11.63%	74.42%
30	G2CSV06	Volcano	0	0	0	85	85	0.00%	0.00%	0.00%	100.00%
31	L1SV02	Volcano	0	0	158	0	158	0.00%	0.00%	100.00%	0.00%
32	L1SV03	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
33	L2BSV01	Volcano	9	0	18	258	285	3.16%	0.00%	6.32%	90.53%
34	L2CSV01	Volcano	0	0	118	120	238	0.00%	0.00%	49.58%	50.42%
35	L2ASV01	Volcano	0	28	38	13	79	0.00%	35.44%	48.10%	16.46%
36	??	Volcano	0	3	68	68	139	0.00%	2.16%	48.92%	48.92%
37	A2BSV01	Volcano	0	22	51	115	188	0.00%	11.70%	27.13%	61.17%
38	G1AMF01	Conventional	0	53	13	0	66	0.00%	80.30%	19.70%	0.00%
39	G2BMN01	Conventional	0	0	0	268	268	0.00%	0.00%	0.00%	100.00%
40	G2CMT02	Conventional	0	0	113	11	124	0.00%	0.00%	91.13%	8.87%
41	M3ASV01	Volcano	0	0	6	75	81	0.00%	0.00%	7.41%	92.59%
42	A2AMD01	Conventional	0	9	10	2	21	0.00%	42.86%	47.62%	9.52%
43	G1BSV05	Volcano	0	0	217	5	222	0.00%	0.00%	97.75%	2.25%
44	G1ASV05	Volcano	0	0	45	9	54	0.00%	0.00%	83.33%	16.67%
45	G2CSV05	Volcano	0	0	3	205	208	0.00%	0.00%	1.44%	98.56%
46	G2ASV01	Volcano	3	11	171	114	299	1.00%	3.68%	57.19%	38.13%
47	M2ASV01	Volcano	0	0	70	184	254	0.00%	0.00%	27.56%	72.44%
48	A2BSV01	Volcano	0	0	60	30	90	0.00%	0.00%	66.67%	33.33%
			78	897	2639	2681	6295				
		Overall Accuracy =	**1.24%**	**14.25%**	**41.92%**	**42.59%**					

Model Run #14
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
1	A2CMD01	Conventional	0	13	25	0	38
2	A1SM01	Conventional	0	47	13	0	60
18	A1SV02	Volcano	0	28	47	59	134
19	A1SV01	Volcano	0	65	32	76	173
20	A2ASV02	Volcano	9	0	101	136	246
21	G1DSV01	Volcano	0	0	3	129	132
22	G1ESV01	Volcano	0	99	183	8	290
23	G1ASV01	Volcano	4	32	160	1	197
24	G1ASV02	Volcano	11	12	70	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	7	7	75	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	22	115	16	153
29	G2ASV01	Volcano	1	23	20	128	172
30	G2CSV06	Volcano	0	0	0	85	85
31	L1SV02	Volcano	0	0	158	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	0	18	258	285
34	L2CSV01	Volcano	0	0	118	120	238
35	L2ASV01	Volcano	0	28	38	13	79
36	??	Volcano	0	3	68	68	139
37	A2BSV01	Volcano	0	22	51	115	188
38	G1AMF01	Conventional	0	53	13	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	113	11	124
41	M3ASV01	Volcano	0	0	6	75	81
42	A2AMD01	Conventional	0	9	10	2	21
43	G1BSV05	Volcano	0	0	217	5	222
44	G1ASV05	Volcano	0	0	45	9	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	3	11	171	114	299
47	M2ASV01	Volcano	0	0	70	184	254
48	A2BSV01	Volcano	0	0	60	30	90
			44	474	2082	2496	5096
		Overall Accuracy =	**0.86%**	**9.30%**	**40.86%**	**48.98%**	

% NL	% P	% L	% VL
0.00%	34.21%	65.79%	0.00%
0.00%	78.33%	21.67%	0.00%
0.00%	20.90%	35.07%	44.03%
0.00%	37.57%	18.50%	43.93%
3.66%	0.00%	41.06%	55.28%
0.00%	0.00%	2.27%	97.73%
0.00%	34.14%	63.10%	2.76%
2.03%	16.24%	81.22%	0.51%
11.83%	12.90%	75.27%	0.00%
0.00%	0.00%	0.00%	100.00%
4.40%	4.40%	47.17%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	14.38%	75.16%	10.46%
0.58%	13.37%	11.63%	74.42%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.00%	6.32%	90.53%
0.00%	0.00%	49.58%	50.42%
0.00%	35.44%	48.10%	16.46%
0.00%	2.16%	48.92%	48.92%
0.00%	11.70%	27.13%	61.17%
0.00%	80.30%	19.70%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	91.13%	8.87%
0.00%	0.00%	7.41%	92.59%
0.00%	42.86%	47.62%	9.52%
0.00%	0.00%	97.75%	2.25%
0.00%	0.00%	83.33%	16.67%
0.00%	0.00%	1.44%	98.56%
1.00%	3.68%	57.19%	38.13%
0.00%	0.00%	27.56%	72.44%
0.00%	0.00%	66.67%	33.33%

Model Run #15
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	G2*SM02	Point - MOPMS	0	0	0	38	38
1	A2CMD01	Conventional	0	3	25	10	38
2	A1SM01	Conventional	0	6	54	0	60
3	ACASF04	Point - ADAM/RAAM	1	0	125	14	140
4	ACASF05	Point - ADAM/RAAM	1	0	135	4	140
5	ACASF06	Point - ADAM/RAAM	3	0	54	83	140
6	G1*SF03	Point - ADAM/RAAM	0	27	113	0	140
7	F2BSF01	Point - ADAM/RAAM	0	17	42	81	140
8	F2ASF02	Point - ADAM/RAAM	29	0	95	17	141
9	L*SF01	Point- ADAM/RAAM	0	140	0	0	140
10	G2CSM01	Point - MOPMS	0	0	0	4	4
11	G2BSM01	Point - MOPMS	0	0	0	4	4
12	L1SM01	Point - MOPMS	0	0	3	0	3
13	F1BSM01	Point - MOPMS	0	0	4	0	4
14	F1BSM03	Point - MOPMS	0	0	3	1	4
15	F2ASM01	Point - MOPMS	0	3	0	0	3
16	A1AHH01	Point - Hornet	0	59	20	0	79
17	ACASF04	Point - ADAM/RAAM	0	0	77	2	79
18	A1SV02	Volcano	0	28	47	59	134
19	A1SV01	Volcano	0	71	9	93	173
20	A2ASV02	Volcano	9	1	102	134	246
21	G1DSV01	Volcano	0	0	3	129	132
22	G1ESV01	Volcano	0	125	157	8	290
23	G1ASV01	Volcano	4	13	179	1	197
24	G1ASV02	Volcano	11	18	64	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	7	12	70	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	50	98	5	153
29	G2ASV01	Volcano	1	31	2	138	172
30	G2CSV06	Volcano	0	0	85	0	85
31	L1SV02	Volcano	0	158	0	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	2	48	226	285
34	L2CSV01	Volcano	0	2	114	122	238
35	L2ASV01	Volcano	0	0	52	27	79
36	??	Volcano	0	31	36	72	139
37	A2BSV01	Volcano	0	0	73	115	188
38	G1AMF01	Conventional	0	66	0	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	122	2	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	0	17	4	21
43	G1BSV05	Volcano	0	0	217	5	222
44	G1ASV05	Volcano	0	9	36	9	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	3	26	156	114	299
47	M2ASV01	Volcano	0	2	68	184	254
48	A2BSV01	Volcano	0	2	58	30	90
			78	902	2645	2670	6295
		Overall Accuracy =	**1.24%**	**14.33%**	**42.02%**	**42.41%**	

% NL	% P	% L	% VL
0.00%	0.00%	0.00%	100.00%
0.00%	7.89%	65.79%	26.32%
0.00%	10.00%	90.00%	0.00%
0.71%	0.00%	89.29%	10.00%
0.71%	0.00%	96.43%	2.86%
2.14%	0.00%	38.57%	59.29%
0.00%	19.29%	80.71%	0.00%
0.00%	12.14%	30.00%	57.86%
20.57%	0.00%	67.38%	12.06%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	75.00%	25.00%
0.00%	100.00%	0.00%	0.00%
0.00%	74.68%	25.32%	0.00%
0.00%	0.00%	97.47%	2.53%
0.00%	20.90%	35.07%	44.03%
0.00%	41.04%	5.20%	53.76%
3.66%	0.41%	41.46%	54.47%
0.00%	0.00%	2.27%	97.73%
0.00%	43.10%	54.14%	2.76%
2.03%	6.60%	90.86%	0.51%
11.83%	19.35%	68.82%	0.00%
0.00%	0.00%	0.00%	100.00%
4.40%	7.55%	44.03%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	32.68%	64.05%	3.27%
0.58%	18.02%	1.16%	80.23%
0.00%	0.00%	100.00%	0.00%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.70%	16.84%	79.30%
0.00%	0.84%	47.90%	51.26%
0.00%	0.00%	65.82%	34.18%
0.00%	22.30%	25.90%	51.80%
0.00%	0.00%	38.83%	61.17%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	98.39%	1.61%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	80.95%	19.05%
0.00%	0.00%	97.75%	2.25%
0.00%	16.67%	66.67%	16.67%
0.00%	0.00%	1.44%	98.56%
1.00%	8.70%	52.17%	38.13%
0.00%	0.79%	26.77%	72.44%
0.00%	2.22%	64.44%	33.33%

Model Run #15
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
1	A2CMD01	Conventional	0	3	25	10	38
2	A1SM01	Conventional	0	6	54	0	60
18	A1SV02	Volcano	0	28	47	59	134
19	A1SV01	Volcano	0	71	9	93	173
20	A2ASV02	Volcano	9	1	102	134	246
21	G1DSV01	Volcano	0	0	3	129	132
22	G1ESV01	Volcano	0	125	157	8	290
23	G1ASV01	Volcano	4	13	179	1	197
24	G1ASV02	Volcano	11	18	64	0	93
25	G1BSV01	Volcano	0	0	0	150	150
26	G2CSV01	Volcano	7	12	70	70	159
27	G2ASV02	Volcano	0	0	0	161	161
28	G2*SV03	Volcano	0	50	98	5	153
29	G2ASV01	Volcano	1	31	2	138	172
30	G2CSV06	Volcano	0	0	85	0	85
31	L1SV02	Volcano	0	158	0	0	158
32	L1SV03	Volcano	0	0	79	0	79
33	L2BSV01	Volcano	9	2	48	226	285
34	L2CSV01	Volcano	0	2	114	122	238
35	L2ASV01	Volcano	0	0	52	27	79
36	??	Volcano	0	31	36	72	139
37	A2BSV01	Volcano	0	0	73	115	188
38	G1AMF01	Conventional	0	66	0	0	66
39	G2BMN01	Conventional	0	0	0	268	268
40	G2CMT02	Conventional	0	0	122	2	124
41	M3ASV01	Volcano	0	0	0	81	81
42	A2AMD01	Conventional	0	0	17	4	21
43	G1BSV05	Volcano	0	0	217	5	222
44	G1ASV05	Volcano	0	9	36	9	54
45	G2CSV05	Volcano	0	0	3	205	208
46	G2ASV01	Volcano	3	26	156	114	299
47	M2ASV01	Volcano	0	2	68	184	254
48	A2BSV01	Volcano	0	2	58	30	90
			44	656	1974	2422	5096
		Overall Accuracy =	**0.86%**	**12.87%**	**38.74%**	**47.53%**	

% NL	% P	% L	% VL
0.00%	7.89%	65.79%	26.32%
0.00%	10.00%	90.00%	0.00%
0.00%	20.90%	35.07%	44.03%
0.00%	41.04%	5.20%	53.76%
3.66%	0.41%	41.46%	54.47%
0.00%	0.00%	2.27%	97.73%
0.00%	43.10%	54.14%	2.76%
2.03%	6.60%	90.86%	0.51%
11.83%	19.35%	68.82%	0.00%
0.00%	0.00%	0.00%	100.00%
4.40%	7.55%	44.03%	44.03%
0.00%	0.00%	0.00%	100.00%
0.00%	32.68%	64.05%	3.27%
0.58%	18.02%	1.16%	80.23%
0.00%	0.00%	100.00%	0.00%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	100.00%	0.00%
3.16%	0.70%	16.84%	79.30%
0.00%	0.84%	47.90%	51.26%
0.00%	0.00%	65.82%	34.18%
0.00%	22.30%	25.90%	51.80%
0.00%	0.00%	38.83%	61.17%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	98.39%	1.61%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	80.95%	19.05%
0.00%	0.00%	97.75%	2.25%
0.00%	16.67%	66.67%	16.67%
0.00%	0.00%	1.44%	98.56%
1.00%	8.70%	52.17%	38.13%
0.00%	0.79%	26.77%	72.44%
0.00%	2.22%	64.44%	33.33%

Model Run #16
Fort Irwin
Minefield Dataset with Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	PT13	Point	3	20	55	0	78	3.85%	25.64%	70.51%	0.00%
1	PT29	Point	0	0	78	0	78	0.00%	0.00%	100.00%	0.00%
2	PT32	Point	0	0	78	0	78	0.00%	0.00%	100.00%	0.00%
3	PT14	Point	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
4	PT15	Point	0	0	0	4	4	0.00%	0.00%	0.00%	100.00%
5	PT16	Point	0	3	1	0	4	0.00%	75.00%	25.00%	0.00%
6	PT22	Point	0	0	1	3	4	0.00%	0.00%	25.00%	75.00%
7	PT36	Point	0	0	2	2	4	0.00%	0.00%	50.00%	50.00%
8	PT1	Point	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
9	PT2	Point	0	0	3	0	3	0.00%	0.00%	100.00%	0.00%
10	MF4-1	Conventional	0	4	45	0	49	0.00%	8.16%	91.84%	0.00%
11	MF4-2	Conventional	0	0	0	187	187	0.00%	0.00%	0.00%	100.00%
12	MF4-3	Conventional	0	4	30	3	37	0.00%	10.81%	81.08%	8.11%
13	MF4-5	Conventional	0	0	0	70	70	0.00%	0.00%	0.00%	100.00%
14	MF4-6	Conventional	0	0	431	154	585	0.00%	0.00%	73.68%	26.32%
15	MF4-7	Conventional	0	0	1	30	31	0.00%	0.00%	3.23%	96.77%
16	MF4-8	Conventional	0	0	0	61	61	0.00%	0.00%	0.00%	100.00%
17	MF4-9	Conventional	0	0	3	24	27	0.00%	0.00%	11.11%	88.89%
18	MF4-10	Conventional	20	0	0	58	78	25.64%	0.00%	0.00%	74.36%
19	MF4-11	Conventional	0	0	45	101	146	0.00%	0.00%	30.82%	69.18%
20	MF4-12	Conventional	0	0	0	40	40	0.00%	0.00%	0.00%	100.00%
21	MF4-13	Conventional	0	0	0	36	36	0.00%	0.00%	0.00%	100.00%
22	MF4-14	Conventional	2	3	37	0	42	4.76%	7.14%	88.10%	0.00%
23	MF4-15	Conventional	0	1	255	215	471	0.00%	0.21%	54.14%	45.65%
24	MF4-4	Conventional	0	0	0	52	52	0.00%	0.00%	0.00%	100.00%
25	MF2	Volcano	0	62	90	0	152	0.00%	40.79%	59.21%	0.00%
26	MF6	Volcano	0	11	75	6	92	0.00%	11.96%	81.52%	6.52%
27	MF7	Volcano	0	0	93	0	93	0.00%	0.00%	100.00%	0.00%
28	MF8	Volcano	0	0	157	0	157	0.00%	0.00%	100.00%	0.00%
29	MF9	Volcano	0	0	4	156	160	0.00%	0.00%	2.50%	97.50%
30	MF10	Volcano	2	0	46	78	126	1.59%	0.00%	36.51%	61.90%
31	MF11	Volcano	0	0	23	94	117	0.00%	0.00%	19.66%	80.34%
32	MF12	Volcano	2	2	74	80	158	1.27%	1.27%	46.84%	50.63%
33	MF26	Volcano	0	35	162	147	344	0.00%	10.17%	47.09%	42.73%
34	MF27	Volcano	0	34	55	23	112	0.00%	30.36%	49.11%	20.54%
35	MF28	Volcano	0	0	16	144	160	0.00%	0.00%	10.00%	90.00%
36	MF29	Volcano	0	9	29	0	38	0.00%	23.68%	76.32%	0.00%
37	MF30	Volcano	0	4	74	71	149	0.00%	2.68%	49.66%	47.65%
38	MF31	Volcano	0	3	86	56	145	0.00%	2.07%	59.31%	38.62%
39	MF4,32	Volcano	0	1	142	5	148	0.00%	0.68%	95.95%	3.38%
40	MF5	Volcano	0	14	131	0	145	0.00%	9.66%	90.34%	0.00%
41	MF34	Volcano	0	14	87	57	158	0.00%	8.86%	55.06%	36.08%
42	MF35	Volcano	0	0	111	35	146	0.00%	0.00%	76.03%	23.97%
43	MF36	Volcano	0	5	74	48	127	0.00%	3.94%	58.27%	37.80%
44	MF1	Volcano	0	14	101	20	135	0.00%	10.37%	74.81%	14.81%
45	MF41	Volcano	2	113	17	0	132	1.52%	85.61%	12.88%	0.00%
46	MF13	Volcano	0	0	66	3	69	0.00%	0.00%	95.65%	4.35%
47	MF14,37	Volcano	3	24	77	7	111	2.70%	21.62%	69.37%	6.31%
48	MF44	Volcano	0	9	56	0	65	0.00%	13.85%	86.15%	0.00%
49	MF15	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
50	MF16,17,18	Volcano	0	0	186	227	413	0.00%	0.00%	45.04%	54.96%
51	MF50,22,21	Volcano	0	0	15	249	264	0.00%	0.00%	5.68%	94.32%
52	MF23	Volcano	0	0	57	2	59	0.00%	0.00%	96.61%	3.39%
53	MF24	Volcano	0	0	42	36	78	0.00%	0.00%	53.85%	46.15%
54	MF53	Volcano	0	0	21	47	68	0.00%	0.00%	30.88%	69.12%
55	MF19,47,20,55	Volcano	0	24	281	306	611	0.00%	3.93%	45.99%	50.08%
			34	413	3598	2937	6982				

Overall Accuracy = **0.49%** **5.92%** **51.53%** **42.07%**

Model Run #16
Fort Irwin
Minefield Dataset without Point Minefields

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
10	MF4-1	Conventional	0	4	45	0	49	0.00%	8.16%	91.84%	0.00%
11	MF4-2	Conventional	0	0	0	187	187	0.00%	0.00%	0.00%	100.00%
12	MF4-3	Conventional	0	4	30	3	37	0.00%	10.81%	81.08%	8.11%
13	MF4-5	Conventional	0	0	0	70	70	0.00%	0.00%	0.00%	100.00%
14	MF4-6	Conventional	0	0	431	154	585	0.00%	0.00%	73.68%	26.32%
15	MF4-7	Conventional	0	0	1	30	31	0.00%	0.00%	3.23%	96.77%
16	MF4-8	Conventional	0	0	0	61	61	0.00%	0.00%	0.00%	100.00%
17	MF4-9	Conventional	0	0	3	24	27	0.00%	0.00%	11.11%	88.89%
18	MF4-10	Conventional	20	0	0	58	78	25.64%	0.00%	0.00%	74.36%
19	MF4-11	Conventional	0	0	45	101	146	0.00%	0.00%	30.82%	69.18%
20	MF4-12	Conventional	0	0	0	40	40	0.00%	0.00%	0.00%	100.00%
21	MF4-13	Conventional	0	0	0	36	36	0.00%	0.00%	0.00%	100.00%
22	MF4-14	Conventional	2	3	37	0	42	4.76%	7.14%	88.10%	0.00%
23	MF4-15	Conventional	0	1	255	215	471	0.00%	0.21%	54.14%	45.65%
24	MF4-4	Conventional	0	0	0	52	52	0.00%	0.00%	0.00%	100.00%
25	MF2	Volcano	0	62	90	0	152	0.00%	40.79%	59.21%	0.00%
26	MF6	Volcano	0	11	75	6	92	0.00%	11.96%	81.52%	6.52%
27	MF7	Volcano	0	0	93	0	93	0.00%	0.00%	100.00%	0.00%
28	MF8	Volcano	0	0	157	0	157	0.00%	0.00%	100.00%	0.00%
29	MF9	Volcano	0	0	4	156	160	0.00%	0.00%	2.50%	97.50%
30	MF10	Volcano	2	0	46	78	126	1.59%	0.00%	36.51%	61.90%
31	MF11	Volcano	0	0	23	94	117	0.00%	0.00%	19.66%	80.34%
32	MF12	Volcano	2	2	74	80	158	1.27%	1.27%	46.84%	50.63%
33	MF26	Volcano	0	35	162	147	344	0.00%	10.17%	47.09%	42.73%
34	MF27	Volcano	0	34	55	23	112	0.00%	30.36%	49.11%	20.54%
35	MF28	Volcano	0	0	16	144	160	0.00%	0.00%	10.00%	90.00%
36	MF29	Volcano	0	9	29	0	38	0.00%	23.68%	76.32%	0.00%
37	MF30	Volcano	0	4	74	71	149	0.00%	2.68%	49.66%	47.65%
38	MF31	Volcano	0	3	86	56	145	0.00%	2.07%	59.31%	38.62%
39	MF4,32	Volcano	0	1	142	5	148	0.00%	0.68%	95.95%	3.38%
40	MF5	Volcano	0	14	131	0	145	0.00%	9.66%	90.34%	0.00%
41	MF34	Volcano	0	14	87	57	158	0.00%	8.86%	55.06%	36.08%
42	MF35	Volcano	0	0	111	35	146	0.00%	0.00%	76.03%	23.97%
43	MF36	Volcano	0	5	74	48	127	0.00%	3.94%	58.27%	37.80%
44	MF1	Volcano	0	14	101	20	135	0.00%	10.37%	74.81%	14.81%
45	MF41	Volcano	2	113	17	0	132	1.52%	85.61%	12.88%	0.00%
46	MF13	Volcano	0	0	66	3	69	0.00%	0.00%	95.65%	4.35%
47	MF14,37	Volcano	3	24	77	7	111	2.70%	21.62%	69.37%	6.31%
48	MF44	Volcano	0	9	56	0	65	0.00%	13.85%	86.15%	0.00%
49	MF15	Volcano	0	0	79	0	79	0.00%	0.00%	100.00%	0.00%
50	MF16,17,18	Volcano	0	0	186	227	413	0.00%	0.00%	45.04%	54.96%
51	MF50,22,21	Volcano	0	0	15	249	264	0.00%	0.00%	5.68%	94.32%
52	MF23	Volcano	0	0	57	2	59	0.00%	0.00%	96.61%	3.39%
53	MF24	Volcano	0	0	42	36	78	0.00%	0.00%	53.85%	46.15%
54	MF53	Volcano	0	0	21	47	68	0.00%	0.00%	30.88%	69.12%
55	MF19,47,20,55	Volcano	0	24	281	306	611	0.00%	3.93%	45.99%	50.08%
			31	390	3374	2928	6723				

Overall Accuracy =	**0.46%**	**5.80%**	**50.19%**	**43.55%**

Model Summary Statistics for Fort Irwin

Minefield Likelihood Surface Summary Statistics
Fort Irwin

MODEL RUN #1 Used VITD Slope

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary

like1_c_r	pixels	km2	acres
Total Pixels=	2,860,818	2,575	636,243
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	1,083,861	37.89%	1,379	21.91%	
Possible	> 0 - 33%	608,630	21.27%	386	6.13%	
Likely	> 33 - 66%	818,741	28.62%	1,829	29.05%	1.02
Very Likely	> 66 - 100%	349,586	12.22%	2,701	42.91%	3.51
		2,860,818	100.00%	6,295	100.00%	4.53

11 of 49 minefields fail (>50% of the minefield within "Not Likely")
6 of the 11 are point minefields
22% failure rate (78% pass rate)

MODEL RUN #1 Used VITD Slope

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary ***Without Point Minefield Data***

like1_c_r	pixels	km2	acres
Total Pixels=	2,860,818	2,575	636,243
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	1,083,861	37.89%	685	13.44%	
Possible	> 0 - 33%	608,630	21.27%	253	4.96%	
Likely	> 33 - 66%	818,741	28.62%	1,628	31.95%	1.12
Very Likely	> 66 - 100%	349,586	12.22%	2,530	49.65%	4.06
		2,860,818	100.00%	5,096	100.00%	5.18

5 of 33 minefields fail (>50% of the minefield within "Not Likely)

15% failure rate (85% pass rate)

MODEL RUN #2 Adjusted MLS Scores of Trafficability, Transportation, and Visibility

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary

like2_c_r	pixels	km2	acres
Total Pixels=	2,860,818	2,575	636,243
mf pixels=	6,306		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	219,811	7.68%	69	1.09%	
Possible	> 0 - 33%	762,191	26.64%	695	11.02%	
Likely	> 33 - 66%	1,422,023	49.71%	2,702	42.85%	0.86
Very Likely	> 66 - 100%	456,793	15.97%	2,840	45.04%	2.82
		2,860,818	100.00%	6,306	100.00%	3.68

1 of 49 minefields fail (>50% of the minefield within "Not Likely")
1 poorly positioned point minefield
2% failure rate (98% pass rate)

MODEL RUN #2 Adjusted MLS Scores of Trafficability, Transportation, and Visibility

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary ***Without Point Minefield Data***

like2_c_r	pixels	km2	acres
Total Pixels=	2,860,818	2,575	636,243
mf pixels=	5,101		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	219,811	7.68%	21	0.41%	
Possible	> 0 - 33%	762,191	26.64%	416	8.16%	
Likely	> 33 - 66%	1,422,023	49.71%	2,015	39.50%	0.79
Very Likely	> 66 - 100%	456,793	15.97%	2,649	51.93%	3.25
		2,860,818	100.00%	5,101	100.00%	4.05

No minefields fail

MODEL RUN #3 Returned to VITD Slope and adjusted MLS score for Visibility (10 to 5)

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary

like4_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	219,766	7.68%	70	1.11%	
Possible	> 0 - 33%	760,626	26.59%	677	10.75%	
Likely	> 33 - 66%	1,128,679	39.46%	2,093	33.25%	0.84
Very Likely	> 66 - 100%	751,454	26.27%	3,455	54.88%	2.09
		2,860,525	100.00%	6,295	100.00%	2.93

1 of 49 minefields fail (>50% of the minefield within "Not Likely")
1 poorly positioned point minefield
2% failure rate (98% pass rate)

MODEL RUN #3 Returned to VITD Slope and adjusted MLS score for Visibility (10 to 5)

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary ***Without Point Minefield Data***

like4_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	219,766	7.68%	18	0.35%	
Possible	> 0 - 33%	760,626	26.59%	426	8.36%	
Likely	> 33 - 66%	1,128,679	39.46%	1,401	27.49%	0.70
Very Likely	> 66 - 100%	751,454	26.27%	3,251	63.80%	2.43
		2,860,525	100.00%	5,096	100.00%	3.13

No minefields fail

MODEL RUN #4 Used DTED2 Slope instead of VITD Slope

Minefield Likelihood for Fort Irwin - 30m Resolution

Clipped to NTC Boundary

like3_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	78	1.24%	
Possible	> 0 - 33%	838,894	29.33%	651	10.34%	
Likely	> 33 - 66%	1,438,471	50.29%	2,808	44.61%	0.89
Very Likely	> 66 - 100%	432,143	15.11%	2,758	43.81%	2.90
		2,860,525	100.00%	6,295	100.00%	3.79

No minefields fail

MODEL RUN #4 Used DTED2 Slope instead of VITD Slope

Minefield Likelihood for Fort Irwin - 30m Resolution

Clipped to NTC Boundary ***Without Point Minefield Data***

like3_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	44	0.86%	
Possible	> 0 - 33%	838,894	29.33%	366	7.18%	
Likely	> 33 - 66%	1,438,471	50.29%	2,112	41.44%	0.82
Very Likely	> 66 - 100%	432,143	15.11%	2,574	50.51%	3.34
		2,860,525	100.00%	5,096	100.00%	4.17

No minefields fail

Minefield Likelihood Surface Summary Statistics
Fort Irwin

MODEL RUN #5 Used Trafficability Layer created by using DTED2 Slope

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary

like5_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	219,766	7.68%	70	1.11%	
Possible	> 0 - 33%	769,922	26.92%	677	10.75%	
Likely	> 33 - 66%	1,372,507	47.98%	2,839	45.10%	0.94
Very Likely	> 66 - 100%	498,330	17.42%	2,709	43.03%	2.47
		2,860,525	100.00%	6,295	100.00%	3.41

1 of 49 minefields fail (>50% of the minefield within "Not Likely")
1 poorly positioned point minefield
2% failure rate (98% pass rate)

MODEL RUN #5 Used Trafficability Layer created by using DTED2 Slope

Minefield Likelihood for Fort Irwin - 30m Resolution
Using VITD Slope Layer & DTED2 30m Digital Elevation Model
Clipped to NTC Boundary ***Without Point Minefield Data***

like5_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	219,766	7.68%	18	0.35%	
Possible	> 0 - 33%	769,922	26.92%	437	8.58%	
Likely	> 33 - 66%	1,372,507	47.98%	2,114	41.48%	0.86
Very Likely	> 66 - 100%	498,330	17.42%	2,527	49.59%	2.85
		2,860,525	100.00%	5,096	100.00%	3.71

No minefields fail

MODEL RUN #6 Used DTED2 Slope Layer combined with new Trafficability layer

Minefield Likelihood for Fort Irwin - 30m Resolution

Clipped to NTC Boundary

like7_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	78	1.24%	
Possible	> 0 - 33%	1,083,537	37.88%	682	10.83%	
Likely	> 33 - 66%	1,234,285	43.15%	2,893	45.96%	1.07
Very Likely	> 66 - 100%	391,686	13.69%	2,642	41.97%	3.07
		2,860,525	100.00%	6,295	100.00%	4.13

No minefields fail

MODEL RUN #6 Used DTED2 Slope Layer combined with new Trafficability layer

Minefield Likelihood for Fort Irwin - 30m Resolution

Clipped to NTC Boundary ***Without Point Minefield Data***

like7_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	44	0.86%	
Possible	> 0 - 33%	1,083,537	37.88%	380	7.46%	
Likely	> 33 - 66%	1,234,285	43.15%	2,201	43.19%	1.00
Very Likely	> 66 - 100%	391,686	13.69%	2,471	48.49%	3.54
		2,860,525	100.00%	5,096	100.00%	4.54

No minefields fail

MODEL RUN #7 L9 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like15_c_r	pixels	km2	acres
Total Pixels=	2,860,376	2,574	636,145
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	112,352	3.93%	67	1.06%	
Possible	> 0 - 33%	1,084,828	37.93%	714	11.34%	
Likely	> 33 - 66%	1,248,256	43.64%	2,875	45.67%	1.05
Very Likely	> 66 - 100%	414,940	14.51%	2,639	41.92%	2.89
		2,860,376	100.00%	6,295	100.00%	3.94

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like14_c_r	pixels	km2	acres
Total Pixels=	2,860,376	2,574	636,145
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	112,352	3.93%	33	0.65%	
Possible	> 0 - 33%	1,084,828	37.93%	411	8.07%	
Likely	> 33 - 66%	1,248,256	43.64%	2,182	42.82%	0.98
Very Likely	> 66 - 100%	414,940	14.51%	2,470	48.47%	3.34
		2,860,376	100.00%	5,096	100.00%	4.32

No minefields fail

MODEL RUN #8 L10 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like16_c_r	pixels	km2	acres
Total Pixels=	2,860,517	2,574	636,176
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	150,860	5.27%	85	1.35%	
Possible	> 0 - 33%	817,264	28.57%	905	14.38%	
Likely	> 33 - 66%	1,295,712	45.30%	1,871	29.72%	0.66
Very Likely	> 66 - 100%	596,681	20.86%	3,434	54.55%	2.62
		2,860,517	100.00%	6,295	100.00%	3.27

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like14_c_r	pixels	km2	acres
Total Pixels=	2,860,517	2,574	636,176
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	150,860	5.27%	51	1.00%	
Possible	> 0 - 33%	817,264	28.57%	419	8.22%	
Likely	> 33 - 66%	1,295,712	45.30%	1,383	27.14%	0.60
Very Likely	> 66 - 100%	596,681	20.86%	3,243	63.64%	3.05
		2,860,517	100.00%	5,096	100.00%	3.65

No minefields fail

MODEL RUN #9 L8 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like14_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	820,341	28.68%	360	5.72%	
Possible	> 0 - 33%	712,925	24.92%	738	11.72%	
Likely	> 33 - 66%	966,185	33.78%	2,561	40.68%	1.20
Very Likely	> 66 - 100%	361,074	12.62%	2,636	41.87%	3.32
		2,860,525	100.00%	6,295	100.00%	4.52

2 of 49 minefields fail (>50% of the minefield within "Not Likely")
4% failure rate (96% pass rate)

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like14_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	820,341	28.68%	258	5.06%	
Possible	> 0 - 33%	712,925	24.92%	388	7.61%	
Likely	> 33 - 66%	966,185	33.78%	1,990	39.05%	1.16
Very Likely	> 66 - 100%	361,074	12.62%	2,460	48.27%	3.82
		2,860,525	100.00%	5,096	100.00%	4.98

1 of 33 minefields fail (>50% of the minefield within "Not Likely)
3% failure rate (97% pass rate)

Minefield Likelihood Surface Summary Statistics
Fort Irwin

MODEL RUN #10 L11 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like17_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	78	1.24%	
Possible	> 0 - 33%	1,222,493	42.74%	533	8.47%	
Likely	> 33 - 66%	1,061,627	37.11%	2,945	46.78%	1.26
Very Likely	> 66 - 100%	425,388	14.87%	2,739	43.51%	2.93
		2,860,525	100.00%	6,295	100.00%	4.19

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like14_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	44	0.86%	
Possible	> 0 - 33%	1,222,493	42.74%	336	6.59%	
Likely	> 33 - 66%	1,061,627	37.11%	2,230	43.76%	1.18
Very Likely	> 66 - 100%	425,388	14.87%	2,486	48.78%	3.28
		2,860,525	100.00%	5,096	100.00%	4.46

No minefields fail

MODEL RUN #11 L12 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like18_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	78	1.24%	
Possible	> 0 - 33%	807,880	28.24%	716	11.37%	
Likely	> 33 - 66%	976,857	34.15%	1,863	29.59%	0.87
Very Likely	> 66 - 100%	924,771	32.33%	3,638	57.79%	1.79
		2,860,525	100.00%	6,295	100.00%	2.65

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like14_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	44	0.86%	
Possible	> 0 - 33%	807,880	28.24%	438	8.59%	
Likely	> 33 - 66%	976,857	34.15%	1,277	25.06%	0.73
Very Likely	> 66 - 100%	924,771	32.33%	3,337	65.48%	2.03
		2,860,525	100.00%	5,096	100.00%	2.76

No minefields fail

MODEL RUN #12 L4 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like10_c_r	pixels	km2	acres
Total Pixels=	2,860,683	2,575	636,213
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	1,043,215	36.47%	1,359	21.59%	
Possible	> 0 - 33%	57	0.00%	0	0.00%	
Likely	> 33 - 66%	1,514,086	52.93%	4,018	63.83%	1.21
Very Likely	> 66 - 100%	303,325	10.60%	918	14.58%	1.38
		2,860,683	100.00%	6,295	100.00%	2.58

15 of 49 minefields fail (>50% of the minefield within "Not Likely")
31% failure rate (69% pass rate)

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like10_c_r	pixels	km2	acres
Total Pixels=	2,860,683	2,575	636,213
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	1,043,215	36.47%	656	12.87%	
Possible	> 0 - 33%	57	0.00%	0	0.00%	
Likely	> 33 - 66%	1,514,086	52.93%	3,633	71.29%	1.35
Very Likely	> 66 - 100%	303,325	10.60%	807	15.84%	1.49
		2,860,683	100.00%	5,096	100.00%	2.84

6 of 33 minefields fail (>50% of the minefield within "Not Likely)
18% failure rate (82% pass rate)

MODEL RUN #13 L5 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like11_c_r	pixels	km2	acres
Total Pixels=	2,860,517	2,574	636,176
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	944,206	33.01%	914	14.52%	
Possible	> 0 - 33%	1,067,900	37.33%	1,392	22.11%	
Likely	> 33 - 66%	310,681	10.86%	566	8.99%	0.83
Very Likely	> 66 - 100%	537,730	18.80%	3,423	54.38%	2.89
		2,860,517	100.00%	6,295	100.00%	3.72

8 of 49 minefields fail (>50% of the minefield within "Not Likely")
16% failure rate (84% pass rate)

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like11_c_r	pixels	km2	acres
Total Pixels=	2,860,517	2,574	636,176
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	944,206	33.01%	437	8.58%	
Possible	> 0 - 33%	1,067,900	37.33%	1,141	22.39%	
Likely	> 33 - 66%	310,681	10.86%	286	5.61%	0.52
Very Likely	> 66 - 100%	537,730	18.80%	3,232	63.42%	3.37
		2,860,517	100.00%	5,096	100.00%	3.89

4 of 33 minefields fail (>50% of the minefield within "Not Likely)
12% failure rate (88% pass rate)

MODEL RUN #14 L2 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like8_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	78	1.24%	
Possible	> 0 - 33%	816,124	28.53%	897	14.25%	
Likely	> 33 - 66%	1,372,605	47.98%	2,639	41.92%	0.87
Very Likely	> 66 - 100%	520,779	18.21%	2,681	42.59%	2.34
		2,860,525	100.00%	6,295	100.00%	3.21

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like8_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	44	0.86%	
Possible	> 0 - 33%	816,124	28.53%	474	9.30%	
Likely	> 33 - 66%	1,372,605	47.98%	2,082	40.86%	0.85
Very Likely	> 66 - 100%	520,779	18.21%	2,496	48.98%	2.69
		2,860,525	100.00%	5,096	100.00%	3.54

No minefields fail

Minefield Likelihood Surface Summary Statistics
Fort Irwin

MODEL RUN #15 L6 Weighting

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary

like12_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,295		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	78	1.24%	
Possible	> 0 - 33%	1,444,815	50.51%	902	14.33%	
Likely	> 33 - 66%	766,868	26.81%	2,645	42.02%	1.57
Very Likely	> 66 - 100%	497,825	17.40%	2,670	42.41%	2.44
		2,860,525	100.00%	6,295	100.00%	4.00

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer; readjusted Vis Layer MLS 5 to 10; used new trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like12_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	5,096		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	44	0.86%	
Possible	> 0 - 33%	1,444,815	50.51%	656	12.87%	
Likely	> 33 - 66%	766,868	26.81%	1,974	38.74%	1.44
Very Likely	> 66 - 100%	497,825	17.40%	2,422	47.53%	2.73
		2,860,525	100.00%	5,096	100.00%	4.18

No minefields fail

MODEL RUN #16 New Minefield Data - Model #6

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer combined with new Trafficability layer
Clipped to NTC Boundary

like7_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,982		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	34	0.49%	
Possible	> 0 - 33%	1,083,537	37.88%	413	5.92%	
Likely	> 33 - 66%	1,234,285	43.15%	3,598	51.53%	1.19
Very Likely	> 66 - 100%	391,686	13.69%	2,937	42.07%	3.07
		2,860,525	100.00%	6,982	100.00%	4.27

No minefields fail

Minefield Likelihood for Fort Irwin - 30m Resolution
Used DTED2 Slope Layer combined with new Trafficability layer
Clipped to NTC Boundary ***Without Point Minefield Data***

like7_c_r	pixels	km2	acres
Total Pixels=	2,860,525	2,574	636,178
mf pixels=	6,723		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	151,017	5.28%	31	0.46%	
Possible	> 0 - 33%	1,083,537	37.88%	390	5.80%	
Likely	> 33 - 66%	1,234,285	43.15%	3,374	50.19%	1.16
Very Likely	> 66 - 100%	391,686	13.69%	2,928	43.55%	3.18
		2,860,525	100.00%	6,723	100.00%	4.34

No minefields fail

Model Run Statistics for Fort Polk

Model Run #1
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	56TF01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
1	56TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
2	56TF03	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
3	57TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
4	57TF03	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
5	57TF04	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
6	57TF05	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
7	57TF06	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
8	57TF08	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
9	57TF10	Point - Conventional	0	0	1	1	2	0.00%	0.00%	50.00%	50.00%
10	55BD02	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
11	55BD01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
12	B57TF13	Point - Conventional	0	0	2	9	11	0.00%	0.00%	18.18%	81.82%
13	B56TF01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
14	B56TF02	Point - Conventional	1	0	0	1	2	50.00%	0.00%	0.00%	50.00%
15	B57TF12	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
16	B57TF15	Point - Conventional	0	0	0	2	2	0.00%	0.00%	0.00%	100.00%
17	B55TF01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
18	B55TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
19	B55TF03	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
20	56BD01	Conventional	0	0	71	3	74	0.00%	0.00%	95.95%	4.05%
21	57TF01	Conventional	0	0	119	10	129	0.00%	0.00%	92.25%	7.75%
			1	0	231	26	258				
		Overall Accuracy =	**0.39%**	**0.00%**	**89.53%**	**10.08%**					

1-merged_mf

Model Run #2
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	2	0	2
1	56TF02	Point - Conventional	0	0	2	0	2
2	56TF03	Point - Conventional	0	0	2	0	2
3	57TF02	Point - Conventional	0	1	1	0	2
4	57TF03	Point - Conventional	0	0	2	0	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	4	0	4
7	57TF06	Point - Conventional	0	0	2	0	2
8	57TF08	Point - Conventional	0	0	2	0	2
9	57TF10	Point - Conventional	0	0	1	1	2
10	55BD02	Point - Conventional	0	0	4	0	4
11	55BD01	Point - Conventional	0	0	2	0	2
12	B57TF13	Point - Conventional	0	0	2	9	11
13	B56TF01	Point - Conventional	0	0	2	0	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	2	0	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	2	0	2
18	B55TF02	Point - Conventional	0	0	2	0	2
19	B55TF03	Point - Conventional	0	0	4	0	4
20	56BD01	Conventional	0	0	71	3	74
21	57TF01	Conventional	0	0	123	6	129
			1	1	234	22	258
		Overall Accuracy =	**0.39%**	**0.39%**	**90.70%**	**8.53%**	

% NL	% P	% L	% VL
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	50.00%	50.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	18.18%	81.82%
0.00%	0.00%	100.00%	0.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	95.95%	4.05%
0.00%	0.00%	95.35%	4.65%

Model Run #3
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	2	0	2
1	56TF02	Point - Conventional	0	0	2	0	2
2	56TF03	Point - Conventional	0	0	2	0	2
3	57TF02	Point - Conventional	0	1	1	0	2
4	57TF03	Point - Conventional	0	0	2	0	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	4	0	4
7	57TF06	Point - Conventional	0	0	2	0	2
8	57TF08	Point - Conventional	0	0	2	0	2
9	57TF10	Point - Conventional	0	0	1	1	2
10	55BD02	Point - Conventional	0	0	4	0	4
11	55BD01	Point - Conventional	0	0	2	0	2
12	B57TF13	Point - Conventional	0	0	2	9	11
13	B56TF01	Point - Conventional	0	0	2	0	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	2	0	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	2	0	2
18	B55TF02	Point - Conventional	0	0	2	0	2
19	B55TF03	Point - Conventional	0	0	4	0	4
20	56BD01	Conventional	0	0	71	3	74
21	57TF01	Conventional	0	0	123	6	129
			1	1	234	22	258
		Overall Accuracy =	**0.39%**	**0.39%**	**90.70%**	**8.53%**	

% NL	% P	% L	% VL
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	50.00%	50.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	18.18%	81.82%
0.00%	0.00%	100.00%	0.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	95.95%	4.05%
0.00%	0.00%	95.35%	4.65%

Model Run #4
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	0	2	2
1	56TF02	Point - Conventional	0	0	2	0	2
2	56TF03	Point - Conventional	0	0	2	0	2
3	57TF02	Point - Conventional	0	0	2	0	2
4	57TF03	Point - Conventional	0	0	2	0	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	4	0	4
7	57TF06	Point - Conventional	0	0	2	0	2
8	57TF08	Point - Conventional	0	0	2	0	2
9	57TF10	Point - Conventional	0	0	1	1	2
10	55BD02	Point - Conventional	0	0	4	0	4
11	55BD01	Point - Conventional	0	0	2	0	2
12	B57TF13	Point - Conventional	0	0	2	9	11
13	B56TF01	Point - Conventional	0	0	2	0	2
14	B56TF02	Point - Conventional	1	0	1	0	2
15	B57TF12	Point - Conventional	0	0	2	0	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	0	2	2
18	B55TF02	Point - Conventional	0	0	2	0	2
19	B55TF03	Point - Conventional	0	0	4	0	4
20	56BD01	Conventional	0	0	71	3	74
21	57TF01	Conventional	0	0	123	6	129
			1	0	232	25	258
		Overall Accuracy =	**0.39%**	**0.00%**	**89.92%**	**9.69%**	

% NL	% P	% L	% VL
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	18.18%	81.82%
0.00%	0.00%	100.00%	0.00%
50.00%	0.00%	50.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	95.95%	4.05%
0.00%	0.00%	95.35%	4.65%

Model Run #5
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	2	0	2
1	56TF02	Point - Conventional	0	0	2	0	2
2	56TF03	Point - Conventional	0	0	2	0	2
3	57TF02	Point - Conventional	0	2	0	0	2
4	57TF03	Point - Conventional	0	0	2	0	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	4	0	4
7	57TF06	Point - Conventional	0	0	2	0	2
8	57TF08	Point - Conventional	0	0	2	0	2
9	57TF10	Point - Conventional	0	0	1	1	2
10	55BD02	Point - Conventional	0	0	4	0	4
11	55BD01	Point - Conventional	0	0	2	0	2
12	B57TF13	Point - Conventional	0	0	2	9	11
13	B56TF01	Point - Conventional	0	0	2	0	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	2	0	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	2	0	2
18	B55TF02	Point - Conventional	0	0	2	0	2
19	B55TF03	Point - Conventional	0	0	4	0	4
20	56BD01	Conventional	0	0	71	3	74
21	57TF01	Conventional	0	0	123	6	129
			1	2	233	22	258
		Overall Accuracy =	**0.39%**	**0.78%**	**90.31%**	**8.53%**	

% NL	% P	% L	% VL
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	18.18%	81.82%
0.00%	0.00%	100.00%	0.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	95.95%	4.05%
0.00%	0.00%	95.35%	4.65%

Model Run #6
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	56TF01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
1	56TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
2	56TF03	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
3	57TF02	Point - Conventional	0	1	1	0	2	0.00%	50.00%	50.00%	0.00%
4	57TF03	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
5	57TF04	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
6	57TF05	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
7	57TF06	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
8	57TF08	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
9	57TF10	Point - Conventional	0	0	1	1	2	0.00%	0.00%	50.00%	50.00%
10	55BD02	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
11	55BD01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
12	B57TF13	Point - Conventional	0	0	2	9	11	0.00%	0.00%	18.18%	81.82%
13	B56TF01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
14	B56TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
15	B57TF12	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
16	B57TF15	Point - Conventional	0	0	0	2	2	0.00%	0.00%	0.00%	100.00%
17	B55TF01	Point - Conventional	0	0	0	2	2	0.00%	0.00%	0.00%	100.00%
18	B55TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
19	B55TF03	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
20	56BD01	Conventional	0	0	71	3	74	0.00%	0.00%	95.95%	4.05%
21	57TF01	Conventional	0	0	123	6	129	0.00%	0.00%	95.35%	4.65%
			0	1	234	23	258				
		Overall Accuracy =	**0.00%**	**0.39%**	**90.70%**	**8.91%**					

Model Run #7
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	2	0	2
1	56TF02	Point - Conventional	0	0	0	2	2
2	56TF03	Point - Conventional	0	0	0	2	2
3	57TF02	Point - Conventional	0	0	2	0	2
4	57TF03	Point - Conventional	0	0	0	2	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	2	2	4
7	57TF06	Point - Conventional	0	0	0	2	2
8	57TF08	Point - Conventional	0	0	0	2	2
9	57TF10	Point - Conventional	0	0	0	2	2
10	55BD02	Point - Conventional	0	0	0	4	4
11	55BD01	Point - Conventional	0	0	0	2	2
12	B57TF13	Point - Conventional	0	0	0	11	11
13	B56TF01	Point - Conventional	0	0	0	2	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	0	2	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	2	0	2
18	B55TF02	Point - Conventional	0	0	0	2	2
19	B55TF03	Point - Conventional	0	0	0	4	4
20	56BD01	Conventional	0	0	13	61	74
21	57TF01	Conventional	0	0	1	128	129
			1	0	24	233	258
		Overall Accuracy =	**0.39%**	**0.00%**	**9.30%**	**90.31%**	

% NL	% P	% L	% VL
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	17.57%	82.43%
0.00%	0.00%	0.78%	99.22%

Model Run #8
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	2	0	0	2
1	56TF02	Point - Conventional	0	0	0	2	2
2	56TF03	Point - Conventional	0	0	0	2	2
3	57TF02	Point - Conventional	0	2	0	0	2
4	57TF03	Point - Conventional	0	0	0	2	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	2	2	4
7	57TF06	Point - Conventional	0	0	0	2	2
8	57TF08	Point - Conventional	0	0	0	2	2
9	57TF10	Point - Conventional	0	0	0	2	2
10	55BD02	Point - Conventional	0	0	0	4	4
11	55BD01	Point - Conventional	0	0	0	2	2
12	B57TF13	Point - Conventional	0	0	0	11	11
13	B56TF01	Point - Conventional	0	0	0	2	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	0	2	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	2	0	0	2
18	B55TF02	Point - Conventional	0	0	0	2	2
19	B55TF03	Point - Conventional	0	0	0	4	4
20	56BD01	Conventional	0	0	13	61	74
21	57TF01	Conventional	0	0	1	128	129
			1	6	18	233	258
		Overall Accuracy =	**0.39%**	**2.33%**	**6.98%**	**90.31%**	

% NL	% P	% L	% VL
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	17.57%	82.43%
0.00%	0.00%	0.78%	99.22%

Model Run #9
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	2	0	2
1	56TF02	Point - Conventional	0	0	2	0	2
2	56TF03	Point - Conventional	0	0	2	0	2
3	57TF02	Point - Conventional	0	2	0	0	2
4	57TF03	Point - Conventional	0	0	2	0	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	4	0	4
7	57TF06	Point - Conventional	0	0	2	0	2
8	57TF08	Point - Conventional	0	0	2	0	2
9	57TF10	Point - Conventional	0	0	1	1	2
10	55BD02	Point - Conventional	0	0	4	0	4
11	55BD01	Point - Conventional	0	0	1	1	2
12	B57TF13	Point - Conventional	0	0	1	10	11
13	B56TF01	Point - Conventional	0	0	0	2	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	0	2	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	2	0	2
18	B55TF02	Point - Conventional	0	0	2	0	2
19	B55TF03	Point - Conventional	0	0	4	0	4
20	56BD01	Conventional	0	0	68	6	74
21	57TF01	Conventional	0	0	99	30	129
			1	2	200	55	258
		Overall Accuracy =	**0.39%**	**0.78%**	**77.52%**	**21.32%**	

% NL	% P	% L	% VL
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	100.00%	0.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	9.09%	90.91%
0.00%	0.00%	0.00%	100.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	91.89%	8.11%
0.00%	0.00%	76.74%	23.26%

Model Run #10
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total	% NL	% P	% L	% VL
0	56TF01	Point - Conventional	0	2	0	0	2	0.00%	100.00%	0.00%	0.00%
1	56TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
2	56TF03	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
3	57TF02	Point - Conventional	0	2	0	0	2	0.00%	100.00%	0.00%	0.00%
4	57TF03	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
5	57TF04	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
6	57TF05	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
7	57TF06	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
8	57TF08	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
9	57TF10	Point - Conventional	0	0	1	1	2	0.00%	0.00%	50.00%	50.00%
10	55BD02	Point - Conventional	0	0	2	2	4	0.00%	0.00%	50.00%	50.00%
11	55BD01	Point - Conventional	0	0	1	1	2	0.00%	0.00%	50.00%	50.00%
12	B57TF13	Point - Conventional	0	0	1	10	11	0.00%	0.00%	9.09%	90.91%
13	B56TF01	Point - Conventional	0	0	0	2	2	0.00%	0.00%	0.00%	100.00%
14	B56TF02	Point - Conventional	1	0	0	1	2	50.00%	0.00%	0.00%	50.00%
15	B57TF12	Point - Conventional	0	0	0	2	2	0.00%	0.00%	0.00%	100.00%
16	B57TF15	Point - Conventional	0	0	0	2	2	0.00%	0.00%	0.00%	100.00%
17	B55TF01	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
18	B55TF02	Point - Conventional	0	0	2	0	2	0.00%	0.00%	100.00%	0.00%
19	B55TF03	Point - Conventional	0	0	4	0	4	0.00%	0.00%	100.00%	0.00%
20	56BD01	Conventional	0	0	68	6	74	0.00%	0.00%	91.89%	8.11%
21	57TF01	Conventional	0	0	99	30	129	0.00%	0.00%	76.74%	23.26%
			1	4	196	57	258				
		Overall Accuracy =	**0.39%**	**1.55%**	**75.97%**	**22.09%**					

Model Run #11
Fort Polk

MFID_1	LABEL	Minefield Type	Not Likely	Possible	Likely	Very Likely	Total
0	56TF01	Point - Conventional	0	0	2	0	2
1	56TF02	Point - Conventional	0	0	1	1	2
2	56TF03	Point - Conventional	0	0	2	0	2
3	57TF02	Point - Conventional	0	0	2	0	2
4	57TF03	Point - Conventional	0	0	2	0	2
5	57TF04	Point - Conventional	0	0	2	0	2
6	57TF05	Point - Conventional	0	0	4	0	4
7	57TF06	Point - Conventional	0	0	2	0	2
8	57TF08	Point - Conventional	0	0	0	2	2
9	57TF10	Point - Conventional	0	0	1	1	2
10	55BD02	Point - Conventional	0	0	0	4	4
11	55BD01	Point - Conventional	0	0	0	2	2
12	B57TF13	Point - Conventional	0	0	1	10	11
13	B56TF01	Point - Conventional	0	0	0	2	2
14	B56TF02	Point - Conventional	1	0	0	1	2
15	B57TF12	Point - Conventional	0	0	0	2	2
16	B57TF15	Point - Conventional	0	0	0	2	2
17	B55TF01	Point - Conventional	0	0	2	0	2
18	B55TF02	Point - Conventional	0	0	2	0	2
19	B55TF03	Point - Conventional	0	0	2	2	4
20	56BD01	Conventional	0	0	68	6	74
21	57TF01	Conventional	0	0	77	52	129
			1	0	170	87	258
		Overall Accuracy =	**0.39%**	**0.00%**	**65.89%**	**33.72%**	

% NL	% P	% L	% VL
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	9.09%	90.91%
0.00%	0.00%	0.00%	100.00%
50.00%	0.00%	0.00%	50.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	0.00%	100.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	100.00%	0.00%
0.00%	0.00%	50.00%	50.00%
0.00%	0.00%	91.89%	8.11%
0.00%	0.00%	59.69%	40.31%

Model Summary Statistics for Fort Polk

Minefield Likelihood Surface Summary Statistics
Fort Polk

MODEL RUN #1 Used VITD Slope

Minefield Likelihood for Fort Polk - 30m Resolution

Using VITD Slope Layer & USGS 30m Digital Elevation Model

like1_r	pixels	km2	acres
Total Pixels=	517,677	466	115,131
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	76,778	14.83%	1	0.39%	
Possible	> 0 - 33%	7,285	1.41%	0	0.00%	
Likely	> 33 - 66%	393,765	76.06%	231	89.53%	1.18
Very Likely	> 66 - 100%	39,849	7.70%	26	10.08%	1.31
		517,677	100.00%	258	100.00%	

No minefields fail

MODEL RUN #2 Used USGS Slope

Minefield Likelihood for Fort Polk - 30m Resolution

Using VITD Slope Layer & USGS 30m Digital Elevation Model

like2_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	76,833	14.80%	1	0.39%	
Possible	> 0 - 33%	54,936	10.58%	1	0.39%	
Likely	> 33 - 66%	357,135	68.78%	234	90.70%	1.32
Very Likely	> 66 - 100%	30,322	5.84%	22	8.53%	1.46
		519,226	100.00%	258	100.00%	

No minefields fail

MODEL RUN #3 No Hydro

Minefield Likelihood for Fort Polk - 30m Resolution

Using USGS Slope Layer & USGS 30m Digital Elevation Model

like3_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	63,618	12.25%	1	0.39%	
Possible	> 0 - 33%	55,338	10.66%	1	0.39%	
Likely	> 33 - 66%	361,445	69.61%	234	90.70%	1.30
Very Likely	> 66 - 100%	38,825	7.48%	22	8.53%	1.14
		519,226	100.00%	258	100.00%	

No minefields fail

Minefield Likelihood Surface Summary Statistics
Fort Polk

MODEL RUN #4 No Trans

Minefield Likelihood for Fort Polk - 30m Resolution
Using USGS Slope Layer & USGS 30m Digital Elevation Model

like4_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	76,663	14.76%	1	0.39%	
Possible	> 0 - 33%	777	0.15%	0	0.00%	
Likely	> 33 - 66%	414,539	79.84%	232	89.92%	1.13
Very Likely	> 66 - 100%	27,247	5.25%	25	9.69%	1.85
		519,226	100.00%	258	100.00%	2.97

No minefields fail

MODEL RUN #5 No Slope

Minefield Likelihood for Fort Polk - 30m Resolution
Using USGS Slope Layer & USGS 30m Digital Elevation Model

like5_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	77,475	14.92%	1	0.39%	
Possible	> 0 - 33%	151,839	29.24%	2	0.78%	
Likely	> 33 - 66%	263,935	50.83%	233	90.31%	1.78
Very Likely	> 66 - 100%	25,977	5.00%	22	8.53%	1.70
		519,226	100.00%	258	100.00%	

No minefields fail

MODEL RUN #6 No Traffic

Minefield Likelihood for Fort Polk - 30m Resolution
Using USGS Slope Layer & USGS 30m Digital Elevation Model

like6_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	16,081	3.10%	0	0.00%	
Possible	> 0 - 33%	129,119	24.87%	1	0.39%	
Likely	> 33 - 66%	329,323	63.43%	234	90.70%	1.43
Very Likely	> 66 - 100%	44,703	8.61%	23	8.91%	1.04
		519,226	100.00%	258	100.00%	

No minefields fail

Minefield Likelihood Surface Summary Statistics
Fort Polk

MODEL RUN #7 No Vis

Minefield Likelihood for Fort Polk - 30m Resolution
Using USGS Slope Layer & USGS 30m Digital Elevation Model

like7_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	76,833	14.80%	1	0.39%	
Possible	> 0 - 33%	487	0.09%	0	0.00%	
Likely	> 33 - 66%	164,924	31.76%	24	9.30%	0.29
Very Likely	> 66 - 100%	276,982	53.35%	233	90.31%	1.69
		519,226	100.00%	258	100.00%	

No minefields fail

MODEL RUN #8 Weight Trans

Minefield Likelihood for Fort Polk - 30m Resolution
Using USGS Slope Layer & USGS 30m Digital Elevation Model

like8_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	76,833	14.80%	1	0.39%	
Possible	> 0 - 33%	159,802	30.78%	6	2.33%	
Likely	> 33 - 66%	5,172	1.00%	18	6.98%	7.00
Very Likely	> 66 - 100%	277,419	53.43%	233	90.31%	1.69
		519,226	100.00%	258	100.00%	8.69

No minefields fail

MODEL RUN #9 Weight Trans & Traffic

Minefield Likelihood for Fort Polk - 30m Resolution
Using USGS Slope Layer & USGS 30m Digital Elevation Model

like9_r	pixels	km2	acres
Total Pixels=	519,226	467	115,475
mf pixels=	258		

	Range	Pixels	% Land Area	mf pixels	%mf	
Not Likely	< 0%	76,833	14.80%	1	0.39%	
Possible	> 0 - 33%	126,766	24.41%	2	0.78%	
Likely	> 33 - 66%	218,887	42.16%	200	77.52%	1.84
Very Likely	> 66 - 100%	96,740	18.63%	55	21.32%	1.14
		519,226	100.00%	258	100.00%	

No minefields fail

Minefield Likelihood Surface Summary Statistics
Fort Polk

MODEL RUN #10 Weight Trans More than Traffic

Minefield Likelihood for Fort Polk - 30m Resolution

Using USGS Slope Layer & USGS 30m Digital Elevation Model

like10_r	pixels	km2	acres			
Total Pixels=	519,226	467	115,475			
mf pixels=	258					
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**	
Not Likely	< 0%	76,833	14.80%	1	0.39%	
Possible	> 0 - 33%	155,582	29.96%	4	1.55%	
Likely	> 33 - 66%	150,561	29.00%	196	75.97%	2.62
Very Likely	> 66 - 100%	136,250	26.24%	57	22.09%	0.84
		519,226	100.00%	258	100.00%	

No minefields fail

MODEL RUN #11 Weight Trans & Slope

Minefield Likelihood for Fort Polk - 30m Resolution

Using USGS Slope Layer & USGS 30m Digital Elevation Model

like11_r	pixels	km2	acres			
Total Pixels=	519,226	467	115,475			
mf pixels=	258					
	Range	**Pixels**	**% Land Area**	**mf pixels**	**%mf**	
Not Likely	< 0%	76,833	14.80%	1	0.39%	
Possible	> 0 - 33%	8,709	1.68%	0	0.00%	
Likely	> 33 - 66%	227,749	43.86%	170	65.89%	1.50
Very Likely	> 66 - 100%	205,935	39.66%	87	33.72%	0.85
		519,226	100.00%	258	100.00%	

No minefields fail

VITA

Edward Pye Chamberlayne was born in Alexandria, Virginia. He attended Virginia Tech and was a member of the Virginia Tech Corps of Cadets. In 1993, he received his undergraduate degree in Civil Engineering and was commissioned in the Corps of Engineers as a US Army second lieutenant. He has spent the last nine years as a combat engineer and has held the positions of platoon leader, company executive officer, brigade engineer planner, and company commander. During these positions, he has served overseas in Germany, Bosnia-Herzegovina, and in Kuwait. In 1997 and 1998, he attended and received a masters degree in Engineering Management from the University of Missouri at Rolla. He is married to Allison Jane Thorborg and has two children – Emma and Eddie.

He is currently a graduate student at Virginia Tech pursuing a masters degree in Civil Engineering. After graduation, he will be assigned overseas to Germany to serve in the US Army Corps of Engineers Europe District as a project engineer.

He can be contacted about the contents of this thesis at edward.chamberlayne@us.army.mil.

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