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Standard for Ground Vehicle Mobility

E. Alex Baylot, Jr., Burhman Q. Gates, John G. Green, Paul W. Richmond, Niki C. Goerger, George L. Mason, Chris L. Cummins, and Laura S. Bunch

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Final report

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ABSTRACT: Mobility implementation in military models and simulations (M&S) currently is tailored primarily for specific models, leading to inconsistency between models. To assist decision-makers in analysis, acquisition, and training activities, it is necessary to provide and promote consistency among the models.

The NATO Reference Mobility Model (NRMM), Version II, is the Army Battle Command, Simulation and Experimentation Directorate, standard for single vehicle ground movement representation. This report describes the development of an NRMM-based Standard Mobility (STNDMob) Application Programming Interface (API) as a means of readily achieving higher fidelity movement representation by incorporating terrain-limited speeds into M&S.

As described in the report, the STNDMob API, Version 3, includes descriptions of two derivative models: the low-resolution (Level 1) and the medium-resolution (Level 2) capabilities of STNDMob within the tactical/entity fidelity. Each level of resolution has two degrees of fidelity. These levels of resolution are an implementation of the physical models for steady-state speed conditions. As a whole, STNDMob can be classified as a service module that provides vehicle speeds to a vehicle routing service/planner.

Included in the report are descriptions of the input/output data, algorithm process and supporting equations, and example data. Appendixes provide supporting data descriptions, software documentation, and a comparison of STNDMob to NRMM.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	25.4	millimeters
miles (U.S. statute)	1.609347	kilometers
pounds (mass)	0.4535924	kilograms
tons (2,000 pounds, mass)	907.1847	kilograms

Preface

The research reported herein was conducted under the sponsorship of the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology under the 62784/T40/154 project element from fiscal years 2000 to 2003. The project was executed in partnership with the U.S. Army Training and Doctrine Command Analysis Center (TRAC) COMBAT^{XXI} simulation team under the guidance of the Army Battle Command, Simulation, and Experimentation Directorate (BCSED). The authors would like to acknowledge the contributions of the COMBAT^{XXI} team, particularly Mr. Dave Durda and MAJ Simon R. Goerger, regarding design and implementation for the COMBAT^{XXI} simulation model.

This research was conducted by personnel of the U.S. Army Engineer Research and Development Center's (ERDC) Geotechnical and Structures Laboratory (GSL) and North Wind, Inc. Work was conducted under the general supervision of Dr. David W. Pittman, Director, GSL; Dr. Albert J. Bush III, Chief, GSL Engineering Systems and Materials Division; and Dr. William E. Willoughby, Acting Chief, GSL Mobility Systems Branch (MSB). Mr. E. Alex Baylot, Jr., led the overall report development. The report was prepared by Messrs. Baylot, Burhman Q. Gates, Jr., John G. Green, and Chris L. Cummins, and Drs. Niki C. Goerger, George L. Mason, Jr., and Paul W. Richmond, GSL; and Ms. Laura S. Bunch, North Wind, Inc.

COL James R. Rowan, EN, was Commander and Executive Director of ERDC, and Dr. James R. Houston was Director.

1 Introduction

Overview

As computer hardware and models improve and the use of computer models and simulations (M&S) escalates, users subsequently demand more realism, and thus, fidelity requirements tend to increase. Many stand-alone, high-fidelity, engineering-level models have been developed, accepted, and repeatedly used in analyses and studies by the Department of Defense. For example, in the area of ground movement, the NATO Reference Mobility Model (NRMM) Version II is the Army Battle Command, Simulation and Experimentation Directorate (BCSED), standard for single vehicle ground movement representation (Ahlvin and Haley 1992). While representation of ground vehicle mobility in both entity- and aggregate-level M&S has typically been simplified, developing M&S such as COMBAT^{XXI} and OneSAF Objective System (OneSAF) have functional and operational requirements to portray mobility at a higher fidelity. This report describes the development of an NRMM-based Standard Mobility (STNDMob) Application Programming Interface (API) as a means of readily achieving higher fidelity movement representation by incorporating terrain-limited speeds into M&S. The Standard Mobility API is written in Java and uses Extensible Markup Language (XML) for database structures. The U.S. Army Engineer Research and Development Center (ERDC) and the U.S. Army Training and Doctrine Command Analysis Center collaborated early on regarding API development and integration into COMBAT^{XXI} as a test-bed to prove the usability of the API (Baylot et al. 2003). Additionally, versions of the API were provided to OneSAF in FY03 for reuse consideration (Baylot and Goerger 2003, U.S. Army 2002). By providing a standard interface for applications, this work helps reduce the proliferation of differing mobility models, provides access to standard speed prediction algorithms, and promotes reuse.

The ultimate goal is to develop three independent but related APIs to provide NRMM-based terrain-limited speed results to aggregate, tactical/entity, and engineering-level models to support the needs of the M&S community. Figure 1.1 illustrates the suite of STNDMob APIs spanning this hierarchy. Aggregate M&S generally model ground vehicle movement as units rather than modeling the movement of individual vehicle platforms. At the tactical/entity level, ground vehicles are modeled as individual entities. At the engineering level, vehicle dynamics and subsystem components are modeled. These models would support such things as engineering design and issues of importance in the research, development, and acquisition domain of M&S.

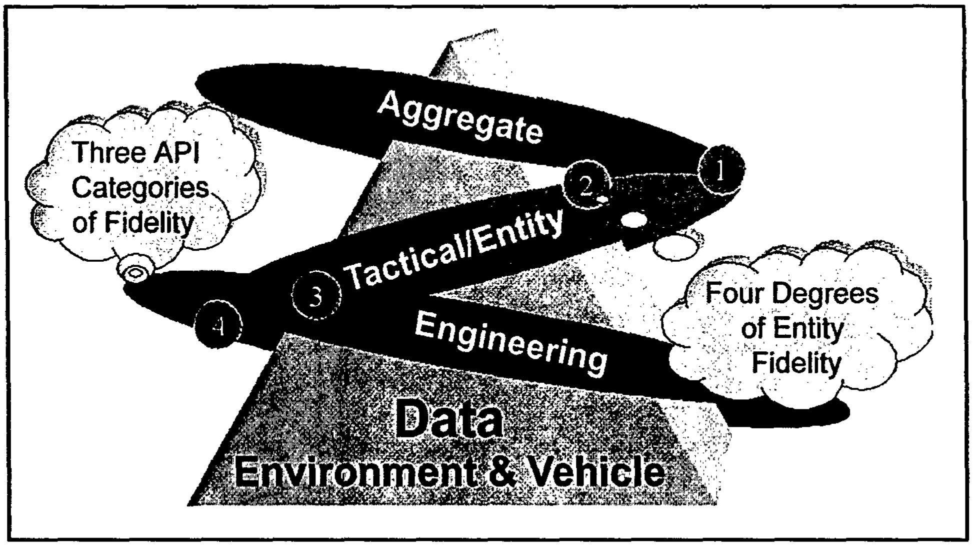

Figure 1.1. The suite of STNDMob APIs will span the hierarchy with expanded degrees of fidelity in the tactical/entity hierarchy level based on terrain and vehicle data

This document describes the implementation of the current STNDMob API, Version 3. This version includes descriptions of two derivative models: the low-resolution (Level 1) and the medium-resolution (Level 2) capabilities of STNDMob within the tactical/entity fidelity. Each level of resolution has two degrees of fidelity. These levels of resolution are an implementation of the physical models for steady-state speed conditions. A diagram showing the current and future hierarchy of the STNDMob API development is given as Figure 1.2. The current STNDMob implementation is shown in bold and italics by the tactical/entity level model as Figure 1.2. Future versions of STNDMob are defined in Figure 1.2 as the aggregate-level and engineering-level representations. Both these additions are expected to support future models and simulations.

The STNDMob API does not handle dynamic conditions, so this document does not discuss dynamic conditions. Some guidance will be given for computing "speed limits" influenced by driver behavior in this document. A series of examples are included to further define how the methodology is employed, providing a means for the developer to verify the model.

Hierarchy

- Aggregate
- *Tactical/Entity*
  - o *Level 1*
    - – ***Fidelity Degree 1***
    - – ***Fidelity Degree 2***
  - o *Level 2*
    - – ***Fidelity Degree 3***
    - – ***Fidelity Degree 4***
- Engineering

Figure 1.2. Structure of model hierarchy

The low-resolution model is based on preprocessed speed predictions from NRMM. Interpolation between slope values is used to allow some sensitivity to variations in terrain characteristics. The medium-resolution model is based on preprocessed tractive force relationships and the forces limiting movement in the environment. The attainable speed resulting from the available traction is determined once the sum of resistant forces and driver/vehicle speed limitations are considered. Additionally, plowing or blade forces are considered when applicable. As a whole, STNDMob can be classified as a service module that provides vehicle speeds to a vehicle routing service/planner.

Scope

This report will describe the two levels of resolution and the corresponding two degrees of fidelity for each level within the tactical/entity fidelity API. Descriptions of the input/output data, algorithm process and supporting equations, and example data will be given. Within the appendixes are supporting data descriptions, software documentation, and a comparison of STNDMob to NRMM.

2 Low-Resolution Mobility Modeling (Level 1)

Overview

The level of representation discussed in this chapter is regarded as low-resolution or Level 1. This modeling method includes accommodations necessary to ensure compatibility with the Warfighter Simulation 2000 (WARSIM) and Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance systems, also known as Battle Command systems. Where possible, equations were reduced to look-up tables to minimize runtime computational loads.

Level 1 has two fidelity level settings. Fidelity Degree 1 refers to using only representative vehicles to model the performance of specific vehicles (Baylot and Gates 2002). Thus, specific vehicles are not explicitly modeled. Fidelity Degree 2 is obtained by modifying the speed of Fidelity Degree 1 by a precomputed speed-reduction factor. The speed-reduction factor scales the performance of the representative vehicle to the specific vehicle based on a ratio of the representative vehicle maximum speed and representative vehicle speed under the given terrain conditions multiplied by the specific vehicle's maximum speed. The assumption, then, is that the specific vehicle's performance is degraded proportionately to the representative vehicle's performance given the different terrain conditions. This methodology was originally applied in WARSIM 2000 for ground vehicle mobility representation.

In Level 1 for both fidelity levels, the terrain features and attributes are mapped to preset levels used to index look-up tables based on climate zone, scenario (dry-normal, wet-slippery, or snow), slope category, obstacle-visibility category, and soil-vegetation category or road category. Other factors, such as soil strength and stem-size distribution for a vegetated area, are needed by NRMM to compute vehicle speed (Ahlvin and Haley 1992). These data are not supported by the current terrain databases developed for M&S or by the National Geospatial and Imagery Agency standard products. In the past years, the ERDC developed inference routines for estimating values for these data elements to support NRMM predictions in environments where the data values were not directly measured or provided in the terrain data (Bullock 1994). These inference routines were used to provide values for terrain attribution for use with the NRMM when computing tables for the STNDMob tactical/entity Level 1.

The overall approach for generating vehicle speeds for Level 1 is as follows. Given a specific vehicle or vehicle bin and information on terrain, the appropriate value in the series of look-up tables can be indexed to provide the application a vehicle speed. The terrain information includes climate zone; dry, wet, or snow condition; soil-vegetation or road surface material; visibility; obstacle spacing; and slope. For Level 1, Fidelity Degree 1, only representative vehicles are used. Thus, if the vehicle in question is not one of the 12 representative vehicles, the vehicle must be binned, or matched, to the closest representative vehicle. For Level 1, Fidelity Degree 2, specific vehicles are represented based on a ratio of performance degradation as determined by the representative vehicle for that mobility bin. The input data for terrain and vehicle and the process for the Fidelity Degrees are discussed in the remainder of this chapter.

Input Data

Terrain

The terrain data (features and attributes) used in STNDMob were determined based on readily available data in the M&S terrain databases and were developed in concert with several M&S developers and terrain database producers. Furthermore, data needed by the mobility model were used as a driver for the set of features and attributes selected. Previous work had been conducted to develop look-up tables for WARSIM 2000 based on NRMM mobility, including the identification of the terrain features and attributes for indices in the look-up tables (U.S. Army 1995). Work was conducted with WARSIM 2000 team members, members of the BCSED MOVE Standards Category, including ERDC, and the U.S. Army Materiel and Systems Analysis Activity (AMSAA).

The terrain data keyed to STNDMob are based on the WARSIM Terrain Common Data Model (TCDM) Surface Trafficability Group Joint Simulations (STGJs) for consistency in M&S (Birkel 1999). The WARSIM TCDM was the basis of the OneSAF Objective System (OOS) Environmental Data Model (EDM) and was extended during OOS EDM development (U.S. Army 2000). The terrain features and attributes related to soil types, vegetation types, and road types did not change; however, the STGJ codes were eliminated from the OOS EDM as they were considered a duplicative feature that could be reconstituted using the soil and vegetation, or road information. The terrain data features and attributes ingested by and used internally in STNDMob are compatible with OOS EDM versions 1.0-1.3, which are the most current. Appendix A contains more detailed information regarding the terrain feature and attribute values used in STNDMob Level 1.

The hierarchical structure of the preset or established terrain features and attributes for which the speed predictions are sensitive is given as *factor*, unit type below. Abbreviations are defined as follows: QB = quantified by, STGJ = Surface Trafficability Group JSIMS, and MLU = mobility look-up. The attributes given in parentheses are the names identified in the OOS EDM.

a. *Climate_Zone* (determines values for Soil_Wetness, Soil_Cone_Index_QB_Measurement, Terrain_Roughness_Root_Mean_Square, Mean_Stem_Diameter, Mean_Stem_Spacing_QB_Stem_Diameter for STGJ Code), index.

b. *Ground* (cross-country or road comes from Terrain_Transportation_Route_Surface_Type, Road_Minimum_Traveled_Way_Width, Path_Count), index.

c. *Condition* (dry, wet, snow: Soil_Wetness & Frozen_Water_Type), index.

d. *STGJ* Codes (combination of Soil_Type, Vegetation_Type, and other factors, mapped to MLU Codes), index.

e. *Vis* (Maximum Visibility Range {four values, road only} derived from weather, sensor range, obscurants, illumination, etc.), index.

f. *VisObs* (Maximum Visibility Range {four values, same as Vis} and Obstacle Spacing {four values} combinations derived from Terrain_Obstacle_Type, Width, Overall_Vertical_Dimension, Row_Distance, Row_Spacing_Interval), index.

g. *Vehicle_Pitch* (use Surface_Slope or pitch along direction of vehicle travel {nine values}), percent.

Vehicle

The 12 representative vehicles bins are given in Table 2.1 (Baylot and Gates 2002).

Table 2.1
Vehicle Bins and Representative Vehicles with Mappings

No.	Vehicle	OOS/WARSIM Name	CCTT-SAF
1	M1A1	High-Mobility Tracked	High-Mobility Tracked
2	M270 MLRS	Medium-Mobility Tracked	Good-Mobility Tracked
3	M60 AVLB	Low-Mobility Tracked	Low-Mobility Tracked
4	M1084 MTV	High-Mobility Wheeled	High-Mobility Wheeled
5	M985 HEMTT	Medium-Mobility Wheeled	Low-Mobility Wheeled
6	M917 Dump Truck	Low-Mobility Wheeled	Not applicable
7	M1084/M1095	High-Mobility Wheeled w/Towed Trailer	Not applicable
8	M985/M989	Medium-Mobility Wheeled w/Towed Trailer	Not applicable
9	M911/M747 HET	Low-Mobility Wheeled w/Towed Trailer	Not applicable
10[1]	M113A2	Tracked ACV	Moderate-Mobility Tracked
11[1]	LAV25	Wheeled ACV	Not applicable
12[1]	Kawasaki ATV (high shock)	Light ATV	Not applicable

[1] Not yet approved by WARSIM, but implemented into JWARS and recommended by Baylot and Gates (2002).

The vehicle data needed to determine bin membership for a specific vehicle and its relationship to the bin's representative vehicle are given below.

a. *Type* (Traction Element: Track or Wheeled), number.

b. *Towing_Trailer* (Attached), number.

c. *Primary_Use* (Truck, Amphibious Combat Vehicle (or similar design), Heavy Equipment Transporter, other), number.

d. *Gross_Weight* (Combat Vehicle Weight), kg.

e. *Engine_Power*, hp.

f. *Maximum_Gradient*, percent.

g. *Maximum_On_Road*, kph.

h. *Amphib_Design*, number.

Additional vehicle data are provided for characterizing the vehicle and establishing speed caps or boundaries. Representative_Bin, Speed_Factor, and Power_to_Weight_Ratio are computed using the above vehicle data.

a. *Vehicle_Name*, text.

b. *Vehicle_ID*, number.

c. *Representative_Bin*, number.

d. *Fording* (speed), kph.

e. *Swimming* (speed), kph.

f. *Speed_Factor*, number.

g. *Power_to_Weight_Ratio*, number.

Process

Representative vehicles and preset terrain (Fidelity Degree 1)

This level will help ensure consistent mobility representation with WARSIM 2000, battle-command systems, theater-level models, and other systems based on unit or aggregation of individual entities. Models that are based on platform entity-level movement may use this level of fidelity, but the user must understand that the speeds are based on preset terrain values and the nature of the representative vehicle-terrain interaction. For example, OOS has a requirement to interoperate with WARSIM 2000 and battle-command systems (U.S. Army 2002). Having this implementation of mobility will support consistent interoperability for mobility speed predictions; however, the implementation of routing and unit movement representation is not within the scope of STNDMob.

Except for slope, exact terrain attributes are required along the heading of the vehicle. To obtain maximum terrain-limited speed for values of slope that are not preprocessed or indexed, a linear interpolation of speed between given preprocessed slope values is performed. Guidance for translating the meaning of visibility, obstacle, and wetness index classes is provided in Appendix A.

Specific vehicles and preset terrain (Fidelity Degree 2)

This level is a close match with current WARSIM 2000 implementation. The difference is that WARSIM 2000 uses data files containing the ratio of actual speed for each mobility look-up (MLU) to the maximum road speed, rather than the actual speed for each MLU. The inputs and outputs are the same as Fidelity Degree 1, except a selected vehicle must be associated with a bin. This is performed with an algorithm using the given attributes of vehicle data and the maximum terrain-limited speed adjusted by a multiplicative factor. This algorithm is described within this section.

Exact terrain attributes are required except for slope/pitch along the heading of the vehicle. For values of slope that are not preprocessed, a linear interpolation of vehicle speed between given slope/vehicle pitch values is performed to compute maximum terrain-limited speed. Guidance for translating the meaning of visibility, obstacle, and wetness classes is provided in Appendix A.

Using the given set of vehicle data, one would compute the bin membership or Semi-Automated Forces (SAF) class from the list of categories/bins given in Table 2.1 using the method described in Baylot and Gates (2002). Then, one would proceed in the same manner as described for Fidelity Degree 1, with the exception that once the maximum terrain-limited speed for the representative vehicle is found, the maximum terrain-limited speed for the given vehicle will be adjusted by a multiplicative factor computed as the ratio of the given vehicle maximum road speed to the representative vehicle maximum road speed of its bin membership. (Note: No known research has been conducted to quantify the accuracy of this multiplication factor. Accuracy is assumed to be sufficient for on-road and cross-country conditions when surfaces are hard and open.)

It is conceivable that bin membership would be computed at simulation startup and not be recomputed during the course of the simulation. However, should the values of the factors that define bin membership change significantly, a new computation might be warranted.

The process is described as such:

If the vehicle is tracked and its Combat Vehicle Weight > 500 kg, then go to step *a*. If the vehicle is wheeled and its Combat Vehicle Weight > 500 kg, go to step *b*. Otherwise, vehicle is a Light All-Terrain Vehicle (ATV); thus, go to step *c*.

a. Tracked Vehicles (Bins 1-3, 10):

(1) Collect, at a minimum, the following information on a tracked vehicle. If the vehicle is an Amphibious Combat Vehicle (ACV), then go to step 2.

Combat Vehicle Weight (kg), Power (hp), Maximum Road Speed (kph)

or

Power-to-Weight Ratio (hp/ton), Maximum Road Speed (kph)

(2) If the Primary Use Code is equal to 2, place the vehicle in Bin 10.

(3) Otherwise, use the following equation to compute Tactical High (TH) Speed, Y_{TH} (kph).

$$Y_{TH} = 2.4 + 0.229 \cdot (Power - to - Weight\ Ratio) + 0.382 \cdot Maximum\ \ Road\ Speed$$

or

$$Y_{TH} = 2.4 + 0.229 \cdot \frac{Power}{Combat\ Vehicle\ Weight \cdot 0.00111} + 0.382 \cdot Maximum\ Road\ Speed$$

(4) Use the value of Y_{TH} to select the vehicle bin using:

Bin 1 $Y_{TH} \geq 31.2$
Bin 2 $Y_{TH} \geq 26.3$ and $Y_{TH} < 31.2$
Bin 3 $Y_{TH} < 26.3$

b. Wheeled Vehicles (Bins 4-9, 11):

(1) Collect the following information on a wheeled vehicle. If the vehicle is an ACV, go to step 2.

Maximum Gradient (percent), Primary Use Code (1: Truck; 2: ACV; 3: Heavy Equipment Transporter), Trailer Attached (True/False), Combat Vehicle Weight (kg), Power (hp)

or

Maximum Gradient (percent), Primary Use Code (1: Truck; 2: ACV; 3: Heavy Equipment Transporter), Trailer Attached (True/False), Power-to-Weight Ratio (hp/ton)

(2) If the Primary Use Code is equal to 2, place the vehicle in Bin 11.

(3) If a trailer is not attached to the wheeled vehicle, use the following equation to compute Tactical Support (SS) speed:

$$Y_{SS} = 1.20 + 1.258 \cdot (Power - to - Weight\ Ratio) + 0.338 \cdot Maximum\ Gradient$$

or

$$Y_{SS} = 1.20 + 1.258 \cdot \frac{Power}{CombatVehicleWeight \cdot 0.00111} + 0.338 \cdot MaximumGradient$$

(4) Use the value of Y_{SS} to select the vehicle bin using:

Bin 4 $Y_{SS} \geq 42.9$ kph
Bin 5 $Y_{SS} \geq 38.2$ kph and $Y_{SS} < 42.9$ kph
Bin 6 $Y_{SS} < 38.2$ kph

(5) If a trailer is attached and the Primary Use Code is equal to 3 or the Combined Vehicle Weight exceeds 60,000 kg, place the vehicle in Bin 9.

(6) Otherwise bin as follows:

Bin 7 Power-to-Weight Ratio ≥ 10.0
Bin 8 Power-to-Weight Ratio < 10.0

c. Light ATV (Bin 12):

If vehicle is a Light ATV or less than 500 kg, place in 12.

Once the specific (S) vehicle bin membership has been determined, apply the following equation to adjust the maximum terrain-limited speed of the representative (R) vehicle found in the process as described for Fidelity 1. Default values for the bin membership value and factor on speed are given in the vehicle data files.

$$Speed_S = \frac{Speed_R \times Maximum\ Road\ Speed_S}{Maximum\ Road\ Speed_R} \qquad (1)$$

The procedure described above is to be used as a tool to consistently, generically categorize vehicles and place them into bins. It is understood that, for particular scenarios, some vehicles might be better represented in another bin. However, it is highly unlikely that it would be beyond the adjacent bin (i.e., low mobility versus high mobility).

Cross-validation with NRMM speed predictions was performed, and there were no instances where the predicted speeds differed by more than one adjacent bin between NRMM and the procedure described above. For 20 percent of the instances, there was disagreement by one adjacent bin and, in half of those instances, the categorization was near the edges of adjoining bins (Baylot and Gates 2002).

Output

Maximum terrain-limited speed as an output will be used to govern whether a commanded speed is achievable or not. A routing service outside this model will determine the heading and position of the ground vehicle.

Data tables

An example of the terrain data and NRMM speed predictions contained in the various input files is given in Table 2.2. The files are divided by climate zone

Table 2.2
File Information

Title: NRMMII Predictions Mapped to MLU Codes
Climate Zone: 2
Bin: High-Mobility Tracked

Ground	Off-Road									
Condition	dry	Speed for the given slope/pitch in percent (mph)								
visobs	1	-40	-30	-20	-10	0	10	20	30	40
mlu	1	0.0	0.0	13.2	36.7	26.9	0.0	0.0	0.0	0.0
mlu	2	0.0	0.0	13.2	36.7	26.9	0.0	0.0	0.0	0.0
mlu	3	40.0	40.0	40.0	40.0	12.3	6.0	3.9	1.9	0.0
•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
mlu	256	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Condition	wet									
visobs	1									
mlu	1	0.0	0.0	13.2	36.7	26.9	0.0	0.0	0.0	0.0
mlu	2	0.0	0.0	13.2	36.7	26.9	0.0	0.0	0.0	0.0
mlu	3	38.1	40.0	40.0	40.0	11.6	5.0	0.0	0.0	0.0
•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
mlu	256	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Condition	snow									
visobs	1									
mlu	1	0.0	30.7	40.0	40.0	40.0	9.3	4.9	0.0	0.0
mlu	2	0.0	30.7	40.0	40.0	40.0	9.3	4.9	0.0	0.0
mlu	3	40.0	40.0	40.0	40.0	23.7	7.6	4.6	3.0	0.0
•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
mlu	256	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ground	road	Speed for the given slope/pitch in percent (mph)								
Condition	dry	-15	-12	-8	-4	0	4	8	12	15
vis	1	27.7	30.0	30.0	30.0	26.6	14.6	0.0	0.0	0.0
mlu	726	27.7	30.0	30.0	30.0	26.6	14.6	0.0	0.0	0.0
mlu	727	30.0	30.0	30.0	23.6	12.3	8.7	6.8	5.5	4.8
mlu	728	•••	•••	•••	•••	•••	•••	•••	•••	•••
		30.0	30.0	30.0	30.0	23.5	12.3	8.8	6.8	5.8

Note: filename: dry_climates_.xml

and subdivided by condition. The reasoning is that it is unlikely that a computer-generated forces simulation (CGF) like OneSAF will simulate a scenario involving more than one climate zone or soil condition, thus, saving computer memory resources. However, this does not preclude additional climatic zone/ soil conditions from being used. Locations of climate zones as 1-deg grids are given in the STNDMob file climate_zones.txt. A utility function is provided for translation in STNDMob. The range and meaning of index values are given in Table 2.3.

Table 2.3
Definition of Index Values

Index	Range of Values	Reference
Climate Zone	Dry climates (2), humid mesothermal (3), humid microthermal (4), undifferentiated highland (6)	See Appendix A
Condition	Dry, wet, snow	See Appendix A
Bin	1 – 12	See Table 1 and Appendix A
Ground	Cross-country, road	See Appendix A,
visobs	1 – 16	See Appendix A
vis	1 – 4	See Appendix A
mlu	1 – 256 (cross-country) 726 – 749 (road)	See Appendix A and Appendix B
slope/pitch	-40, -30, -20, -10, 0, 10, 20, 30, 40 (cross-country) -15, -12, -8, -4, 0, 4, 8, 12, 15 (road)	See Appendix A

Vehicle data

The following tables present the characterization data for the High-Mobility Tracked representative vehicle and two other members of this bin. Vehicle ID values are arbitrary with values 1 to 99 reserved for representative bins. For an example, see Table 2.4.

Table 2.4
Vehicle Information

Title	**Vehicle Data File**		
Date-Time of Creation	**11/25/2002**		
Developer	**USAERDC**		
Certifier	**Pending**		
Vehicle Name	**M1A1**	**AMX 30 LeClerc**	**T-80**
Vehicle ID	1	100	103
Representative Bin	1	1	1
Speed Factor	1.0	0.9	0.97
Gross Weight (kg)	54545	36000	42500
On Road Speed Max (kph)	72	65	70
Swimming Speed Max (kph)	0	0	0
Fording Speed Max (kph)	8	8	8
Amphibious Capable	0	0	0
Maximum Gradient	60	60	63
Engine Power (hp)	1500	793	1213
Type (tracked, wheeled)	1	1	1
Primary Use	5	5	5
Towing Trailer (Y/N)	0	0	0
Note: vehicleIDmap.xml			

Example Output

Representative vehicles and preset terrain (Level 1, Fidelity 1)

For the most part, the input data indexes to a given NRMM representative vehicle speed prediction. The exception is that linear interpolation is performed on the speed prediction given two adjacent slopes on the index. Table 2.5 provides an example for a high-mobility tracked vehicle.

Table 2.5
Predictions for High Mobility Tracked Vehicle

Input					Output
Climate Zone	**Soil Wetness**	**Visibility/ Obstacles**	**STGJ Code MLU**	**Slope %**	**Speed mph**
2	Dry	1	270 (19)	0	26.9
2	Dry	1	270 (19)	10	0
2	Dry	1	270 (19)	-10	30.0
2	Dry	16	270 (19)	0	0
2	Wet	1	313 (37)	0	11.6
2	Wet	1	313 (37)	10	5.0
2	Wet	1	313 (37)	5	8.3[1]

[1] Interpolated from 0- and 10-percent slopes for NRMM predictions.

Specific vehicles and preset terrain (Fidelity 2)

Level 1, Fidelity 2, uses the representative vehicle to serve effectively as the basis of the speed prediction for a specific vehicle. The ratio of the specific vehicle's maximum road speed and the representative vehicle's maximum road speed serves as a factor for the speed as given for Fidelity 1. Table 2.6 provides an example for a T-80 tank as represented by a high-mobility tracked vehicle (M1A1).

Table 2.6
Predictions for a T-80 Tank

Input					Output
Climate Zone	**Soil Wetness**	**Visibility/ Obstacles**	**STGJ Code MLU**	**Slope %**	**Speed mph**
2	Dry	1	270 (19)	0	26.2
2	Dry	1	270 (19)	10	0
2	Dry	1	270 (19)	-10	29.2
2	Dry	16	270 (19)	0	0
2	Wet	1	313 (37)	0	11.3
2	Wet	1	313 (37)	10	4.9
2	Wet	1	313 (37)	5	8.1[1]

[1] Interpolated from 0- and 10-percent slopes for NRMM predictions.
Note: Max speed for M1A1 = 72 kph; max speed for T-80 = 70 kph.

3 Medium-Resolution Mobility Modeling (Level 2)

Medium-resolution or Level 2 mobility has two degrees of fidelity. These are enumerated as 3 and 4. The fidelity as described for Degree 3 is much more complex than Fidelity Degree 1 and 2 (from Level 1) because of the variability of the terrain state and characteristic attributes of the given representative vehicle. Fidelity Degree 4 is described in exactly the same manner as Degree 3, with the exception that a specific vehicle is chosen over a representative vehicle.

Fidelity Degree 4 is an improvement over the Close Combat Tactical Trainer Semi-Automated Forces (CCTT-SAF) as CCTT-SAF uses only representative vehicles (U.S. Army 1996a, b). Furthermore, this capability will allow models such as computer-generated forces to serve better as an analytical tool to distinguish mobility performance between specific vehicles or vehicle designs.

Input Data

Terrain

For this degree of fidelity specific vehicles are not modeled, and their mobility performance is dictated strictly by their representative vehicle. The terrain data attribution is generally mapped to the corresponding OneSAF Environmental Data Model label given inside parentheses.

a. soilUSCSType (Soil_Type), number.

b. soilStrengthCone_40 (Soil_Cone_Index_QB_Measurement to 40 cm).

c. frozen_Water_Type (Frozen_Water_Type).

d. surfaceType (Terrain_Route_Type).

e. surfaceCondition (Surface_Slippery).

f. surfaceRoughness (Terrain_roughness_root_mean_square).

g. snowDepth (Snow_Depth).

h. snowDensity (Snow_Density).

i. vegetationTreeDiameter (Mean_Stem_Diameter).

j. vegetationAverageStemSpacing (Mean_Stem_Spacing_QB_Stem_Diameter).

k. obstacleHeight (Height_Above_Surface_Level).

l. obstacleWidth (Width).

m. obstacleApproachAngle (Surface_Slope).

n. obstacleMaterialType (Primary_Material_Type).

o. obstacleMu (Obstacle_Traction_Coefficient).

p. radiusCurvature (computed from array of segment nodes, not in EDM).

Vehicle

Description attributions for vehicle data are as follows:

a. Configuration

(1) Traction_Element _Type (Track or Wheeled)

(2) Trailer_Attached

(3) Plow_Blade_Capable

(4) Primary _Use (truck, amphibious (or similar design) combat vehicle, heavy equipment transporter, other)

b. Dimensional_Data

(1) Gross_Vehicle_Weight, kg

(2) Units (Independent units: powered or unpowered)

(3) Unit_Length, in.

(4) Maximum _Unit_Width, in.

(5) Minimum_Unit _Ground_Clearance, in.

(6) Maximum_Push_Bar_Force, lb

(7) Engine_Power, hp

(8) Rotating_Mass_Factor, none

(9) Center_Of_Gravity, in.

(10) Tipping_Angle, rad

(11) Axle_Width, in.

(12) AvgTireCorneringStiffness, deg

(13) AssemblyWeight, N

(14) CenterToCenterTreadWidth, m

(15) TrackGroundLength, m

(16) NumTires, none

c. Speed_Boundaries

(1) Speed_Boundaries, kph

(2) Maximum_Road_Speed, kph

(3) Fording, kph

(4) Swimming, kph

(5) Ride_Comfort, rms and kph

(6) Shock, g/kph

d. Obstacle_Maneuver

(1) Maximum_Vertical_Obstacle, m

(2) Maximum_Articulation_Angle, deg

(3) Maximum_Fording_Depth, m

(4) Maximum_Gradient, %

(5) Obstacle_Geometry_versus_Over_Ride_Force_Matrix, in. and rad

(6) Obstacle_Geometry_Induced_Shock_versus_Speed_Matrix, in./sec

e. Surface_Traction_Data (for each Power/Throttle Setting, same as CCTT-SAF)

(1) Dry conditions

(2) Slippery conditions

(3) Winter conditions (snow and ice)

f. Braking_Data (for five positions)

(1) Dry conditions

(2) Slippery conditions

(3) Winter conditions (snow and ice)

g. Motion_Attribution

(1) Vehicle_Pitch (Surface_Slope or pitch)

(2) Throttle_Position (100, 80, 60, 40, 20 percent of maximum throttle)

NOTE: More detail and example data are given in Appendix C.

Process

Description

This level resembles the mobility implementation in OTB-JVB, OTB-MMBL, JointSAF 5.7, and CCTT-SAF (U.S. Army 1996a, b; Mason et al. 2001; JPSD Program Office 2002). The implementation considers the physical interaction between forces and the effects on the velocity of the vehicle. Additionally, behavioral factors are addressed.

Physical model

Tractive forces. The traction-speed relation for the vehicle is determined from the vehicle's power train and traction element characteristics and the current soil type, strength, and surface condition. Various vehicle mobility impediments in the form of resistances are determined. The sum of all impeding resistances is compared with the traction-speed relation. If the traction exceeds the resistance force sum, excess vehicle traction is available and a suitable running speed is determined. Otherwise, if resisting forces are greater than available traction, a vehicle immobilization (maximum speed = 0) condition results.

NRMM incorporates a representation of a vehicle's power train to estimate the vehicle's theoretical power in the form of a maximum available-traction-versus-drive-element-speed relation. This model requires performance and configuration characteristics of the power train including the engine output torque versus speed (rpm) relation curve, torque converter characteristics (if applicable), transmission gear ratios and efficiencies, and final drive information. Optionally, the theoretical traction-speed relation can be determined through physical testing and provided as an input to NRMM.

The traction-slip relation and soil motion resistance is derived for the given soil type, soil strength, and surface condition. NRMM uses this information to produce a traction-speed relation for the specific vehicle/terrain combination. The fundamental soil relations in NRMM use an empirical system that relates vehicle performance to soil strength in terms of rating cone index (RCI) for cohesive soils (clays, silts, and wet sands) or the (semi-empirical) numeric system relating performance to soil cone index (CI) for noncohesive soils (dry sands). Performance on winter surfaces (ice, snow, packed snow, snow over soft soil) is based on empirical algorithms within the NRMM.

In Figure 3.1, a comparison of tractive force required by a typical vehicle and maximum tractive force made available to the drive train is given (U.S. Army 1996a). NRMM, and thus STNDMob, uses an approximation of the tractive-force available to estimate the performance of the vehicle. The difference between these forces is the force available for accelerating the vehicle. Lower throttle settings would yield a smaller difference.

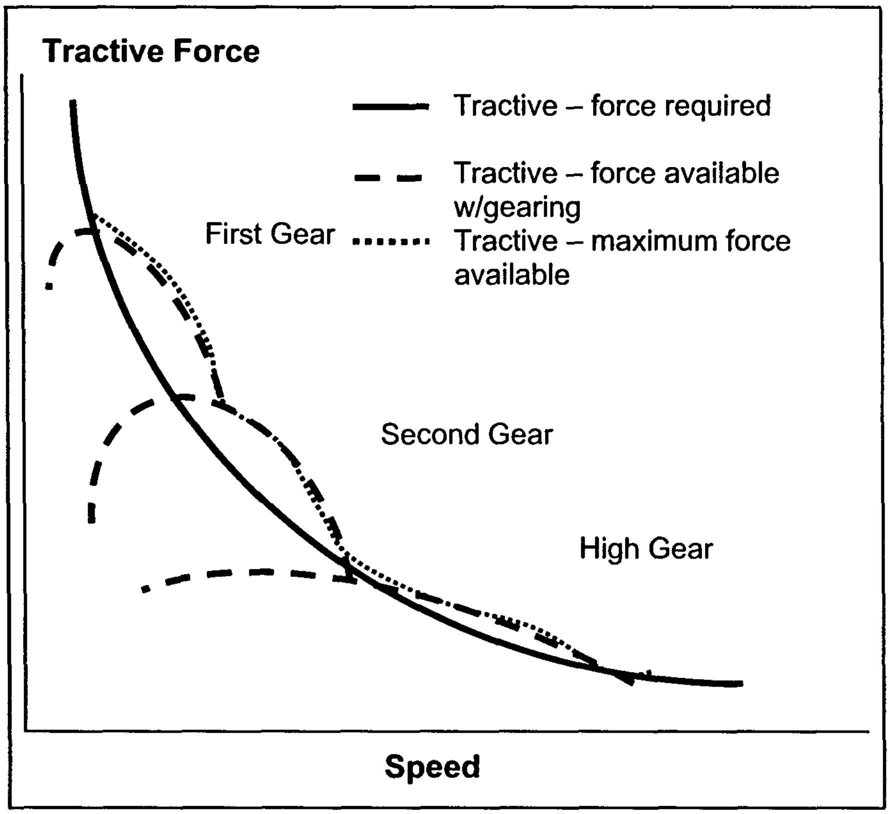

Figure 3.1. Comparison of tractive force required and tractive force available

The traction coefficient can relate directly to the vehicle's ability to climb slopes, override vegetation, and negotiate obstacles. Soil strength is defined for the subsurface and is indicated by Rating Cone Index (RCI) on the axis. The traction coefficient is defined as the required tractive force divided by vehicle weight.

$$f_T = \frac{F_T}{W_V} \tag{2}$$

where

FT = required tractive force {func of TP, Vt, ST, SS, SL, SN, SD, Sd}

W_V = gross vehicle weight

TP = throttle position

V = translatory speed

ST = soil type, USCS, nondimensional

SS = soil strength, RCI

SL = slipperiness, nondimensional

SN = snow type

SD = snow depth

Sd = snow density

Figure 3.2 illustrates the variation of tractive force required to achieve a given speed. These relationships will change as a function of soil types and soil strength.

To reduce the complexity and data volume for lower resolution models, NRMM can produce traction coefficient tables that vary as a function of soil type, soil strength, slipperiness, and throttle position. The tractive force coefficient is based on a rectangular hyperbola in Equation 3 and is fitted to the traction-speed relation using a modified least-squares curve-fit algorithm. Additionally, maximum and minimum traction coefficients are provided to realistically bound the extents of the hyperbolic equation values. This level of fidelity is sufficient for a CGF.

$$f_T = f_{TMIN} \geq \frac{b_o}{V - b_1} - b_2 \leq f_{TMAX} \tag{3}$$

where

f_{TMAX} = normalized maximum tractive force, coefficient

f_{TMIN} = normalized minimum tractive force, coefficient

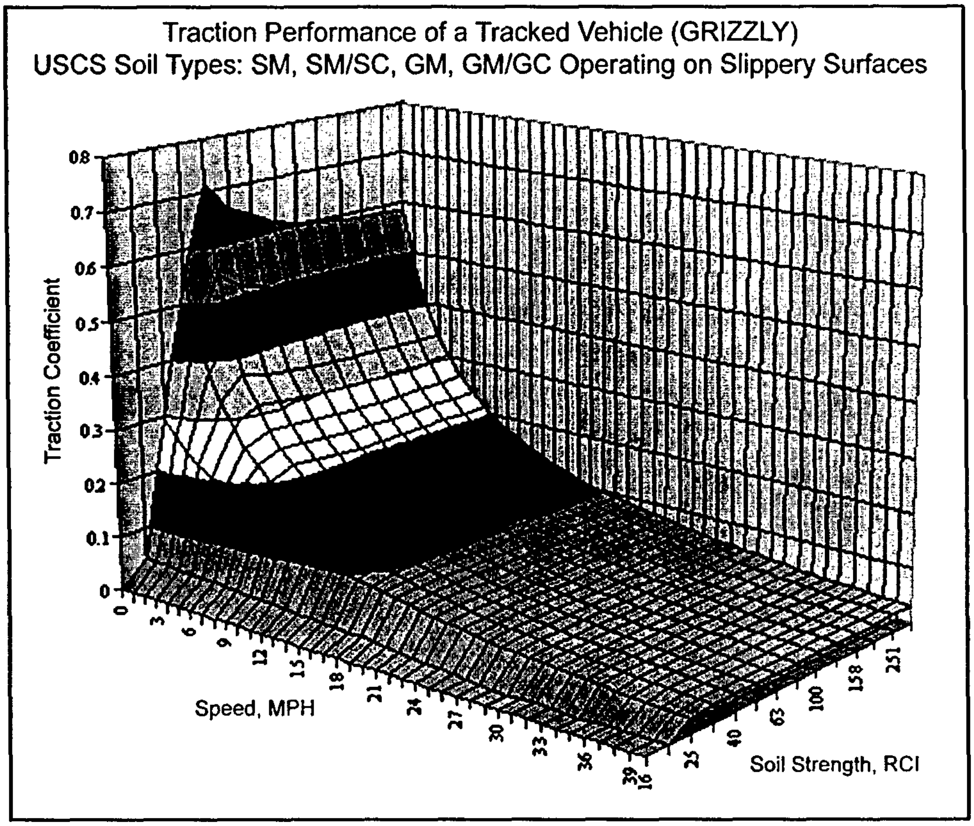

Figure 3.2. Traction-required relationships under slippery conditions for the given soil group for a vehicle as a function of soil strength and vehicle speed

F_{TMAX} = maximum tractive force {func of TP, Vt, ST, SS, SL, SN, SD, Sd}

F_{TMIN} = minimum tractive force {func of TP, Vt, ST, SS, SL, SN, SD, Sd}

b_0, b_1, b_2 = hyperbolic curve-fit coefficients for tractive force

and the normalized tractive force can be computed at a given speed, V, and no acceleration.

Resistance forces. The forces considered here encompass resistances due to soil interaction/surface friction, air, snow, water, and gravity. Adhesion to surfaces is greatly affected by the contact area of the tire (sensitive to inflation pressure) or track, surface material, and conditions of the surface. Thus, the resulting rolling resistance force, F_R, can widely vary. This is illustrated in Table 3.1.

Table 3.1
Coefficient of Rolling Resistance

Vehicle Type	Concrete	Hard Soil	Sand
Heavy truck	0.012	0.06	0.25
Tracked vehicle	0.038[1]	0.045[1]	

Note: Computed by dividing rolling resistance, F_R, by vehicle weight W (Taborek 1957).
[1] Field observed values used for on-road conditions by NRMM.

There are empirical methods for computing rolling resistance as a function of soil type, road type, snow, ice, vehicle traction element (wheel/track), etc. These methods are found in pages 58-67 of the NRMM User's Guide with specific updates to snow/ice found in the appendix of the NRMM Addendum.[1] NRMM holds the value of F_R as a constant although it tends to increase as the speed of the vehicle increases (Taborek 1957). Since cross-country speeds are typically a great deal less than on-road speeds, this is a good assumption and suitable for a CGF.

The drag forces caused by water and air are modeled in NRMM. Empirical formulas for computing the hydrodynamic drag and aerodynamic drag resistance forces are found in the NRMM User's Guide (Ahlvin and Haley 1992). These forces can be substantial and limiting. For purposes of a CGF, hydrodynamic forces will not be considered since ground vehicles are expected to be in water only a small fraction of the operation duration. Instead, a maximum speed for fording and swimming is provided for the vehicle when crossing bodies of water.

As was shown for the required tractive forces, NRMM has a method for reducing the complexity for models such as a CGF. It does this by adding the aerodynamic resistance coefficient to the tractive force required. This is acceptable as they both are a function of vehicle speed. Thus, as implemented in STNDMob, the values for tractive-force-required is a summation of the surface resistance and the aerodynamic resistance (at sea level).

Braking forces. The NRMM defines total braking as the sum of the motion resistance of braked and unbraked traction elements and the forces acting on the braking mechanisms for each traction element. Furthermore, NRMM considers the weight of the vehicle as supported by braked, unbraked, powered, and unpowered traction elements. STNDMod differs in that it does not consider the individual attributes of each traction element when applying the braking force; instead, it uses the net effect on the vehicle. Therefore, STNDMob is dependent upon NRMM to yield the net effect and is sufficient for a CGF. The total braking force occurs at the centroid of the vehicle body and is a function of the force applied to the braking mechanism, the motion resistance as limited by the terrain, and the power train resistance internal to the vehicle. NRMM does not consider any change in motion resistance that varies with speed. For simplification, the

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[1] R. B. Ahlvin, "NRMM Edition II, User's Guide Addendum" (in preparation), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

braking force due to braked traction elements, BF, on a level surface will be supplied from NRMM.

$$F_B = \min(BP \cdot BF, F_{TMAX}) \tag{4}$$

where

BP = brake setting expressed as a fraction from zero to one

BF = braking force due to braked traction elements {func of *ST, SS, SL, SN, SD, Sd*}

F_{TMAX} = maximum tractive force {func of *ST, SS, SL, SN, SD, Sd*}

Sum of longitudinal resistive forces and gravitational effect. Resistive forces discussed thus far in this section have dealt with forces that impede the movement of the vehicle at the traction element. Their sum and available tractive force, F, on a level surface is given as

$$F = F_T + F_R + F_B \tag{5}$$

where F is the sum and available tractive force along a level surface, in pounds.

Since these forces act only in the direction of travel, their effect on available tractive force is diminished by the cosine of the grade, Θ, and the force of gravity, W_V, will vary by the sine of the grade. Thus, on a level surface there is no effect of gravity, and on a vertical surface the force of gravity is equal to the weight of the vehicle.

Since the field data used by NRMM available for F_T, F_R, and F_B are measured only on a level surface and act only along this vector component, the available tractive force, F_G, must be resolved to the vector component parallel to the grade. Thus,

$$F_G = F_T \cdot \cos\Theta + F_R \cdot \cos\Theta + F_B \cdot \cos\Theta + W_V \cdot \sin\Theta \tag{6}$$

where Θ is the slope (pitch, grade).

However, the tractive force-speed relationships used in NRMM and thus STNDMob are developed strictly for a level surface. Thus,

$$F_G = \frac{F}{\cos\Theta} \tag{7}$$

After substitution of F_G in Equation 6 and with simplification:

$$F = F_T + F_R + F_B + W_V \cdot \tan\Theta \tag{8}$$

This relationship is important, as it is the basis for Equation 3. This relationship will be further developed in later sections.

Vegetation and obstacle forces. The NRMM computes vegetation and obstacle interaction effects as external forces acting on the vehicle, typically via interpolated look-up tables or empirical equations. These forces as modeled by NRMM can act as either a point obstacle or area obstacle. The key distinction between vegetation modeled as an obstacle and other obstacles is that, if the vehicle is powerful enough, it can deform a tree (drive over) and thus override.

The force required to override a tree is referred to as the push-bar-force, F_{PB}. This force occurs at the impact point, h_{PB}, of the vehicle bumper and tree. The amount of force required to override the tree is given as a function of tree diameter, D. The field data used by NRMM for push-bar forces were measured at various heights and are valid for heights below 80 in. The empirical formulation is given in Equation 8.

The required push-bar force is

$$F_{PB} = c_1 \cdot \left(40 - \frac{h_{PB}}{2}\right) \cdot D^3 \qquad (9)$$

where

c_1 = conversion factor, lb/in.^{4}

h_{PB} = vehicle bumper/push-bar height above ground, in.

D = tree diameter, in.

If the value of F_{PB} is greater than or equal to the maximum push-bar force allowed either by vehicle design or driver comfort, the vehicle will not be allowed to override the tree. Equation 9 is useful for calculating the force required to override a single-tree encounter or perhaps an orchard of trees with equal diameters. The NRMM uses another method for computing multiple simultaneous encounters within a typical forest. This method considers the average stem diameter, $\underline{D}$ of trees within a class of tree stem diameters. There are eight stem diameter classes: >0 cm, >2.5 cm, >6 cm, >10 cm, >14 cm, >18 cm, >22 cm, and >25 cm. These values also are used to set the maximum stem diameters, D_{MAX}, for each class. The sum of the simultaneously encountered forces for all stem diameter classes is given in the empirical equation below.

$$F_{VEG} = c_2 \cdot 12 \cdot wd \cdot 100 \cdot \sum_{j=1}^{n} d_j \underline{D}_j^{\,3} \qquad (10)$$

where

c_2 = conversion factor, lb/in.^{2}

wd = vehicle width, in.

n = number of classes

j = index increment

d = vegetation density for each class, in.$^{-2}$

$\underline{D}$ = average stem diameter of class, in.

At present, obstacles other than vegetation are assumed to be nondeformable. Thus, the concept of push-bar force does not apply. NRMM uses preprocessed data from other models such as OBSMOD or VEHDYN to determine whether the geometry of a vehicle can traverse an obstacle without the geometry of an obstacle interfering with the crossing (Creighton 1986). The obstacle geometry is assumed to be a trapezoid defined by the approach (ingress/egress) angle, height, and width. The interaction between geometries is ultimately reduced to the clearance of a vehicle over the obstacle. A zero or negative value of clearance in the data would indicate a "no-go" condition and, thus, the vehicle certainly could not traverse the obstacle without deformation.

For the case when the minimum clearance is greater than zero, a linear, multidimensional interpolation is performed on the generalized trapezoidal shapes found in the given data to be the closest in shape to the obstacle in question, in order to compute the maximum required tractive force, F_{OBMAX}, required to traverse the obstacle and the average resistance force, F_{OB}. The average resistance force is used for considerations of simultaneous encounters of other obstacles such as trees, whereby their sum of forces required to override may cause a "no-go" or speed-reduction circumstance. STNDMob does not yet consider this complex obstacle case.

Plowing forces. The STNDMob uses a data table to interpolate the plowing force resistance, F_P, from a multidimensional array of plow depths, soil strengths, and soil groups (NRMM specific). These tables are provided for a full-width plow with tines, a track-width plow with tines, a full-width blade/rake with no tines, and a track-width blade/rake with no tines. In the final sum of forces equation, this force is treated simply as an additional resistance.

Resistance forces and speed limits associated with steering. It is beyond the scope of this effort to provide a complete review of the tire/terrain/vehicle dynamics involved in a turning maneuver. However, two significant textbooks that address this are Milliken and Milliken (1995) and Gillespie (1992). Additionally, as the Army Standard Mobility Model and the basis for STNDMob API, the NRMM documentation also provides insight and applicable algorithms (Ahlvin and Haley 1992). The STNDMob API was not intended to model all aspects of vehicle dynamics, but to capture the effects of vehicle performance and terrain interaction to the extent that, in a CGF application, vehicle behaviors need only be represented to the point where an analyst or user does not observe unrealistic behavior.

Table 3.2 indicates which terrain effects can be easily modeling in two dimensions and within a CGF. Studying the issue from another perspective, speeds on a curve or in a turning maneuver can be controlled primarily by traction (slide/spin or overshoot) or by the vehicle suspension (rollover).

Table 3.2
Description of Effects to Be Modeled During a Turning Maneuver

Effect	Description/Example/Issue	Important parameters[1]
Limit speed on a curve	"Spin out," rollover	Lateral force, super-elevation, weight distribution, wheelbase, radius of curvature or planned path, current heading, tire cornering stiffness, suspension
Steering angle and yaw velocity	How fast can the vehicle react to a change in steering angle/or react to change in heading order	Slip angle, velocity, cornering stiffness
Limit/reduce speed due to maneuver anticipation	Given that a future maneuver requires a lower speed, some method is required to determine the deceleration as that maneuver location is approached	Route plan, radius of curvature, current speed
Induced resistance in the longitudinal direction	Longitudinal component of cornering force; give an example of 20 percent power requirement to overcome force (Milliken and Milliken 1995)	Cornering stiffness, radius of curvature, super-elevation

[1] Surface type, grade, and other parameters associated with straight-line movement are assumed.

The rationale, algorithms, and procedures for implementation of turning effects on vehicle performance in STNDMob API are often described by a friction circle diagram, which can be used to portray traction forces in a turning maneuver (Figure 3.3). The y-axis represents the traction available for longitudinal motion (in the direction of the current heading), negative values indicate braking. The x-axis represents the traction available for changing the current heading (lateral force); positive values are for right-hand turns, and negative values for left-hand turns. What is important to recognize is that a vehicle generally operates within the circle (race car drivers attempt to operate on the circle) and that the magnitude of the resultant of the traction forces required for forward and lateral motion is

$$F_{result} \leq \left(F_{long}^{2} + F_{lateral}^{2}\right)^{1/2} \tag{11}$$

where F_{long} and $F_{lateral}$ are functions of longitudinal slip, slip angle, and maximum traction coefficient. (The term coefficient implies that the normal force was used to normalize the lateral or longitudinal force, i.e., a friction coefficient).

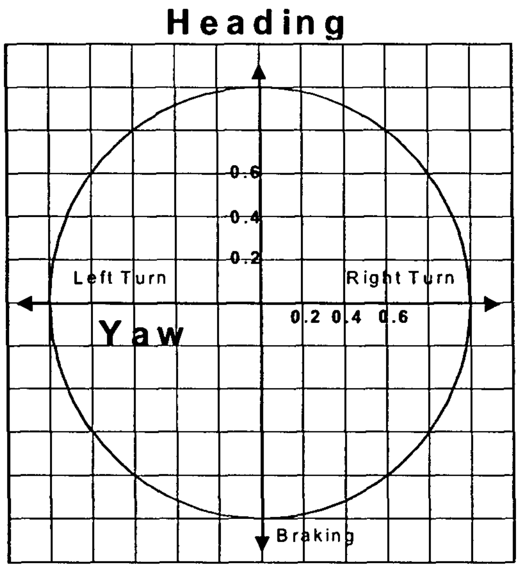

Figure 3.3. Friction circle, with forces in coefficient form

For on-road analysis, NRMM uses the friction coefficients in Table 3.3. Within STNDMob, dry normal and wet slippery coefficients are implemented and are selected through use of variables found in the EDM (see Input Data section of this chapter).

Table 3.3
On-Road Friction Coefficients Available for Use in NRMM

Road Surface Condition[1]	Driving	Braking
Dry, normal	0.9	0.75
Dry, slippery	0.8	0.75
Wet, normal	0.7	0.6
Wet slippery	0.5	0.45
Ice	0.1	0.07

[1] These descriptions correspond to NRMM scenario names and typical combinations.

Within the NRMM, as previously discussed, a tractive force-speed curve is developed based on non-velocity-dependent forces (soil strength, engine power, slope resistance, etc.), and this curve is then adjusted for speed-dependent forces (e.g., cornering forces, aerodynamic drag). Finally, those effects that produce absolute speed limits are determined (e.g., absorbed shock, rollover) to adjust the speed. The minimum of the speed limits and the tractive force-speed curve is output as the maximum terrain-limited speed for the given conditions. In other words, the NRMM produces estimates of both velocity- and non-velocity-dependent resistances to motion, along with absolute speed limits, and combines these with potential vehicle performance to estimate a maximum vehicle-capable speed for a given set of terrain conditions.

Much of the following is extracted directly from Ahlvin and Haley (1992) and the NRMM source code. The resulting effects-associated algorithms and applications associated with vehicle performance during a turn are described below. For cornering and side slope effects, NRMM considers three terrain conditions:

a. Roads (superhighway, primary and secondary roads).

b. Trails (deformable soil surfaces).

c. Cross-country (deformable soil surfaces).

Additionally, wheeled and tracked vehicles or vehicles that have both wheel and track elements are treated differently. For roads and trails, radius of curvature and super-elevation are inputs; for cross-country, a radius of curvature is calculated based on vegetation stem spacing (for each vegetation class). The assumption is that the only reason to turn on cross-country terrain is related to vegetation avoidance. Cornering forces are generally velocity dependent and are used to adjust the tractive-force-speed curve, while stability effects are represented as speed limits. Calculations are generally made on a traction element (axle) basis and summed over traction elements, differentiating between powered and nonpowered elements when necessary.

Vehicle cornering speed limits and resistances on trails. Longitudinal resistance during cornering induced by lateral forces is summed over the wheel elements (axles) of wheeled or partially wheeled vehicles (e.g., half-tracks). The longitudinal cornering resistance (F_{cc}) is originally from Smith (1970):

$$F_{cc} = \Sigma(V^2 m/R)^2 \, \pi / [180 \, nfc \, (\mu/0.75)] \qquad (12)$$

where

V = tangential velocity of the vehicle

m = mass of the vehicle supported by an element

R = radius of curvature to the center of gravity of the vehicle

n = number of tires on the element

f = empirical correlation coefficient (0.96)

c = average cornering stiffness (lbf/deg)

μ = maximum friction coefficient for current terrain

Interestingly, Smith (1970) suggests this as an approximation with μ as an empirical constant of 0.2 based on limited testing. It may be possible to derive a similar equation based on an expanded bicycle model, but the approach taken for Equation 12 has yet to be implemented.

Super-elevation correction factor for tire cornering resistance. Although not fully implemented yet, a correction (multiplier) to the cornering resistance for super-elevation is given as

$$F_E = (1 - gR\Theta/V^2)^2 \tag{13}$$

where

Θ = road super-elevation angle, rad

g = acceleration of gravity, ft/sec^2

Tandem axle alignment drag force on a level surface. This applies to all wheel assembles identified as tandem. Thus, the summation over the number of tandem assemblies is given by

$$F_{TC} = (\mu \Sigma W_T \cos(grade)\, L_T)/2R \tag{14}$$

where

μ = traction coefficient (μ_s or T_f as appropriate)

W_T = weight on i^{th} tandem axle, lb

$grade$ = current slope (vehicle pitch) angle, rad

L_T = center-to-center spacing of tandem wheels on i^{th} tandem axle, in.

R = radius of curvature of road, in.

Tipping and sliding on trails (cross country). The sliding equation for trails is the same as for on-road, using the traction coefficient based on soil type and strength, or snow type, and the slope (vehicle roll direction) for super-elevation. Tipping off-road is concerned with both static rollover, rollover down hill, and dynamic rollover (primarily down hill, as in a turn with negative super-elevation). The equation is much more elaborate than the on-road algorithm, and requires significant amounts of information regarding the suspension. The documentation does not state why this is the case, although it is possible that it is due to the steep off-road slopes and increased deflections. The required simultaneous equations and their solution is much too complex to include in STNDMob API, thus static analysis is used.

Tracked vehicles on roads and trails. Lateral forces associated with steering tracked suspension elements (NRMM subroutine_IV6R2) are computed as a resistance. This resistance is given by the Merritt equation (Merritt 1946 or Ray 1979) in terms of the vehicle width-to-length ratio (Merrit 1946, Ray 1979, Peters 1995).

For an individual traction element (or track "set") I, the "Merritt constant" is calculated as

$$M_{ki} = a_0 + a_1 A_i + a_2 A_i^2\, a_3 A_i^3 \tag{15}$$

where

A_i = center-to-center distance between tracks on ground

$a_0 = 1.0624$

$a_1 = -0.6999$

$a_2 = 0.051848$

$a_3 = 0.05488$

thus, a "radius factor" (K_i) is derived as

$$K_i = M_{ki}(a_0 - a_1 R + a_2 R^2 + a_3 R^3) \quad (16)$$

where

R = radius of curvature of road, ft

$a_0 = 1.18$

$a_1 = -9.0895 \times 10^{-3}$

$a_2 = 3.779 \times 10^{-5}$

$a_3 = -6.70476 \times 10^{-8}$

Furthermore, where the summation is over the total number of tracked assemblies and

μ = surface traction coefficient

W_i = weight on the i^{th} tracked assembly (lb)

the turning resistance is then calculated by

$$F_{CT} = \mu \Sigma K_i W_i \quad (17)$$

Additionally, the radius of curvature should be less then 309 ft for tracked vehicles because K_i can become negative and thus

$$K_i = \text{MAX}(K_i, 0.0) \quad (18)$$

On-road cornering speed limits and resistances. Speed limited by sliding (NRMM subroutine IV10R) is the speed at which the centrifugal force of the vehicle in the curve is balanced by the contact friction force (Figure 3.4), as follows:

$$V_{SLIDING} = [Rg(\mu + \tan \Theta)/(1 - \mu \tan \Theta)]^{1/2} \quad (19)$$

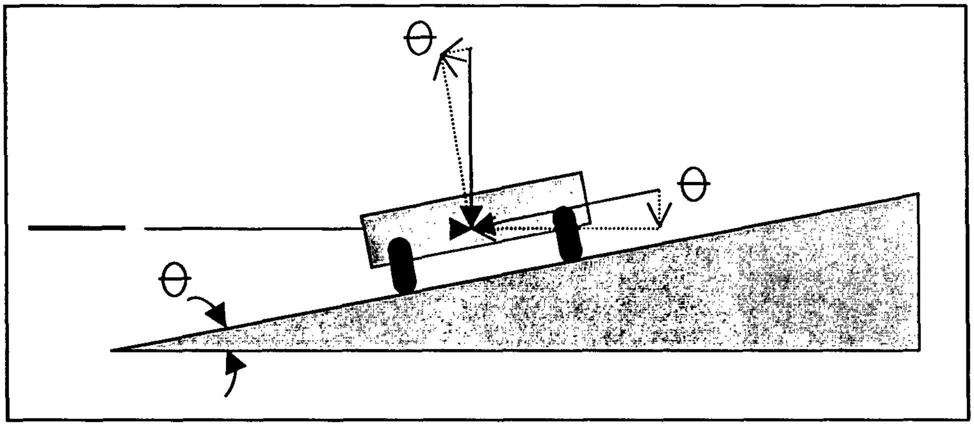

Figure 3.4. Free-body diagram

Speed limited by tipping. Tipping is obtained from the equation expressing the equilibrium of moments around the outer tire (or track) and the pavement contact point. The forces involved are the centrifugal force and the weight of the vehicle. Thus, the tipping velocity, V_{TIP}, can be determined by

$$V_{\mathrm{TIP}} = [Rg(W_{tmax} + Y_{cg} \tan(\Theta)/(Y_{cg} - W_{tmax} \tan \Theta)]^{1/2} \qquad (20)$$

where

R = radius of curvature, ft

g = gravity, ft/sec^2

W_{tmax} = controlling lateral distance to the center of gravity (the smallest of 1/2 the distance between wheel centers over all axles)

Y_{cg} = height of center of gravity, corrected for tire inflation, in.

Θ = road super-elevation angle, rad

The AASHO maximum speeds are taken from relations derived from criteria used by the American Association of State Highway Officials (1966). (AASHO is now called the American Association of State Highway and Transportation Officials, AASHTO.) There are two implementations within the NRMM. The original is an interpolation of Table 3.4, shown plotted in Figure 3.5. These values are based on conservative traction forces. The second implementation was developed from changes to this rationale and is explained in Ahlvin and Haley (1992). This revised algorithm was implemented in NRMM version 2.2.0 and is referenced as the function "ASHATO2." Primarily, this approach now estimates a lateral friction coefficient based on the AASHTO ratio and NRMM-predicted longitudinal force. The following equations are solved iteratively, by comparing the input radius of curvature to that produced by Equation 21:

Table 3.4
AASHO Maximum Speeds Used in NRMM

Radius of Curvature, ft	Superhighways mph	Primary Roads, mph	Secondary Roads, mph	Trails, mph
5730	100	100	70	55
1910	70	70	60	49
1146	60	60	58	44
819	54	54	50	42
637	48	48	43	39
458	41	41	36	34
327	34	34	31	29
229	29	29	26	23
164	25	25	23	19
115	19	19	19	14
82	13	13	13	10

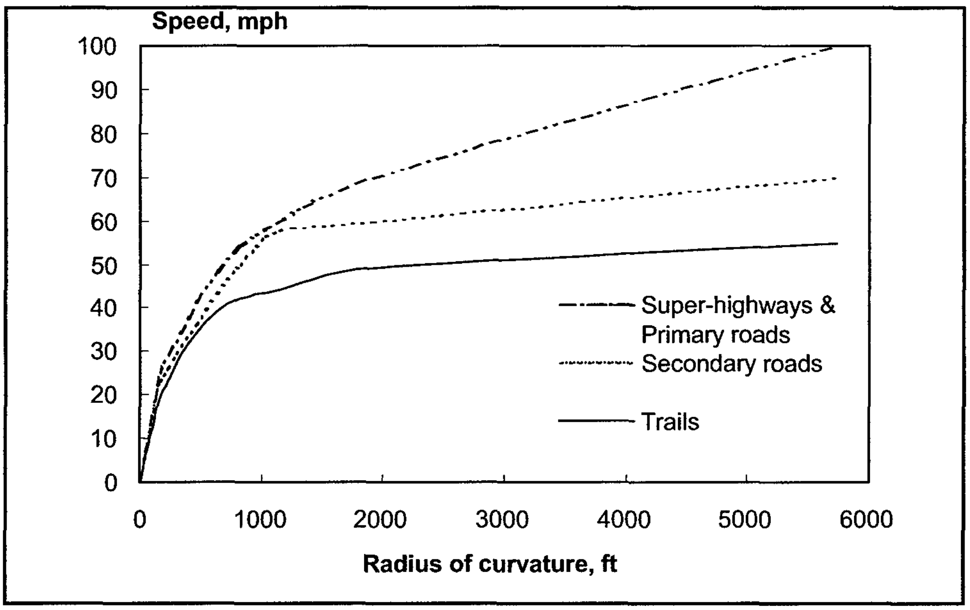

Figure 3.5. Plot of maximum vehicle speeds for the AASHO algorithm in NRMM

$$R = \frac{V^2}{14.95(e+f)} \quad (21)$$

where

V = maximum safe speed, mph

f = friction coefficient, none

e = $\tan \Theta$

This empirical equation will yield the maximum safe speed V, for a given radius R (ft). The AASHTO friction coefficient, f_{AS}, is a function of speed, V, where f_{AS} is the AASHTO friction coefficient (none). Thus,

$$f_{AS} = 0.678 - 0.00468V \tag{22}$$

A straight-line fit of the AASHTO coefficient of longitudinal friction for dry pavements was obtained from a variety of stopping tests, f_{AL}, versus speed, where f_{AL} is the AASHTO longitudinal friction coefficient (none). Thus,

$$f_{AL} = 0.670 - 0.00174V \tag{23}$$

The ratio of the side friction to longitudinal friction for a given speed is used as a factor to convert the actual NRMM-predicted coefficient to an equivalent side friction. The following equation is used to determine the side friction coefficient for curvature speed predictions (f_{PS}) as a function of speed and NRMM-predicted longitudinal friction coefficient (f_{PL}):

$$f_{PS} = \frac{f_{AS}}{f_{AL}} f_{PL} \tag{24}$$

where

f_{PS} = side friction coefficient, none

f_{PL} = NRMM-computed longitudinal friction coefficient, none

The next relation determines the margin of "safety factor" to be included. This is related to the AASHTO-recommended design coefficient (f_A) by setting the safety factor, S, to a value of 1.0 and to the maximum side coefficient (f_{PS}) by setting it to a value of 0.0 or anywhere in between as a compromise. The following equation yields the final friction coefficient:

$$f = (f_A - f_{PS})S + f_{PS} \tag{25}$$

where

f_A = AASHTO road design coefficient, none

S = compromising factor from physical and AASHTO design limit, none

To facilitate obtaining the AASHTO-recommended side friction coefficients (f_A), the following curve was obtained by fitting the data points to a hyperbola. For speeds <20 mph, the value for 20 mph (0.21) is used. The following equation yields the side friction coefficient:

$$f_A = \frac{1}{(3.264 + 0.07648V)}, \quad V \geq 20$$
$$= 0.21, \quad V < 20 \tag{26}$$

where f_{AL} is the recommended side friction coefficient (none).

In the implementation, the maximum AASHTO-recommended coefficient of friction is not allowed to exceed the model prediction for longitudinal traction. The scheme used for hard surfaces was arbitrarily applied to the soft soils (trails) and snow-covered roads and trails. The AASHTO reference provides very little information concerning the friction coefficients for wet pavements. The implications are that the longitudinal friction coefficients are usually much less than for dry pavements. The AASHTO design criterion used is the same since it is assumed to apply to an arbitrarily poor condition. Therefore, the same friction reduction scheme used for dry pavements was assumed to apply to wet pavements. Note that, for the NRMM implementation, the AASHTO information regarding coefficients of friction on dry pavements is used only to determine the ratio of longitudinal to lateral friction; the actual longitudinal friction is obtained from other relations in the NRMM model.

Figure 3.6 illustrates this algorithm, which compares the "bicycle" model approximation with the NRMM ASHATO2 algorithm for two high-mobility multipurpose wheeled vehicles (HMMWVs) in a steady-state turn of radius 132 m. Based on this analysis, the STNDMob implementation uses a value of 0.5 for *S*.

The final on-road curvature speed limit is the minimum of V_{SLID}, V_{TIP}, and the ASHATO2 speed. This is later compared with other terrain-limited speeds to arrive at the maximum predicted speed of the vehicle in question.

Sum of longitudinal forces. The physical forces discussed thus far act on the centroid of the vehicle. The previous sections dealt with resistance forces acting at the traction element, gravitational forces, and forces external to the vehicle. Since the weight of obstacles is seldom known, any gravitational effect from these external forces is neglected. However, the gravitational force induced by the weight of an attached plow is accounted for in Equation 28. Building upon the previously described Equation 6, the available tractive force, *F*, is

$$F_G = (F_T + F_R + F_B) \cdot \cos\Theta + (W_V + W_P) \cdot \sin\Theta + (F_{PB} or F_{VEG}) + (F_{OBMAX} or F_{OB}) + F_P \tag{27}$$

where W_P is the weight of attached plow/rake and, with simplification using Equation 7,

$$F = (F_T + F_R + F_B) + (W_V + W_P) \cdot \tan\Theta + \frac{[(F_{PB} or F_{VEG}) + (F_{OB} or F_{OBMAX})]}{\cos\Theta} \tag{28}$$

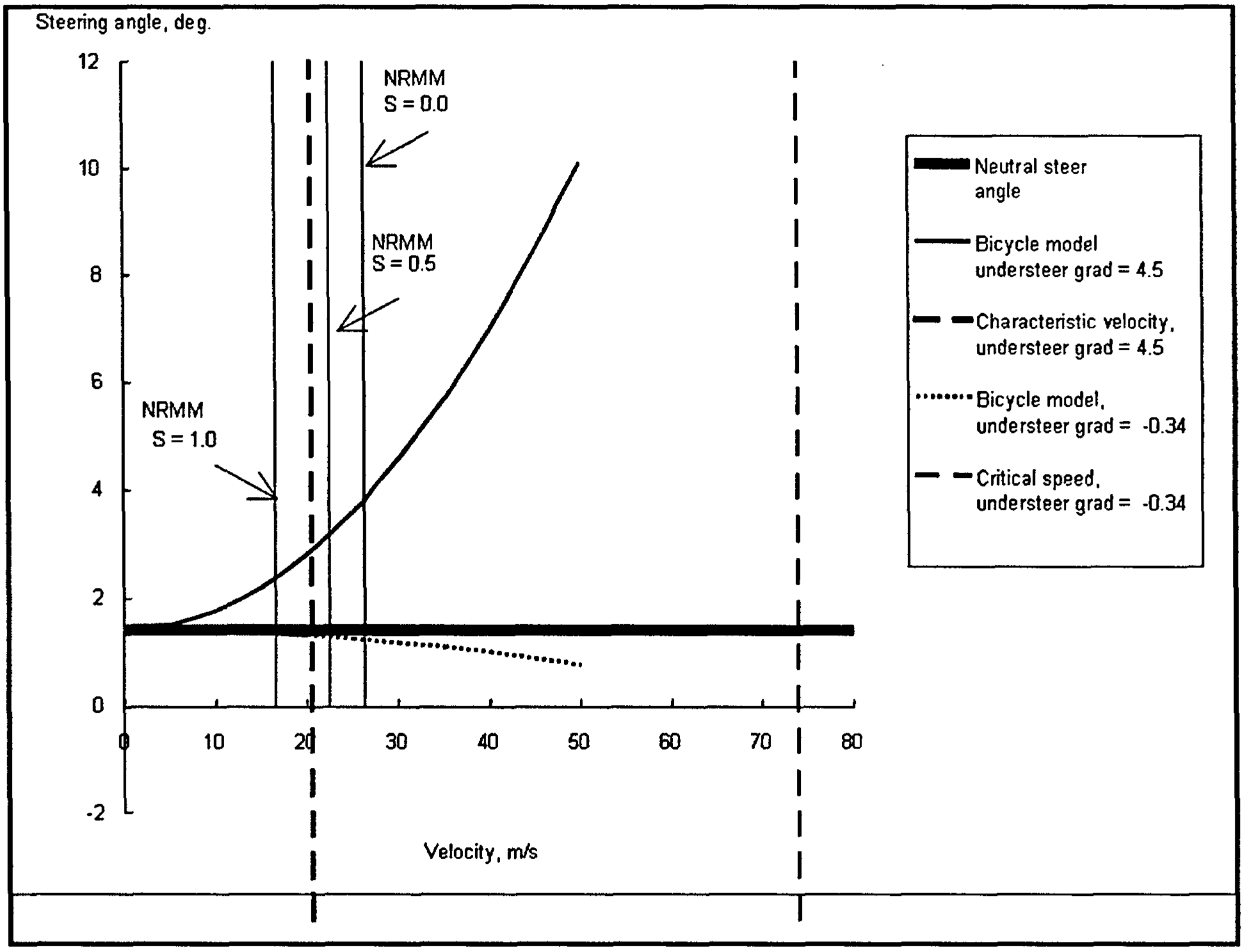

Figure 3.6. Comparison of the "bicycle" model (HMMWVs with understeer gradients of 4.5 and –0.34) with the NRMM ASHATO2 algorithm

Maximum terrain-limited speed, longitudinal. The maximum terrain-limited speed can be computed by solving Equation 3 for V, substituting it with V_{TL}, substituting f_T with $F/(W_V+W_P)$ and f_{TMIN} and f_{TMAX}. The resulting Equation 29 is developed. This is the concluding equation found in STNDMob for computing maximum terrain-limited speed. Where V_{TL} is the maximum terrain-limited speed (mph),

$$V_{TL} = \frac{b_0}{\left(\frac{F}{W_V + W_P} + b_1\right)} + b_2, F_{TMIN} \geq F \leq F_{TMAX} \qquad (29)$$

Behavioral Model

Vehicle behavior should not be limited to what "should be done," but rather what the driver, be it human or autonomous, directs the vehicle to do. The physical model should report to the behavioral model that sliding or tipping is about to occur, so that the decision can be made in the next time period whether to change the settings for throttle, steering, and braking. Some of these speed boundaries were introduced in the previous sections regarding tipping and sliding. It is a source of debate whether AASHTO-recommended settings are a physical or behavioral boundary.

Without debate, a vehicle predicted speed due to visibility conditions is driver dependent. Visibility inputs are expected to come from three sources. The atmosphere will provide an attribute-defining visibility as correlated to obscurants such as fog or smoke near the ground. The terrain will provide attribution-defining visibility as controlled by the vegetation. There will be a line-of-sight based on elevation contours. The minimum of these three attributes will be the input for mobility modeling purposes.

Speed constraints on a vehicle due to a driver's recognition distance (visibility) are based on stopping distance. The standard method for measuring visibility in vegetation is based on a 1-ft star placed just above the ground and at a height of 5 ft above the ground. The driver must recognize at least two points on the star. For on-road purposes, the visibility is based on the recognition distance for a small object in the road. For the purposes of a CGF we can assume that visibility and driver recognition distances are equal and neglect the effect of height above ground.

As discussed in a previous section, braking force is conditional to the braking position as dictated by the driver in Equation 4. An expansion of this relationship is

$$F_B = \min\left(DCLMAX \cdot W, BP \cdot BF, F_{TMAX}\right) \tag{30}$$

where $DCLMAX$ is the maximum braking acceleration the driver will accept, expressed as a factor on acceleration of gravity ($g = 32.2$ ft/sec^2).

Additionally, if the distance, D, is greater than the distance required to avoid impact or miss a way-point, the F_B should be increased by increasing BP and the required deceleration to come to a complete stop at the desired point. Thus,

$$a = \frac{F_B g}{W} \tag{31}$$

where a is the required deceleration (ft/sec^2).

The maximum speed or velocity permitted in order to stop within or at the specified distance is given by

$$V_{VIS} = a\left(-t + \sqrt{t^2 + 2\frac{D}{a}}\right) \quad (32)$$

where

V_{VIS} = required speed, ft/sec

t = time between recognition and application of brakes, sec

D = recognition distance and distance required to stop, ft

In consideration of the amount of absorbed-power due to surface roughness the driver/equipment is willing to endure over a given amount of time, a "ride" speed, V_{RIDE}, is set. This limit is usually about 8 hr for 6 W absorbed power by the driver/equipment. STNDMob provides this as a look-up table as a function of surface roughness and speed.

Similarly, STNDMob considers the amount of shock that a driver or equipment is willing to sustain when encountering an obstacle. The impact of the vehicle's traction element and the obstacle varies and usually increases as the height of the obstacle increases. Thus, the impact speed, V_{OBS}, will decrease as the height of the obstacle increases and will eventually become zero at a given height. STNDMob provides this as a look-up table as a function of obstacle height and speed.

For safe tire operation, STNDMob provides "limits" on speed, V_{TIRE}, due to tire design and suspension of the vehicle. This is the maximum safe tire speed, V_{TIRE}, and is the speed limit for which a tire of a particular design and deflection can endure the buildup of heat within the tire for a sustained hour. Neither of these speed limits is suitable for a CGF unless the speed limit is given as a function of sustained time.

After consideration of both terrain-limited speed and driver-behavior-limited speed, the predicted speed is

$$V = \min\left(V_{TL}, V_{VIS}, V_{RIDE}, V_{OBS}, V_{TIRE}\right) \quad (33)$$

Example Output

Representative vehicles and variable terrain (Level 2, Fidelity 3)

Table 3.5 provides an example for a high-mobility tracked vehicle. An M1A1 is used as the representative vehicle.

Table 3.5 Example of High-Mobility Tracked Vehicle							
Soil Type (USCS)	**Soil Strength (RCI/CI)**	**Surface Condition**	**Obstacle Height, in.**	**Vegetation Avg Spacing ft**	**Surface Roughness (RMS), in.**	**Slope %**	**Speed mph**
SM	300	Dry	0	0	0	0	39.5
SM	300	Dry	0	0	0	10	17.5
SM	300	Dry	0	0	0	40	4.1
SM	50	Dry	0	0	0	0	22.0
SM	50	Dry	0	0	0	10	12.3
SM	50	Dry	0	0	0	40	2.8
SM	50	Slippery	0	0	0	40	1.5
SM	100	Snow	0	0	0	0	33.3
SM	100	Snow	0	0	0	20	7.3
SM	300	Dry	24	0	0	0	25.3
SM	300	Dry	0	20	0	0	27.8
SM	300	Dry	0	0	3	0	13.3
SP	300	Dry	0	0	0	0	40.7
SP	300	Dry	0	0	0	10	18.8
SP	300	Dry	0	0	0	40	0.0
Note: All terrain attributes as defined in the input data section are not given in this example.							

Specific vehicles and variable terrain (Level 2, Fidelity 4)

Level 2, Fidelity 3, uses the representative vehicle to serve effectively as a substitute for the speed prediction of a specific vehicle, whereas Fidelity 4 uses the actual vehicle data file for a specific vehicle. Table 3.6 provides an example for a T-72 tank.

Table 3.6 Example of T-72 Tank							
Soil Type (USCS)	**Soil Strength (RCI/CI)**	**Surface Condition**	**Obstacle Height in.**	**Vegetation Avg Spacing, ft**	**Surface Roughness (RMS), in.**	**Slope %**	**Speed mph**
SM	300	Dry	0	0	0	0	31.5
SM	300	Dry	0	0	0	10	16.0
SM	300	Dry	0	0	0	40	2.9
SM	50	Dry	0	0	0	0	19.7
SM	50	Dry	0	0	0	10	11.1
SM	50	Dry	0	0	0	40	1.7
SM	50	Slippery	0	0	0	40	1.5
SM	100	Snow	0	0	0	0	27.5
SM	100	Snow	0	0	0	20	6.3
SM	300	Dry	24	0	0	0	0.0
SM	300	Dry	0	20	0	0	20.4
SM	300	Dry	0	0	3	0	12.0
SP	300	Dry	0	0	0	0	35.5
SP	300	Dry	0	0	0	10	16.8
SP	300	Dry	0	0	0	40	0.0
Note: All terrain attributes as defined in the input data section are not given in this example.							

4 Summary

Mobility is a key performance parameter that must be represented accurately and consistently within and across military M&S to produce valid interactions and support conclusions for decision-makers regarding system performance, force design, tactics, and doctrine. The detail required to represent ground vehicle mobility varies with the study level (engineering level versus tactical versus operational) with the goal of the simulation (e.g., training versus analysis). Model implementation within a simulation impacts the consistency with representations in other simulations. These further impact consistencies between unit locations, selected routes, traverse times, and discrimination in platform performance. A model-centric approach to mobility implementation tends to preclude generalized applicability to other simulations within or across levels of fidelity.

Current mobility implementation in M&S is largely tailored for specific models, leading to inconsistency between models. Cross-model consistency refers to agreement between representations in M&S of differing resolutions or levels of detail. For example, the mobility implementation in one simulation is such that vehicles are grouped into four classes for performance calculations: high and low mobility wheeled and tracked vehicles. Furthermore, vehicle speed within a class is calculated based on nine slope values and one of four visibility levels. In the second simulation vehicles are mapped into nine bins, and speed calculations incorporate a continuous function of slope and visibility levels. Thus, the same vehicle will likely exhibit different speed performance under the same conditions in the two simulations.

To assist the decision-makers in analysis, acquisition, and training issues, it is necessary to provide and promote consistency between models to be used in the analysis. The developing M&S systems plan to employ the NRMM, the AMSO standard for ground vehicle mobility (e.g., OneSAF Operational Requirements Document, COMBAT^{XXI} Functional Requirements Document). Without a holistic approach, actual implementations could produce inconsistencies and invalid behaviors for cross-model analysis and interoperability. Furthermore, this approach should enable NRMM enhancements and upgrades to be readily implemented as the STNDMob matures to accommodate advanced system issues (e.g., robotics and urban operations use).

The development of the STNDMob API suite is a definitive step in achieving the goal of cross-model consistency for ground vehicle mobility representation. The STNDMob API is a generalized, platform-independent implementation derived from NRMM to facilitate the standardized integration of entity-level mobility constraints into Department of Defense (DoD) simulations. A validation study of Level 1 was conducted by the AMSAA and has been documented (Fischer 2004). A comparison of NRMM and STNDMob Level 2 is given in Appendix D so that a user can understand the limitations of the derivation.

Ease of integration was accomplished with the assistance of software enhancements such as Java and XML. The use of the API in COMBAT^{XXI} shows its viability as a DoD product. Within the STNDMob API design, there are implementations that account for various levels of fidelity associated with the resolution of the input and output parameters. The development of generic APIs or object models will facilitate integration of the model into future simulations. Moreover, this approach will allow for upgrading the model with minimal reengineering of simulation links. The results of this research will save developers time and money and will promote implementation of model and algorithm improvements.

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Appendix A
Generation of Mobility Speed Predictions

The U.S. Army Engineer Research and Development Center (ERDC) has developed a set of standard databases for use in representing vehicle mobility across major M&S programs. The Program Executive Office Simulation Training Instrumentation for the Warfare Simulation 2000 (WARSIM) sponsored the development of the off-road mobility requirements. Resulting mobility databases have been implemented in JWARS, OneSAF, and COMBAT^{XXI} in an effort to promote reuse and interoperability among M&S programs.

NRMM terrain databases were built for four major regions (climate zones) using WARSIM-specific soil, vegetation, slopes, visibilities, and obstacle requirements and inference algorithms developed by the ERDC Geotechnical and Structures Laboratory (GSL). Mobility predictions were made for dry, wet, and snow scenarios using representative vehicles from each mobility class.

Regions

The Worldwide Climate Zones as produced by G. T. Trewartha and published in *Goode's World Atlas* (16th edition, Rand McNally and Company, 1983) are listed in Table A1. Terrain databases have been produced for all major climate zones excluding the Tropical Rainy and the Polar Climates. The Desert, the Humid Subtropical, and the Humid Continental-Warm Summer subclimate zones were selected to represent the Dry, the Humid Mesothermal, and the Humid Microthermal climate zones, respectively.

Scenarios

ERDC-GSL was sponsored by WARSIM to provide mobility data for dry-normal and wet-slippery scenarios. In support of COMBAT^{XXI} and JWARS mobility efforts, snow data were also generated.

Table A1 Worldwide Climate Zones – Subclimate Zones
A. Tropical Rainy Climates
Tropical Rainforest, Tropical Savanna
B. Dry Climates
Steppe, Desert
C. Humid Mesothermal Climates
Mediterranean or Dry Summer Subtropical, Humid Subtropical, Marine West Coast
D. Humid Microthermal Climates
Humid Continental, Warm Summer, Humid Continental, Cool Summer, Sub-Arctic
E. Polar Climates
Tundra, Ice Caps
F. Undifferentiated Highlands
Undifferentiated Highlands

Vehicles

Vehicles were bundled into 12 groups based on mobility and configuration, and representative vehicles were selected per group. Table A2 lists the vehicle bundles and representative vehicle for each bundle.

Table A2
Vehicle Bundles and Representative Vehicles

Vehicle Bundle	Representative Vehicle
High-Mobility Tracked	M1A1
Medium-Mobility Tracked	M270-MLRS
Low-Mobility Tracked	M60-AVLB
High- Mobility Wheeled	M1084
Medium-Mobility Wheeled	M985
Low-Mobility Wheeled	M917
High-Mobility Wheeled w/trailer	M1084-M1095
Medium-Mobility Wheeled w/trailer	M985-M989
Low-Mobility Wheeled w/trailer	M911-M747
Amphibious Combat Vehicle Tracked	M113A2
Amphibious Combat Vehicle Wheeled	LAV25
Light ATV (unmanned)	Kawasaki ATV

MLU Code Development

There are 255 Mobility Look-Up (MLU) off-road and 24 MLU on-road trafficability codes that map to the WARSIM Terrain Common Data Model (TCDM) surface trafficability groups JSIMS (STGJ) (Birkel 1999).[1] These off-road codes are based on the exhaustive combinations of 15 Interim Terrain Data (ITD) vegetation coverage codes and 17 ITD soil types (Table A3). The on-road codes are based on road type and surface material combinations (Table A4). (Note: Not every vegetation and soil type combination exists in the real world. Furthermore, codes exist only in particular regions of the world. However, for

[1] See References at the conclusion of the main text.

implementation and balance purposes, all 255 indices are used in each climate zone.)

Table A3
Specified Vegetation and Soil Types

Index	Vegetation	Soil
1	Wetlands	GW
2	Bareground	GP
3	Dry Agriculture	GM
4	Wet Agriculture	GC
5	Orchard/Plantation	SW
6	Vineyard/Hops	SP
7	Grassland/Pasture/Meadow	SM
8	Brushland/Scrub	SC
9	Bamboo/Cane	ML
10	Deciduous Forest	CL
11	Coniferous Forest	OL
12	Mixed Forest	CH
13	Forest Clearing	MH
14	Swamp	OH
15	Mangrove	PT
16		Evaporites (CLML)
17		Rock Crops (Rock)

Table A4
Road Descriptions

Cart Track or US-Trail UK-Trail/Footpath: GW
Cart Track or US-Trail UK-Trail/Footpath: GP
Cart Track or US-Trail UK-Trail/Footpath: GM
Cart Track or US-Trail UK-Trail/Footpath: GC
Cart Track or US-Trail UK-Trail/Footpath: SW
Cart Track or US-Trail UK-Trail/Footpath: SP
Cart Track or US-Trail UK-Trail/Footpath: SM
Cart Track or US-Trail UK-Trail/Footpath: SC
Cart Track or US-Trail UK-Trail/Footpath: ML
Cart Track or US-Trail UK-Trail/Footpath: CL
Cart Track or US-Trail UK-Trail/Footpath: OL
Cart Track or US-Trail UK-Trail/Footpath: CH
Cart Track or US-Trail UK-Trail/Footpath: MH
Cart Track or US-Trail UK-Trail/Footpath: OH
Cart Track or US-Trail UK-Trail/Footpath: PT
Cart Track or US-Trail UK-Trail/Footpath: Evaporites
Road: Hard/Paved
Road: Loose/Paved
Road: Loose/Light
Road: Corduroy
Road: Grass/Sod (Soft)
Road: Natural
Road: Permanent
Road: Temporary

NRMM Terrain Development

NRMM terrain format 7 was used to create the terrain files. This format was selected because it allows both road and spatial data in the same terrain file and it is in a free-field format (space or comma delimited). Both on-road and off-road terrain require the following characteristics: surface condition and depth, soil type, soil strengths for 0- to 6-in. and 6- to 12-in. layers, depth to bedrock, slope, surface roughness and visibility. Additional characteristics include road type and surface, super-elevation angle (in degrees), and radius of curvature (feet) for on-road terrain and obstacle geometry and vegetation spacing for off-road terrain (Bullock 1994).

WARSIM specified values for off-road slopes and for visibility and obstacle spacing distances. ERDC-GSL inference routines were used to define region-specific soil strengths, surface roughness, and vegetation spacing. ERDC subject matter experts provided number values for road type, soil/surface type, surface condition and depth, depth to bedrock, super-elevation angle, and radius of curvature. Separate terrain files were created by climate zone, scenario, road type, and visibility-obstacle spacing categories.

Specified Data

Visibility

Situational visibility is a function of the surface and slope on which the vehicle is operating, the distance the driver can see, and the vehicle's maximum braking ability. Visibility is related to the maximum speed the vehicle can travel and still be brought to a stop under maximum braking within the visibility distance. Based on work with WARSIM developers, the visibility distances were set at 25, 50, 100, 300 ft (where 300 ft is equivalent to an unlimited visibility condition). Table A5 provides the rationale for these values. Table A6 further extends the rationale for visibility of off-road terrain based upon land use, seasons, and climate zone.

Battlefield clutter or obstacle spacing

Based on work with WARSIM developers, it was determined that all obstacles would be 8 ft long, 8 ft wide, and 45 in. tall with a 90-deg approach angle. Obstacles would be simulated at spacings of 20, 25, 30, and 150 ft (where 150 ft is equivalent to a no-clutter condition). These settings virtually ensured that no vehicle could maneuver over the obstacles and that distinctions in maneuverability between larger and smaller vehicles would be apparent. See Table A7 for visibility settings when obstacles are combined.

Table A5
Visibility for On-Road Conditions

Visibility (vis, road)	Distance (ft)	Meaning
1	300	Unlimited, distance spacing of vehicles, no precipitation, daytime lighting, headlights at night, no obscurants, good contrast.
2	100	Somewhat limited, distant spacing of vehicles, light precipitation, daytime lighting, headlights at night, obscurants or blackout w/vision enhancement devices, fair contrast.
3	50	Limited, close spacing of vehicles, heavy precipitation/fog, low solar/lunar illumination, heavy obscurants w/vision enhancement devices, poor contrast.
4	25	Very limited, close spacing of vehicles, no solar/lunar illumination, heavy obscurants and/or blackout w/no enhanced vision devices, very poor contrast.

[1] See the references listed below for additional information on these topics:

- Convoy spacing [McKinley et al. 2001]
- Computing transmissivity due to obscurants ["Combined obscuration model for battlefield induced contaminants (COMBIC)," U.S. Army Research Laboratory, Adelphi, MD]
- Computing recognition distance due to contrast as a function of transmissivity ["Target Acquisition Model (TARGAC)," U.S. Army Research Laboratory, Adelphi, MD, and "Night Vision Goggle Operations (NOWS)," Phillips Laboratory, Geophysics Directorate, Hanscom AFB, Maine]

Table A6
Seasonal Visibility Based on Land Use Type

	Climate Zone															
	Dry				Humid Mesothermal				Humid Microthermal				Undifferentiated Highlands			
Land Use Type	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Wetland	3	3	4	3	2	3	3	2	2	3	3	2	2	2	2	2
Dry crop	1	4	4	1	1	3	4	1	1	3	3	1	1	4	4	1
Shifting crop	1	4	4	1	1	3	4	1	1	3	3	1	1	4	4	1
Terraced crop	1	4	4	1	1	3	4	2	1	3	3	1	1	4	4	1
Rice paddy	1	3	4	1	1	3	3	1	1	3	3	1	1	3	4	1
Agricult. w/scat trees	1	4	4	1	1	3	3	1	1	3	3	1	1	4	4	1
Orchard	2	3	3	2	2	2	3	2	2	2	2	2	2	3	3	2
Vineyard	2	3	3	2	2	3	3	2	2	3	3	2	2	3	3	2
Pasture/meadow	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1
Grassland	1	3	4	1	1	2	2	1	1	2	2	1	1	2	2	1
Grassland w/scat trees	1	3	4	2	1	2	2	1	1	2	2	1	1	2	2	1
Scrub	3	4	4	2	2	3	4	2	2	2	2	2	2	3	3	2
Bamboo	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Deciduous forest	2	3	3	3	2	3	3	2	2	3	3	3	2	3	3	2
Coniferous forest	2	3	3	3	2	3	3	3	2	3	3	3	2	3	3	2
Mixed forest	3	3	3	3	2	3	3	3	2	3	3	3	2	3	3	2
Palm	2	3	4	2	2	2	3	2	2	2	2	2	2	2	3	2
Mangrove	4	4	4	4	4	4	4	4	3	4	4	3	4	4	4	4
Forest clearing	1	2	2	1	1	1	1	1	1	1	1	1	1	2	2	1
Bareground	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

W – Winter Jan-Mar, S – Spring Apr-Jun, S – Summer Jul-Sep, F – Fall Oct-Dec.
Visibility 1 (300 ft), 2 (100 ft), 3 (50 ft), 4 (25 ft).
More climate zones are given in Bullock (1994), but must be mapped to the 4 visibility distances.

Table A7 Visibility and Obstacle Combinations			
Visibility and Obstacle Combinations (visobs, cross-country)	Distance ft	Obstacle Spacing ft	Meaning
1	300	150	See vis meaning plus uncluttered, no vegetation, bareground.
2	100	150	See vis meaning plus uncluttered, sparse vegetation or vegetation in winter.
3	50	150	See vis meaning plus uncluttered, vegetation in spring to fall.
4	25	150	See vis meaning plus uncluttered, dense vegetation.
5	300	30	See vis meaning, cluttered due to urban or industrial area damage, concentration of damaged vehicles, cratering, rubble, rock outcrops, some vegetation.
6	100	30	"
7	50	30	"
8	25	30	"
9	300	25	Same as above and redundant.
10	100	25	"
11	50	25	"
12	25	25	"
13	300	20	See vis meaning, *severely* cluttered due to heavy urban or industrial area damage, *dense* concentration of damaged vehicles, cratering, rubble, rock outcrops, dense vegetation.
14	100	20	"
15	50	20	"
16	25	20	"
Note: See Tables A4 and A5.			

Slopes

Off-road. WARSIM predetermined slopes for off-road terrain were set as -40, -30, -20, -10, 0, 10, 20, 30, and 40 percent. These values correspond with the CCTT values.

On-road. By road design, major roads will not have slopes greater than 30 or 40 percent. According to research accomplished in concurrence with the JWARS mobility effort, maximum slopes would be 15 percent (McKinley et al. 2001). Based on input from subject matter experts, it was determined that trail categories could be set as equivalent to off-road slope categories (0, 10, 20, 30, 40 percent), but maximum slopes on superhighways, primary, and secondary roads should be limited to 15 percent. Thus, slopes were assigned for these roads as 0, 4, 8, 12, 15, -4, -8, -12, and -15 percent (McKinley et al. 2001).

Surface condition

Surface condition was set to 1 for normal conditions and 2 for slippery conditions.

Surface depth

Surface depth equals 0 when scenario is dry or wet. Surface depth equals depth of snow or ice for winter conditions.

Depth to bedrock

Depth to bedrock was arbitrarily set to 99 in. NRMM ignores any value larger than 12.

Distance

Distance per terrain unit was set to 0.05 mile (264 ft).

Super-elevation and radius of curvature

ERDC specified super-elevation angles (EANG) and radius of curvature values (RADC) for roads are shown in Table A8.

Table A8
Super-Elevation (EANG) and Radius of Curvature (RADC) Data

Road Type	IROAD	EANG, deg	RADC, ft
Off-road	0	n/a	n/a
Superhighway	1	0.12	5730
Primary road	2	0.12	5730
Secondary road	3	0.06	5730
Trail	4	0.00	5730

Road and road surface material types

ERDC specified road type (IROAD) and surface material type for roads and cart tracks, as shown in Table A9.

Table A9
Road and Road Surface Material Types

Road Description	IROAD	Surface Type/ Material
Cart Track or US-Trail UK-Trail/Footpath: GW	4	GW
Cart Track or US-Trail UK-Trail/Footpath: GP	4	GP
Cart Track or US-Trail UK-Trail/Footpath: GM	4	GM
Cart Track or US-Trail UK-Trail/Footpath: GC	4	GC
Cart Track or US-Trail UK-Trail/Footpath: SW	4	SW
Cart Track or US-Trail UK-Trail/Footpath: SP	4	SP
Cart Track or US-Trail UK-Trail/Footpath: SM	4	SM
Cart Track or US-Trail UK-Trail/Footpath: SC	4	SC
Cart Track or US-Trail UK-Trail/Footpath: ML	4	ML
Cart Track or US-Trail UK-Trail/Footpath: CL	4	CL
Cart Track or US-Trail UK-Trail/Footpath: OL	4	OL
Cart Track or US-Trail UK-Trail/Footpath: CH	4	CH
Cart Track or US-Trail UK-Trail/Footpath: MH	4	MH
Cart Track or US-Trail UK-Trail/Footpath: OH	4	OH
Cart Track or US-Trail UK-Trail/Footpath: PT	4	PT
Cart Track or US-Trail UK-Trail/Footpath: Evaporites	4	CLML
Road: Hard/Paved	2	PAVE
Road: Loose/Paved	3	ML
Road: Loose/Light	4	ML
Road: Corduroy	1	PAVE
Road: Grass/Sod (Soft)	4	SM
Road: Natural	4	SM
Road: Permanent	1	PAVE
Road: Temporary	4	SM

Inference Data

Soil strength

Soil strength, or Relative Cone Index (RCI), values are given for layers 0-6 in. and 6-12 in., respectively. RCIs are inferred from wetness index, soil type, soil moisture, and region. Soil moisture is determined using soil type, and wetness index is inferred by slope, soil type, vegetation, and region.

a. Wetness indices (Table A10) are dependent upon climate zone and slope.

Table A10
Wetness Index

Wetness Index	Description
0	Arid
1	Dry (steep slopes, semiarid regions)
2	Average (well drained)
3	Wet (poorly drained, bottomlands)
4	Saturated (flooded part of the year)
5	Waterlogged (perennially waterlogged)

b. Rules used for assigning the wetness index (WI) are as follows (Bullock 1994):

(1) If vegetation = wetlands, swamp, or mangrove, WI = 5.

(2) If vegetation = wet crops, WI = 4.

(3) If vegetation ≠ wetlands, swamp, mangrove, or wet crops, consider the climate region and slope as given in the following table.

Table A11
Wetness Indices for Vegetation Not Equal to Wetlands, Swamp, Mangrove, or Wet Crops

Region/Slope	0	10	20	30	40
Desert	2	1	1	1	1
Humid Mesothermal	4	3	3	2	2
Humid Microthermal	4	4	3	2	2
Undiff Highlands	3	2	2	2	2

(4) WI for negative slopes: use those given for positive slopes.

Surface roughness

Surface roughness measurements (RMS) were inferred from vegetation, soil type, and region. Sources include Table 46 of Bullock (1994) and the XLATE translation algorithm that contained some of the tables as referenced. When the two differed, Table 46 of Bullock (1994) was used. Table A12 provides the pertinent values.

a. *Major versus minor.* XLATE contained RMS values for each major climate zone but not for the subclimate zones.

b. *Bareground.* Table 46 shows that RMS varies by soil type when vegetation = bareground. In discussing RMS values for trails, this would also be true.

c. *Swamp.* No RMS data are given in Table 46 for swamps. In XLATE, swamps were assumed mixed, and RMS data for mixed forests were assigned to swamps. This was assumed in TVCC-VEG as well.

d. *Crops.* Dry crops = wet crops.

e. *Forests.* Coniferous forest = mixed forest = swamp.

Table A12
RMS Data Used

	Desert	Humid Mesothermal	Humid Microthermal	Undiff Highlands
Wetland	0.3	1.4	1.4	1.4
Bareground – Gravel	0.6	0.6	0.6	1.0
Bareground – Sand	0.3	0.6	0.6	1.0
Bareground – Clay/Silt	0.6	0.6	0.6	1.4
Bareground – Rock	1.8	1.8	1.8	2.2
Dry Crops	0.6	0.6	0.6	1.0
Orchard/Plantation	0.6	0.6	1.0	1.0
Vineyard	0.6	0.6	1.0	1.0
Grassland	0.6	0.6	0.6	1.0
Brush/Scrub	1.4	1.4	1.4	1.8
Bamboo	1.0	1.0	1.0	1.0
Deciduous Forest	1.0	1.0	1.4	1.4
Coniferous Forest	1.0	1.4	1.4	1.4
Forest Clearing	1.0	1.4	1.8	1.8
Mangrove	1.8	1.8	1.8	1.8

Vegetation

Vegetation is necessary only for orchards, forests, and swamps. Bullock (1994) does not include vegetation for swamps. Swamps were assumed mixed tree types. Swamps and mangroves are not different by climate zone, and neither are orchards. Tables A13-A16 provide the indicated spacings given in units of feet. The value of 328 ft (100 m) is assumed to be the greatest distance that the spacing of vegetation would influence speed.

Table A13
Vegetation for Desert

	Bins	S1	S2	S3	S4	S5	S6	S7	S8
Dec Forest	1-5	1	3	15	328	328	328	328	328
Con Forest	1-5	1	2	25	328	328	328	328	328
Mix Forest	1-5	1	2	21	328	328	328	328	328
Orchard	XLATE[1]	30	30	32	32	34	45	55	60
Swamp	XLATE	30	30	32	32	34	45	55	60
Mangrove	XLATE	22	22	22	22	22	28	28	30

[1] Inferred from the ERDC-GSL XLATE algorithm for vegetation spacing and given in feet.

Table A14
Vegetation for Humid Mesothermal

	Bins	S1	S2	S3	S4	S5	S6	S7	S8
0	26-30	9	10	11	12	15	20	31	115
Con Forest	26-30	9	10	10	12	14	20	34	248
Mix Forest	26-30	9	9	12	15	18	22	28	66
Orchard	XLATE[1]	30	30	32	32	34	45	55	60
Swamp	XLATE	30	30	32	32	34	45	55	60
Mangrove	XLATE	22	22	22	22	22	28	28	30

[1] Inferred from the ERDC-GSL XLATE algorithm for vegetation spacing and given in feet.

Table A15
Vegetation for Humid Microthermal

	Bins	S1	S2	S3	S4	S5	S6	S7	S8
Dec Forest	11-15	4	5	11	45	328	328	328	328
Con Forest	11-15	4	5	11	45	328	328	328	328
Mix Forest	11-15	4	5	11	38	195	328	328	328
Orchard	XLATE[1]	30	30	32	32	34	45	55	60
Swamp	XLATE	30	30	32	32	34	45	55	60
Mangrove	XLATE	22	22	22	22	22	28	28	30

[1] Inferred from the ERDC-GSL XLATE algorithm for vegetation spacing and given in feet.

Table A16
Vegetation for Undifferentiated Highlands

	Bins	S1	S2	S3	S4	S5	S6	S7	S8
Dec Forest	26-30	9	10	11	12	14	18	27	87
Con Forest	26-30	9	9	10	11	14	22	41	328
Mix Forest	26-30	9	9	12	14	17	21	28	78
Orchard	XLATE[1]	30	30	32	32	34	45	55	60
Swamp	XLATE	30	30	32	32	34	45	55	60
Mangrove	XLATE	22	22	22	22	22	28	28	30

[1] Inferred from the ERDC-GSL XLATE algorithm for vegetation spacing and given in feet.

Appendix B WARSIM Terrain Common Data Model (TCDM) STGJ to MLU Mappings

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
0	Unknown										0
1	Areal Urban: AA010 Mine	AA010									0
2	Areal Urban: AA012 Quarry	AA012									0
3	Areal Urban: AA052 Oil / Gas Field; STP: GW	AA052							1		18
4	Areal Urban: AA052 Oil / Gas Field; STP: GP	AA052							2		19
5	Areal Urban: AA052 Oil / Gas Field; STP: GM	AA052							3		20
6	Areal Urban: AA052 Oil / Gas Field; STP: GC	AA052							4		21
7	Areal Urban: AA052 Oil / Gas Field; STP: SW	AA052							5		22
8	Areal Urban: AA052 Oil / Gas Field; STP: SP	AA052							6		23
9	Areal Urban: AA052 Oil / Gas Field; STP: SM	AA052							7		24
10	Areal Urban: AA052 Oil / Gas Field; STP: SC	AA052							8		25
11	Areal Urban: AA052 Oil / Gas Field; STP: ML	AA052							9		26
12	Areal Urban: AA052 Oil / Gas Field; STP: CL	AA052							10		27
13	Areal Urban: AA052 Oil / Gas Field; STP: OL	AA052							11		28
14	Areal Urban: AA052 Oil / Gas Field; STP: CH	AA052							12		29
15	Areal Urban: AA052 Oil / Gas Field; STP: MH	AA052							13		30
16	Areal Urban: AA052 Oil / Gas Field; STP: OH	AA052							14		31
17	Areal Urban: AC000 Processing Plant	AC000									0
18	Areal Urban: AC030 Settling Pond	AC030									0
19	Areal Urban: AC040 Oil / Gas Facilities	AC040									0
20	Areal Urban: AD010 Power Plant	AD010									0
21	Areal Urban: AD030 Substation	AD030									0
22	Areal Urban: AE010 Fabrication Facility	AE010									0
23	Areal Urban: AK030 Amusement Park; STP: GW	AK030							1		18
24	Areal Urban: AK030 Amusement Park; STP: GP	AK030							2		19
25	Areal Urban: AK030 Amusement Park; STP: GM	AK030							3		20
26	Areal Urban: AK030 Amusement Park; STP: GC	AK030							4		21
27	Areal Urban: AK030 Amusement Park; STP: SW	AK030							5		22
28	Areal Urban: AK030 Amusement Park; STP: SP	AK030							6		23
29	Areal Urban: AK030 Amusement Park; STP: SM	AK030							7		24
30	Areal Urban: AK030 Amusement Park; STP: SC	AK030							8		25
31	Areal Urban: AK030 Amusement Park; STP: ML	AK030							9		26
32	Areal Urban: AK030 Amusement Park; STP: CL	AK030							10		27
33	Areal Urban: AK030 Amusement Park; STP: OL	AK030							11		28
34	Areal Urban: AK030 Amusement Park; STP: CH	AK030							12		29
35	Areal Urban: AK030 Amusement Park; STP: MH	AK030							13		30
36	Areal Urban: AK030 Amusement Park; STP: OH	AK030							14		31
37	Areal Urban: AK110 Grandstand	AK110									0

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
38	Areal Urban: AK130 US Race Track; STP: GW	AK130							1		0
39	Areal Urban: AK130 US Race Track; STP: GP	AK130							2		0
40	Areal Urban: AK130 US Race Track; STP: GM	AK130							3		0
41	Areal Urban: AK130 US Race Track; STP: GC	AK130							4		0
42	Areal Urban: AK130 US Race Track; STP: SW	AK130							5		0
43	Areal Urban: AK130 US Race Track; STP: SP	AK130							6		0
44	Areal Urban: AK130 US Race Track; STP: SM	AK130							7		0
45	Areal Urban: AK130 US Race Track; STP: SC	AK130							8		0
46	Areal Urban: AK130 US Race Track; STP: ML	AK130							9		0
47	Areal Urban: AK130 US Race Track; STP: CL	AK130							10		0
48	Areal Urban: AK130 US Race Track; STP: OL	AK130							11		0
49	Areal Urban: AK130 US Race Track; STP: CH	AK130							12		0
50	Areal Urban: AK130 US Race Track; STP: MH	AK130							13		0
51	Areal Urban: AK130 US Race Track; STP: OH	AK130							14		0
52	Areal Urban: AK160 US Stadium / Amphitheater	AK160									0
53	Areal Urban: AL015 Building	AL015									0
54	Areal Urban: AL020 Built-Up Area	AL020									0
55	Areal Urban: AL105 Settlement; STP: GW	AL105							1		18
56	Areal Urban: AL105 Settlement; STP: GP	AL105							2		19
57	Areal Urban: AL105 Settlement; STP: GM	AL105							3		20
58	Areal Urban: AL105 Settlement; STP: GC	AL105							4		21
59	Areal Urban: AL105 Settlement; STP: SW	AL105							5		22
60	Areal Urban: AL105 Settlement; STP: SP	AL105							6		23
61	Areal Urban: AL105 Settlement; STP: SM	AL105							7		24
62	Areal Urban: AL105 Settlement; STP: SC	AL105							8		25
63	Areal Urban: AL105 Settlement; STP: ML	AL105							9		26
64	Areal Urban: AL105 Settlement; STP: CL	AL105							10		27
65	Areal Urban: AL105 Settlement; STP: OL	AL105							11		28
66	Areal Urban: AL105 Settlement; STP: CH	AL105							12		29
67	Areal Urban: AL105 Settlement; STP: MH	AL105							13		30
68	Areal Urban: AL105 Settlement; STP: OH	AL105							14		31
69	Areal Urban: AL135 Native Settlement; STP: GW	AL135							1		18
70	Areal Urban: AL135 Native Settlement; STP: GP	AL135							2		19
71	Areal Urban: AL135 Native Settlement; STP: GM	AL135							3		20
72	Areal Urban: AL135 Native Settlement; STP: GC	AL135							4		21
73	Areal Urban: AL135 Native Settlement; STP: SW	AL135							5		22
74	Areal Urban: AL135 Native Settlement; STP: SP	AL135							6		23
75	Areal Urban: AL135 Native Settlement; STP: SM	AL135							7		24

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
76	Areal Urban: AL135 Native Settlement; STP: SC	AL135							8		25
77	Areal Urban: AL135 Native Settlement; STP: ML	AL135							9		26
78	Areal Urban: AL135 Native Settlement; STP: CL	AL135							10		27
79	Areal Urban: AL135 Native Settlement; STP: OL	AL135							11		28
80	Areal Urban: AL135 Native Settlement; STP: CH	AL135							12		29
81	Areal Urban: AL135 Native Settlement; STP: MH	AL135							13		30
82	Areal Urban: AL135 Native Settlement; STP: OH	AL135							14		31
83	Areal Urban: AL200 Ruins; STP: GW	AL200							1		18
84	Areal Urban: AL200 Ruins; STP: GP	AL200							2		19
85	Areal Urban: AL200 Ruins; STP: GM	AL200							3		20
86	Areal Urban: AL200 Ruins; STP: GC	AL200							4		21
87	Areal Urban: AL200 Ruins; STP: SW	AL200							5		22
88	Areal Urban: AL200 Ruins; STP: SP	AL200							6		23
89	Areal Urban: AL200 Ruins; STP: SM	AL200							7		24
90	Areal Urban: AL200 Ruins; STP: SC	AL200							8		25
91	Areal Urban: AL200 Ruins; STP: ML	AL200							9		26
92	Areal Urban: AL200 Ruins; STP: CL	AL200							10		27
93	Areal Urban: AL200 Ruins; STP: OL	AL200							11		28
94	Areal Urban: AL200 Ruins; STP: CH	AL200							12		29
95	Areal Urban: AL200 Ruins; STP: MH	AL200							13		30
96	Areal Urban: AL200 Ruins; STP: OH	AL200							14		31
97	Areal Urban: AM010 Depot (Storage)	AM010									0
98	Areal Urban: AN060 Rail Yard	AN060									0
99	Areal Urban: AT050 Communication Building	AT050									0
100	Areal Water: Fore Shore; BMC: Clay and Silt	BA020	1								0
101	Areal Water: BA020 Fore Shore; BMC: Silty Sands	BA020	2								0
102	Areal Water: BA020 Fore Shore; BMC: Sand and Gravel	BA020	3								0
103	Areal Water: BA020 Fore Shore; BMC: Gravel and Cobble	BA020	4								0
104	Areal Water: BA020 Fore Shore; BMC: Rocks and Boulders	BA020	5								0
105	Areal Water: BA020 Fore Shore; BMC: Bedrock	BA020	6								0
106	Areal Water: BA020 Fore Shore; BMC: Paved	BA020	7								0
107	Areal Water: BA020 Fore Shore; BMC: Peat	BA020	8								0
108	Areal Water: BA020 Fore Shore; BMC: Sand over mud	BA020	9								0
109	Areal Water: BA020 Fore Shore; BMC: Mixed qualities	BA020	10								0
110	Areal Water: BA020 Fore Shore; BMC: Coral	BA020	11								0
111	Areal Water: BA020 Fore Shore; BMC: Slash	BA020	12								0
112	Areal Water: BA020 Fore Shore; BMC: Seamount	BA020	13								0

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
113	Areal Water: BA020 Fore Shore; BMC: Sand	BA020	14								0
114	Areal Water: BA040 Water (Except Inland); BMC: Clay and Silt	BA040	1								0
115	Areal Water: BA040 Water (Except Inland); BMC: Silty Sands	BA040	2								0
116	Areal Water: BA040 Water (Except Inland); BMC: Sand and Gravel	BA040	3								0
117	Areal Water: BA040 Water (Except Inland); BMC: Gravel and Cobble	BA040	4								0
118	Areal Water: BA040 Water (Except Inland); BMC: Rocks and Boulders	BA040	5								0
119	Areal Water: BA040 Water (Except Inland); BMC: Bedrock	BA040	6								0
120	Areal Water: BA040 Water (Except Inland); BMC: Paved	BA040	7								0
121	Areal Water: BA040 Water (Except Inland); BMC: Peat	BA040	8								0
122	Areal Water: BA040 Water (Except Inland); BMC: Sand over mud	BA040	9								0
123	Areal Water: BA040 Water (Except Inland); BMC: Mixed qualities	BA040	10								0
124	Areal Water: BA040 Water (Except Inland); BMC: Coral	BA040	11								0
125	Areal Water: BA040 Water (Except Inland); BMC: Slash	BA040	12								0
126	Areal Water: BA040 Water (Except Inland); BMC: Seamount	BA040	13								0
127	Areal Water: BA040 Water (Except Inland); BMC: Sand	BA040	14								0
128	Areal Water or Hydrography: BH010 Aqueduct; BMC: Clay and Silt	BH010	1								0
129	Areal Water or Hydrography: BH010 Aqueduct; BMC: Silty Sands	BH010	2								0
130	Areal Water or Hydrography: BH010 Aqueduct; BMC: Sand and Gravel	BH010	3								0
131	Areal Water or Hydrography: BH010 Aqueduct; BMC: Gravel and Cobble	BH010	4								0
132	Areal Water or Hydrography: BH010 Aqueduct; BMC: Rocks and Boulders	BH010	5								0
133	Areal Water or Hydrography: BH010 Aqueduct; BMC: Bedrock	BH010	6								0
134	Areal Water or Hydrography: BH010 Aqueduct; BMC: Paved	BH010	7								0
135	Areal Water or Hydrography: BH010 Aqueduct; BMC: Peat	BH010	8								0
136	Areal Water or Hydrography: BH010 Aqueduct; BMC: Sand over mud	BH010	9								0
137	Areal Water or Hydrography: BH010 Aqueduct; BMC: Mixed qualities	BH010	10								0
138	Areal Water or Hydrography: BH010 Aqueduct; BMC: Sand	BH010	14								0
139	Areal Water or Hydrography: BH020 Canal; BMC: Clay and Silt	BH020	1								0
140	Areal Water or Hydrography: BH020 Canal; BMC: Silty Sands	BH020	2								0
141	Areal Water or Hydrography: BH020 Canal; BMC: Sand and Gravel	BH020	3								0
142	Areal Water or Hydrography: BH020 Canal; BMC: Gravel and Cobble	BH020	4								0
143	Areal Water or Hydrography: BH020 Canal; BMC: Rocks and Boulders	BH020	5								0

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
144	Areal Water or Hydrography: BH020 Canal; BMC: Bedrock	BH020	6								0
145	Areal Water or Hydrography: BH020 Canal; BMC: Paved	BH020	7								0
146	Areal Water or Hydrography: BH020 Canal; BMC: Peat	BH020	8								0
147	Areal Water or Hydrography: BH020 Canal; BMC: Sand over mud	BH020	9								0
148	Areal Water or Hydrography: BH020 Canal; BMC: Mixed qualities	BH020	10								0
149	Areal Water or Hydrography: BH020 Canal; BMC: Sand	BH020	14								0
150	Areal Urban: BH040 Filtration Beds	BH040									0
151	Areal Water: BH050 Fish Hatchery	BH050									0
152	Areal Water: BH080 Lake / Pond; BMC: Clay and Silt	BH080	1								0
153	Areal Water: BH080 Lake / Pond; BMC: Silty Sands	BH080	2								0
154	Areal Water: BH080 Lake / Pond; BMC: Sand and Gravel	BH080	3								0
155	Areal Water: BH080 Lake / Pond; BMC: Gravel and Cobble	BH080	4								0
156	Areal Water: BH080 Lake / Pond; BMC: Rocks and Boulders	BH080	5								0
157	Areal Water: BH080 Lake / Pond; BMC: Bedrock	BH080	6								0
158	Areal Water: BH080 Lake / Pond; BMC: Paved	BH080	7								0
159	Areal Water: BH080 Lake / Pond; BMC: Peat	BH080	8								0
160	Areal Water: BH080 Lake / Pond; BMC: Sand over mud	BH080	9								0
161	Areal Water: BH080 Lake / Pond; BMC: Mixed qualities	BH080	10								0
162	Areal Water: BH080 Lake / Pond; BMC: Sand	BH080	14								0
163	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: GW	BH095			?				1		222
164	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: GP	BH095			?				2		223
165	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: GM	BH095			?				3		224
166	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: GC	BH095			?				4		225
167	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: SW	BH095			?				5		226
168	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: SP	BH095			?				6		227
169	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: SM	BH095			?				7		228
170	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: SC	BH095			?				8		229
171	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: ML	BH095			?				9		230
172	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: CL	BH095			?				10		231
173	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: OL	BH095			?				11		232
174	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: CH	BH095			?				12		233
175	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: MH	BH095			?				13		234

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
176	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: OH	BH095			?				14		235
177	Areal Vegetation: BH095 Marsh / Swamp; DMT <= 25, STP: PT	BH095			?				15		236
178	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: GW	BH095			?				1		222
179	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: GP	BH095			?				2		223
180	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: GM	BH095			?				3		224
181	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: GC	BH095			?				4		225
182	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: SW	BH095			?				5		226
183	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: SP	BH095			?				6		227
184	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: SM	BH095			?				7		228
185	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: SC	BH095			?				8		229
186	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: ML	BH095			?				9		230
187	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: CL	BH095			?				10		231
188	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: OL	BH095			?				11		232
189	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: CH	BH095			?				12		233
190	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: MH	BH095			?				13		234
191	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: OH	BH095			?				14		235
192	Areal Vegetation: BH095 Marsh / Swamp; DMT >= 26, STP: PT	BH095			?				15		236
193	Hydrography: BH120 Rapids; BMC: Silty Sands	BH120	2								0
194	Hydrography: BH120 Rapids; BMC: Sand and Gravel	BH120	3								0
195	Hydrography: BH120 Rapids; BMC: Gravel and Cobble	BH120	4								0
196	Hydrography: BH120 Rapids; BMC: Rocks and Boulders	BH120	5								0
197	Hydrography: BH120 Rapids; BMC: Bedrock	BH120	6								0
198	Hydrography: BH120 Rapids; BMC: Paved	BH120	7								0
199	Hydrography: BH120 Rapids; BMC: Mixed qualities	BH120	10								0
200	Areal Water: BH130 Reservoir; BMC: Clay and Silt	BH130	1								0
201	Areal Water: BH130 Reservoir; BMC: Silty Sands	BH130	2								0
202	Areal Water: BH130 Reservoir; BMC: Sand and Gravel	BH130	3								0
203	Areal Water: BH130 Reservoir; BMC: Gravel and Cobble	BH130	4								0
204	Areal Water: BH130 Reservoir; BMC: Rocks and Boulders	BH130	5								0
205	Areal Water: BH130 Reservoir; BMC: Bedrock	BH130	6								0
206	Areal Water: BH130 Reservoir; BMC: Paved	BH130	7								0
207	Areal Water: BH130 Reservoir; BMC: Peat	BH130	8								0

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
208	Areal Water: BH130 Reservoir; BMC: Sand over mud	BH130	9								0
209	Areal Water: BH130 Reservoir; BMC: Mixed qualities	BH130	10								0
210	Areal Water: BH130 Reservoir; BMC: Sand	BH130	14								0
211	Areal Vegetation: BH135 Rice Field; STP: GW	BH135							1		35
212	Areal Vegetation: BH135 Rice Field; STP: GP	BH135							2		36
213	Areal Vegetation: BH135 Rice Field; STP: GM	BH135							3		37
214	Areal Vegetation: BH135 Rice Field; STP: GC	BH135							4		38
215	Areal Vegetation: BH135 Rice Field; STP: SW	BH135							5		39
216	Areal Vegetation: BH135 Rice Field; STP: SP	BH135							6		40
217	Areal Vegetation: BH135 Rice Field; STP: SM	BH135							7		41
218	Areal Vegetation: BH135 Rice Field; STP: SC	BH135							8		42
219	Areal Vegetation: BH135 Rice Field; STP: ML	BH135							9		43
220	Areal Vegetation: BH135 Rice Field; STP: CL	BH135							10		44
221	Areal Vegetation: BH135 Rice Field; STP: OL	BH135							11		45
222	Areal Vegetation: BH135 Rice Field; STP: CH	BH135							12		46
223	Areal Vegetation: BH135 Rice Field; STP: MH	BH135							13		47
224	Areal Vegetation: BH135 Rice Field; STP: OH	BH135							14		48
225	Areal Water or Hydrography: BH140 River / Stream; BMC: Clay and Silt	BH140	1								0
226	Areal Water or Hydrography: BH140 River / Stream; BMC: Silty Sands	BH140	2								0
227	Areal Water or Hydrography: BH140 River / Stream; BMC: Sand and Gravel	BH140	3								0
228	Areal Water or Hydrography: BH140 River / Stream; BMC: Gravel and Cobble	BH140	4								0
229	Areal Water or Hydrography: BH140 River / Stream; BMC: Rocks and Boulders	BH140	5								0
230	Areal Water or Hydrography: BH140 River / Stream; BMC: Bedrock	BH140	6								0
231	Areal Water or Hydrography: BH140 River / Stream; BMC: Paved	BH140	7								0
232	Areal Water or Hydrography: BH140 River / Stream; BMC: Peat	BH140	8								0
233	Areal Water or Hydrography: BH140 River / Stream; BMC: Sand over mud	BH140	9								0
234	Areal Water or Hydrography: BH140 River / Stream; BMC: Mixed qualities	BH140	10								0
235	Areal Water or Hydrography: BH140 River / Stream; BMC: Sand	BH140	14								0
236	Areal Physiography: BH150 Salt Pan; STP: Evaporites	BH150							18		33
237	Areal Urban: BH155 Salt Evaporator; STP: Evaporites	BH155							18		33
238	Areal Physiography: BH160 Sebkha; STP: Evaporites	BH160							18		33
239	Areal Water: BH190 Lagoon / Reef Pool; BMC: Clay and Silt	BH190	1								0
240	Areal Water: BH190 Lagoon / Reef Pool; BMC: Silty Sands	BH190	2								0
241	Areal Water: BH190 Lagoon / Reef Pool; BMC: Sand and Gravel	BH190	3								0

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
242	Areal Water: BH190 Lagoon / Reef Pool; BMC: Gravel and Cobble	BH190	4								0
243	Areal Water: BH190 Lagoon / Reef Pool; BMC: Rocks and Boulders	BH190	5								0
244	Areal Water: BH190 Lagoon / Reef Pool; BMC: Bedrock	BH190	6								0
245	Areal Water: BH190 Lagoon / Reef Pool; BMC: Paved	BH190	7								0
246	Areal Water: BH190 Lagoon / Reef Pool; BMC: Peat	BH190	8								0
247	Areal Water: BH190 Lagoon / Reef Pool; BMC: Sand over mud	BH190	9								0
248	Areal Water: BH190 Lagoon / Reef Pool; BMC: Mixed qualities	BH190	10								0
249	Areal Water: BH190 Lagoon / Reef Pool; BMC: Coral	BH190	11								0
250	Areal Water: BH190 Lagoon / Reef Pool; BMC: Slash	BH190	12								0
251	Areal Water: BH190 Lagoon / Reef Pool; BMC: Sand	BH190	14								0
252	Areal Vegetation: BJ110 Tundra; STP: GW, VEG: Tundra	BJ110							1	69	103
253	Areal Vegetation: BJ110 Tundra; STP: GP, VEG: Tundra	BJ110							2	69	104
254	Areal Vegetation: BJ110 Tundra; STP: GM, VEG: Tundra	BJ110							3	69	105
255	Areal Vegetation: BJ110 Tundra; STP: GC, VEG: Tundra	BJ110							4	69	106
256	Areal Vegetation: BJ110 Tundra; STP: SW, VEG: Tundra	BJ110							5	69	107
257	Areal Vegetation: BJ110 Tundra; STP: SP, VEG: Tundra	BJ110							6	69	108
258	Areal Vegetation: BJ110 Tundra; STP: SM, VEG: Tundra	BJ110							7	69	109
259	Areal Vegetation: BJ110 Tundra; STP: SC, VEG: Tundra	BJ110							8	69	110
260	Areal Vegetation: BJ110 Tundra; STP: ML, VEG: Tundra	BJ110							9	69	111
261	Areal Vegetation: BJ110 Tundra; STP: CL, VEG: Tundra	BJ110							10	69	112
262	Areal Vegetation: BJ110 Tundra; STP: OL, VEG: Tundra	BJ110							11	69	113
263	Areal Vegetation: BJ110 Tundra; STP: CH, VEG: Tundra	BJ110							12	69	114
264	Areal Vegetation: BJ110 Tundra; STP: MH, VEG: Tundra	BJ110							13	69	115
265	Areal Vegetation: BJ110 Tundra; STP: OH, VEG: Tundra	BJ110							14	69	116
266	Areal Vegetation: BJ110 Tundra; STP: PT, VEG: Tundra	BJ110							15	69	117
267	Areal Physiography: BJ100 Snow Field; SIC: Snow	BJ100						1			0
268	Areal Physiography: BJ100 Snow Field; SIC: Ice	BJ100						2			0
269	Areal Physiography: DA010 Ground Surface Element; STP: GW	DA010							1		18
270	Areal Physiography: DA010 Ground Surface Element; STP: GP	DA010							2		19
271	Areal Physiography: DA010 Ground Surface Element; STP: GM	DA010							3		20
272	Areal Physiography: DA010 Ground Surface Element; STP: GC	DA010							4		21

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
273	Areal Physiography: DA010 Ground Surface Element; STP: SW	DA010							5		22
274	Areal Physiography: DA010 Ground Surface Element; STP: SP	DA010							6		23
275	Areal Physiography: DA010 Ground Surface Element; STP: SM	DA010							7		24
276	Areal Physiography: DA010 Ground Surface Element; STP: SC	DA010							8		25
277	Areal Physiography: DA010 Ground Surface Element; STP: ML	DA010							9		26
278	Areal Physiography: DA010 Ground Surface Element; STP: CL	DA010							10		27
279	Areal Physiography: DA010 Ground Surface Element; STP: OL	DA010							11		28
280	Areal Physiography: DA010 Ground Surface Element; STP: CH	DA010							12		29
281	Areal Physiography: DA010 Ground Surface Element; STP: MH	DA010							13		30
282	Areal Physiography: DA010 Ground Surface Element; STP: OH	DA010							14		31
283	Areal Physiography: DB160 Rock Strata / Rock Formation	DB160									34
284	Areal Physiography: DB170 Sand Dune / Hills; STP: GP	DB170							2		19
285	Areal Physiography: DB170 Sand Dune / Hills; STP: GM	DB170							3		20
286	Areal Physiography: DB170 Sand Dune / Hills; STP: GC	DB170							4		21
287	Areal Physiography: DB170 Sand Dune / Hills; STP: SW	DB170							5		22
288	Areal Physiography: DB170 Sand Dune / Hills; STP: SP	DB170							6		23
289	Areal Physiography: DB170 Sand Dune / Hills; STP: SM	DB170							7		24
290	Areal Physiography: DB170 Sand Dune / Hills; STP: SC	DB170							8		25
291	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: GW	EA010				0			1		35
292	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: GW	EA010				1			1		35
293	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: GW	EA010				2			1		35
294	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: GW	EA010				4			1		35
295	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: GW	EA010				5			1		35
296	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: GW	EA010				6			1		35
297	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: GW	EA010				7			1		35
298	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: GW	EA010				9			1		35
299	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: GW	EA010				98			1		35
300	Areal Vegetation: EA010 Cropland; FTC: Other, STP: GW	EA010				999			1		35
301	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: GP	EA010				0			2		36
302	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: GP	EA010				1			2		36
303	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: GP	EA010				2			2		36

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
304	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: GP	EA010				4			2		36
305	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: GP	EA010				5			2		36
306	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: GP	EA010				6			2		36
307	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: GP	EA010				7			2		36
308	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: GP	EA010				9			2		36
309	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: GP	EA010				98			2		36
310	Areal Vegetation: EA010 Cropland; FTC: Other, STP: GP	EA010				999			2		36
311	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: GM	EA010				0			3		37
312	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: GM	EA010				1			3		37
313	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: GM	EA010				2			3		37
314	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: GM	EA010				4			3		37
315	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: GM	EA010				5			3		37
316	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: GM	EA010				6			3		37
317	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: GM	EA010				7			3		37
318	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: GM	EA010				9			3		37
319	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: GM	EA010				98			3		37
320	Areal Vegetation: EA010 Cropland; FTC: Other, STP: GM	EA010				999			3		37
321	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: GC	EA010				0			4		38
322	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: GC	EA010				1			4		38
323	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: GC	EA010				2			4		38
324	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: GC	EA010				4			4		38
325	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: GC	EA010				5			4		38
326	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: GC	EA010				6			4		38
327	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: GC	EA010				7			4		38
328	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: GC	EA010				9			4		38
329	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: GC	EA010				98			4		38
330	Areal Vegetation: EA010 Cropland; FTC: Other, STP: GC	EA010				999			4		38
331	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: SW	EA010				0			5		38
332	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: SW	EA010				1			5		39
333	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: SW	EA010				2			5		39
334	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: SW	EA010				4			5		39

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
335	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: SW	EA010				5			5		39
336	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: SW	EA010				6			5		39
337	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: SW	EA010				7			5		39
338	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: SW	EA010				9			5		39
339	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: SW	EA010				98			5		39
340	Areal Vegetation: EA010 Cropland; FTC: Other, STP: SW	EA010				999			5		39
341	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: SP	EA010				0			6		40
342	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: SP	EA010				1			6		40
343	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: SP	EA010				2			6		40
344	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: SP	EA010				4			6		40
345	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: SP	EA010				5			6		40
346	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: SP	EA010				6			6		40
347	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: SP	EA010				7			6		40
348	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: SP	EA010				9			6		40
349	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: SP	EA010				98			6		40
350	Areal Vegetation: EA010 Cropland; FTC: Other, STP: SP	EA010				999			6		40
351	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: SM	EA010				0			7		41
352	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: SM	EA010				1			7		41
353	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: SM	EA010				2			7		41
354	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: SM	EA010				4			7		41
355	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: SM	EA010				5			7		41
356	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: SM	EA010				6			7		41
357	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: SM	EA010				7			7		41
358	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: SM	EA010				9			7		41
359	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: SM	EA010				98			7		41
360	Areal Vegetation: EA010 Cropland; FTC: Other, STP: SM	EA010				999			7		41
361	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: SC	EA010				0			8		42
362	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: SC	EA010				1			8		42
363	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: SC	EA010				2			8		42
364	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: SC	EA010				4			8		42
365	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: SC	EA010				5			8		42

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
366	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: SC	EA010				6			8		42
367	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: SC	EA010				7			8		42
368	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: SC	EA010				9			8		42
369	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: SC	EA010				98			8		42
370	Areal Vegetation: EA010 Cropland; FTC: Other, STP: SC	EA010				999			8		42
371	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: ML	EA010				0			9		43
372	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: ML	EA010				1			9		43
373	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: ML	EA010				2			9		43
374	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: ML	EA010				4			9		43
375	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: ML	EA010				5			9		43
376	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: ML	EA010				6			9		43
377	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: ML	EA010				7			9		43
378	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: ML	EA010				9			9		43
379	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: ML	EA010				98			9		43
380	Areal Vegetation: EA010 Cropland; FTC: Other, STP: ML	EA010				999			9		43
381	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: CL	EA010				0			10		44
382	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: CL	EA010				1			10		44
383	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: CL	EA010				2			10		44
384	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: CL	EA010				4			10		44
385	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: CL	EA010				5			10		44
386	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: CL	EA010				6			10		44
387	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: CL	EA010				7			10		44
388	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: CL	EA010				9			10		44
389	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: CL	EA010				98			10		44
390	Areal Vegetation: EA010 Cropland; FTC: Other, STP: CL	EA010				999			10		44
391	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: OL	EA010				0			11		45
392	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: OL	EA010				1			11		45
393	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: OL	EA010				2			11		45
394	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: OL	EA010				4			11		45
395	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: OL	EA010				5			11		45
396	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: OL	EA010				6			11		45

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
397	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: OL	EA010				7			11		45
398	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: OL	EA010				9			11		45
399	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: OL	EA010				98			11		45
400	Areal Vegetation: EA010 Cropland; FTC: Other, STP: OL	EA010				999			11		45
401	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: CH	EA010				0			12		46
402	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: CH	EA010				1			12		46
403	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: CH	EA010				2			12		46
404	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: CH	EA010				4			12		46
405	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: CH	EA010				5			12		46
406	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: CH	EA010				6			12		46
407	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: CH	EA010				7			12		46
408	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: CH	EA010				9			12		46
409	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: CH	EA010				98			12		46
410	Areal Vegetation: EA010 Cropland; FTC: Other, STP: CH	EA010				999			12		46
411	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: MH	EA010				0			13		47
412	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: MH	EA010				1			13		47
413	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: MH	EA010				2			13		47
414	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: MH	EA010				4			13		47
415	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: MH	EA010				5			13		47
416	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: MH	EA010				6			13		47
417	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: MH	EA010				7			13		47
418	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: MH	EA010				9			13		47
419	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: MH	EA010				98			13		47
420	Areal Vegetation: EA010 Cropland; FTC: Other, STP: MH	EA010				999			13		47
421	Areal Vegetation: EA010 Cropland; FTC: Unknown, STP: OH	EA010				0			14		48
422	Areal Vegetation: EA010 Cropland; FTC: Slash and Burn-Shifting cultivation, STP: OH	EA010				1			14		48
423	Areal Vegetation: EA010 Cropland; FTC: Permanent field, STP: OH	EA010				2			14		48
424	Areal Vegetation: EA010 Cropland; FTC: Ditch Irrigation, STP: OH	EA010				4			14		48
425	Areal Vegetation: EA010 Cropland; FTC: Grazing, STP: OH	EA010				5			14		48
426	Areal Vegetation: EA010 Cropland; FTC: Regular (planting pattern), STP: OH	EA010				6			14		48
427	Areal Vegetation: EA010 Cropland; FTC: Linear (planting pattern), STP: OH	EA010				7			14		48

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
428	Areal Vegetation: EA010 Cropland; FTC: Not Applicable, STP: OH	EA010				9			14		48
429	Areal Vegetation: EA010 Cropland; FTC: Type of field Pattern, STP: OH	EA010				98			14		48
430	Areal Vegetation: EA010 Cropland; FTC: Other, STP: OH	EA010				999			14		48
431	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: GW	EA010				3			1		35
432	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: GP	EA010				3			2		36
433	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: GM	EA010				3			3		37
434	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: GC	EA010				3			4		38
435	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: SW	EA010				3			5		39
436	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: SP	EA010				3			6		40
437	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: SM	EA010				3			7		41
438	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: SC	EA010				3			8		42
439	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: ML	EA010				3			9		43
440	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: CL	EA010				3			10		44
441	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: OL	EA010				3			11		45
442	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: CH	EA010				3			12		46
443	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: MH	EA010				3			13		47
444	Areal Vegetation: EA010 Cropland; FTC: Terraced, STP: OH	EA010				3			14		48
445	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: GW	EA010				8			1		35
446	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: GP	EA010				8			2		36
447	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: GM	EA010				8			3		37
448	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: GC	EA010				8			4		38
449	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: SW	EA010				8			5		39
450	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: SP	EA010				8			6		40
451	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: SM	EA010				8			7		41
452	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: SC	EA010				8			8		42
453	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: ML	EA010				8			9		43
454	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: CL	EA010				8			10		44
455	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: OL	EA010				8			11		45
456	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: CH	EA010				8			12		46
457	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: MH	EA010				8			13		47
458	Areal Vegetation: EA010 Cropland; FTC: Crop Rotation, STP: OH	EA010				8			14		48

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
459	Areal Vegetation: EA040 Orchard; STP: GW	EA040							1		69
460	Areal Vegetation: EA040 Orchard; STP: GP	EA040							2		70
461	Areal Vegetation: EA040 Orchard; STP: GM	EA040							3		71
462	Areal Vegetation: EA040 Orchard; STP: GC	EA040							4		72
463	Areal Vegetation: EA040 Orchard; STP: SW	EA040							5		73
464	Areal Vegetation: EA040 Orchard; STP: SP	EA040							6		74
465	Areal Vegetation: EA040 Orchard; STP: SM	EA040							7		75
466	Areal Vegetation: EA040 Orchard; STP: SC	EA040							8		76
467	Areal Vegetation: EA040 Orchard; STP: ML	EA040							9		77
468	Areal Vegetation: EA040 Orchard; STP: CL	EA040							10		78
469	Areal Vegetation: EA040 Orchard; STP: OL	EA040							11		79
470	Areal Vegetation: EA040 Orchard; STP: CH	EA040							12		80
471	Areal Vegetation: EA040 Orchard; STP: MH	EA040							13		81
472	Areal Vegetation: EA040 Orchard; STP: OH	EA040							14		82
473	Areal Vegetation: EA050 Vineyard; STP: GW	EA050							1		86
474	Areal Vegetation: EA050 Vineyard; STP: GP	EA050							2		87
475	Areal Vegetation: EA050 Vineyard; STP: GM	EA050							3		88
476	Areal Vegetation: EA050 Vineyard; STP: GC	EA050							4		89
477	Areal Vegetation: EA050 Vineyard; STP: SW	EA050							5		90
478	Areal Vegetation: EA050 Vineyard; STP: SP	EA050							6		91
479	Areal Vegetation: EA050 Vineyard; STP: SM	EA050							7		92
480	Areal Vegetation: EA050 Vineyard; STP: SC	EA050							8		93
481	Areal Vegetation: EA050 Vineyard; STP: ML	EA050							9		94
482	Areal Vegetation: EA050 Vineyard; STP: CL	EA050							10		95
483	Areal Vegetation: EA050 Vineyard; STP: OL	EA050							11		96
484	Areal Vegetation: EA050 Vineyard; STP: CH	EA050							12		97
485	Areal Vegetation: EA050 Vineyard; STP: MH	EA050							13		98
486	Areal Vegetation: EA050 Vineyard; STP: OH	EA050							14		99
487	Areal Vegetation: EA055 Hops; STP: GW	EA055							1		86
488	Areal Vegetation: EA055 Hops; STP: GP	EA055							2		87
489	Areal Vegetation: EA055 Hops; STP: GM	EA055							3		88
490	Areal Vegetation: EA055 Hops; STP: GC	EA055							4		89
491	Areal Vegetation: EA055 Hops; STP: SW	EA055							5		90
492	Areal Vegetation: EA055 Hops; STP: SP	EA055							6		91
493	Areal Vegetation: EA055 Hops; STP: SM	EA055							7		92
494	Areal Vegetation: EA055 Hops; STP: SC	EA055							8		93
495	Areal Vegetation: EA055 Hops; STP: ML	EA055							9		94
496	Areal Vegetation: EA055 Hops; STP: CL	EA055							10		95

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
497	Areal Vegetation: EA055 Hops; STP: OL	EA055							11		96
498	Areal Vegetation: EA055 Hops; STP: CH	EA055							12		97
499	Areal Vegetation: EA055 Hops; STP: MH	EA055							13		98
500	Areal Vegetation: EA055 Hops; STP: OH	EA055							14		99
501	Areal Vegetation: EB010 Grassland; STP: GW, VEG: Pasture, meadow, steppe	EB010							1	8	103
502	Areal Vegetation: EB010 Grassland; STP: GW, VEG: Tropical Grass	EB010							1	10	103
503	Areal Vegetation: EB010 Grassland; STP: GP, VEG: Pasture, meadow, steppe	EB010							2	8	104
504	Areal Vegetation: EB010 Grassland; STP: GP, VEG: Tropical Grass	EB010							2	10	104
505	Areal Vegetation: EB010 Grassland; STP: GM, VEG: Pasture, meadow, steppe	EB010							3	8	105
506	Areal Vegetation: EB010 Grassland; STP: GM, VEG: Tropical Grass	EB010							3	10	105
507	Areal Vegetation: EB010 Grassland; STP: GC, VEG: Pasture, meadow, steppe	EB010							4	8	106
508	Areal Vegetation: EB010 Grassland; STP: GC, VEG: Tropical Grass	EB010							4	10	106
509	Areal Vegetation: EB010 Grassland; STP: SW, VEG: Pasture, meadow, steppe	EB010							5	8	107
510	Areal Vegetation: EB010 Grassland; STP: SW, VEG: Tropical Grass	EB010							5	10	107
511	Areal Vegetation: EB010 Grassland; STP: SP, VEG: Pasture, meadow, steppe	EB010							6	8	108
512	Areal Vegetation: EB010 Grassland; STP: SP, VEG: Tropical Grass	EB010							6	10	108
513	Areal Vegetation: EB010 Grassland; STP: SM, VEG: Pasture, meadow, steppe	EB010							7	8	109
514	Areal Vegetation: EB010 Grassland; STP: SM, VEG: Tropical Grass	EB010							7	10	109
515	Areal Vegetation: EB010 Grassland; STP: SC, VEG: Pasture, meadow, steppe	EB010							8	8	110
516	Areal Vegetation: EB010 Grassland; STP: SC, VEG: Tropical Grass	EB010							8	10	110
517	Areal Vegetation: EB010 Grassland; STP: ML, VEG: Pasture, meadow, steppe	EB010							9	8	111
518	Areal Vegetation: EB010 Grassland; STP: ML, VEG: Tropical Grass	EB010							9	10	111
519	Areal Vegetation: EB010 Grassland; STP: CL, VEG: Pasture, meadow, steppe	EB010							10	8	112
520	Areal Vegetation: EB010 Grassland; STP: CL, VEG: Tropical Grass	EB010							10	10	112
521	Areal Vegetation: EB010 Grassland; STP: OL, VEG: Pasture, meadow, steppe	EB010							11	8	113
522	Areal Vegetation: EB010 Grassland; STP: OL, VEG: Tropical Grass	EB010							11	10	113
523	Areal Vegetation: EB010 Grassland; STP: CH, VEG: Pasture, meadow, steppe	EB010							12	8	114
524	Areal Vegetation: EB010 Grassland; STP: CH, VEG: Tropical Grass	EB010							12	10	114
525	Areal Vegetation: EB010 Grassland; STP: MH, VEG: Pasture, meadow, steppe	EB010							13	8	115
526	Areal Vegetation: EB010 Grassland; STP: MH, VEG: Tropical Grass	EB010							13	10	115
527	Areal Vegetation: EB010 Grassland; STP: OH, VEG: Pasture, meadow, steppe	EB010							14	8	116
528	Areal Vegetation: EB010 Grassland; STP: OH,	EB010							14	10	116

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
	VEG: Tropical Grass										
529	Areal Vegetation: EB010 Grassland; STP: GW, VEG: Grassland with scattered trees	EB010							1	9	103
530	Areal Vegetation: EB010 Grassland; STP: GP, VEG: Grassland with scattered trees	EB010							2	9	104
531	Areal Vegetation: EB010 Grassland; STP: GM, VEG: Grassland with scattered trees	EB010							3	9	105
532	Areal Vegetation: EB010 Grassland; STP: GC, VEG: Grassland with scattered trees	EB010							4	9	106
533	Areal Vegetation: EB010 Grassland; STP: SW, VEG: Grassland with scattered trees	EB010							5	9	107
534	Areal Vegetation: EB010 Grassland; STP: SP, VEG: Grassland with scattered trees	EB010							6	9	108
535	Areal Vegetation: EB010 Grassland; STP: SM, VEG: Grassland with scattered trees	EB010							7	9	109
536	Areal Vegetation: EB010 Grassland; STP: SC, VEG: Grassland with scattered trees	EB010							8	9	110
537	Areal Vegetation: EB010 Grassland; STP: ML, VEG: Grassland with scattered trees	EB010							9	9	111
538	Areal Vegetation: EB010 Grassland; STP: CL, VEG: Grassland with scattered trees	EB010							10	9	112
539	Areal Vegetation: EB010 Grassland; STP: OL, VEG: Grassland with scattered trees	EB010							11	9	113
540	Areal Vegetation: EB010 Grassland; STP: CH, VEG: Grassland with scattered trees	EB010							12	9	114
541	Areal Vegetation: EB010 Grassland; STP: MH, VEG: Grassland with scattered trees	EB010							13	9	115
542	Areal Vegetation: EB010 Grassland; STP: OH, VEG: Grassland with scattered trees	EB010							14	9	116
543	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: GW	EB020		1					1		120
544	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: GW	EB020		2					1		120
545	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: GW	EB020		3					1		120
546	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: GP	EB020		1					2		121
547	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: GP	EB020		2					2		121
548	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: GP	EB020		3					2		121
549	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: GM	EB020		1					3		122
550	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: GM	EB020		2					3		122
551	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: GM	EB020		3					3		122
552	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: GC	EB020		1					4		123
553	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: GC	EB020		2					4		123
554	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: GC	EB020		3					4		123
555	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: SW	EB020		1					5		124
556	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: SW	EB020		2					5		124
557	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: SW	EB020		3					5		124
558	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: SP	EB020		1					6		125

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
559	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: SP	EB020		2					6		125
560	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: SP	EB020		3					6		125
561	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: SM	EB020		1					7		126
562	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: SM	EB020		2					7		126
563	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: SM	EB020		3					7		126
564	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: SC	EB020		1					8		127
565	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: SC	EB020		2					8		127
566	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: SC	EB020		3					8		127
567	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: ML	EB020		1					9		128
568	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: ML	EB020		2					9		128
569	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: ML	EB020		3					9		128
570	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: CL	EB020		1					10		129
571	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: CL	EB020		2					10		129
572	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: CL	EB020		3					10		129
573	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: OL	EB020		1					11		130
574	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: OL	EB020		2					11		130
575	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: OL	EB020		3					11		130
576	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: CH	EB020		1					12		131
577	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: CH	EB020		2					12		131
578	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: CH	EB020		3					12		131
579	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: MH	EB020		1					13		132
580	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: MH	EB020		2					13		132
581	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: MH	EB020		3					13		132
582	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Open (<=5%), STP: OH	EB020		1					14		133
583	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Sparse (>5% and <=15%), STP: OH	EB020		2					14		133
584	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Medium (>15% and <=50%), STP: OH	EB020		3					14		133
585	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: GW	EB020		4					1		120
586	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: GP	EB020		4					2		121
587	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: GM	EB020		4					3		122
588	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: GC	EB020		4					4		123
589	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: SW	EB020		4					5		124

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
590	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: SP	EB020		4					6		125
591	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: SM	EB020		4					7		126
592	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: SC	EB020		4					8		127
593	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: ML	EB020		4					9		128
594	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: CL	EB020		4					10		129
595	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: OL	EB020		4					11		130
596	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: CH	EB020		4					12		131
597	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: MH	EB020		4					13		132
598	Areal Vegetation: EB020 Scrub / Brush / Bush; BUD: Dense (>50%), STP: OH	EB020		4					14		133
599	Areal Vegetation: EC010 Bamboo; STP: GW, VEG: Bamboo	EC010							1	68	137
600	Areal Vegetation: EC010 Bamboo; STP: GP, VEG: Bamboo	EC010							2	68	138
601	Areal Vegetation: EC010 Bamboo; STP: GM, VEG: Bamboo	EC010							3	68	139
602	Areal Vegetation: EC010 Bamboo; STP: GC, VEG: Bamboo	EC010							4	68	140
603	Areal Vegetation: EC010 Bamboo; STP: SW, VEG: Bamboo	EC010							5	68	141
604	Areal Vegetation: EC010 Bamboo; STP: SP, VEG: Bamboo	EC010							6	68	142
605	Areal Vegetation: EC010 Bamboo; STP: SM, VEG: Bamboo	EC010							7	68	143
606	Areal Vegetation: EC010 Bamboo; STP: SC, VEG: Bamboo	EC010							8	68	144
607	Areal Vegetation: EC010 Bamboo; STP: ML, VEG: Bamboo	EC010							9	68	145
608	Areal Vegetation: EC010 Bamboo; STP: CL, VEG: Bamboo	EC010							10	68	146
609	Areal Vegetation: EC010 Bamboo; STP: OL, VEG: Bamboo	EC010							11	68	147
610	Areal Vegetation: EC010 Bamboo; STP: CH, VEG: Bamboo	EC010							12	68	148
611	Areal Vegetation: EC010 Bamboo; STP: MH, VEG: Bamboo	EC010							13	68	149
612	Areal Vegetation: EC010 Bamboo; STP: OH, VEG: Bamboo	EC010							14	68	150
613	Areal Vegetation: EC030 Trees; STP: GW, VEG: Coniferous	EC030							1	12	171
614	Areal Vegetation: EC030 Trees; STP: GP, VEG: Coniferous	EC030							2	12	172
615	Areal Vegetation: EC030 Trees; STP: GM, VEG: Coniferous	EC030							3	12	173
616	Areal Vegetation: EC030 Trees; STP: GC, VEG: Coniferous	EC030							4	12	174
617	Areal Vegetation: EC030 Trees; STP: SW, VEG: Coniferous	EC030							5	12	175
618	Areal Vegetation: EC030 Trees; STP: SP, VEG: Coniferous	EC030							6	12	176
619	Areal Vegetation: EC030 Trees; STP: SM, VEG: Coniferous	EC030							7	12	177
620	Areal Vegetation: EC030 Trees; STP: SC, VEG: Coniferous	EC030							8	12	178

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
621	Areal Vegetation: EC030 Trees; STP: ML, VEG: Coniferous	EC030							9	12	179
622	Areal Vegetation: EC030 Trees; STP: CL, VEG: Coniferous	EC030							10	12	180
623	Areal Vegetation: EC030 Trees; STP: OL, VEG: Coniferous	EC030							11	12	181
624	Areal Vegetation: EC030 Trees; STP: CH, VEG: Coniferous	EC030							12	12	182
625	Areal Vegetation: EC030 Trees; STP: MH, VEG: Coniferous	EC030							13	12	183
626	Areal Vegetation: EC030 Trees; STP: OH, VEG: Coniferous	EC030							14	12	184
627	Areal Vegetation: EC030 Trees; STP: GW, VEG: Deciduous	EC030							1	24	154
628	Areal Vegetation: EC030 Trees; STP: GP, VEG: Deciduous	EC030							2	24	155
629	Areal Vegetation: EC030 Trees; STP: GM, VEG: Deciduous	EC030							3	24	156
630	Areal Vegetation: EC030 Trees; STP: GC, VEG: Deciduous	EC030							4	24	157
631	Areal Vegetation: EC030 Trees; STP: SW, VEG: Deciduous	EC030							5	24	158
632	Areal Vegetation: EC030 Trees; STP: SP, VEG: Deciduous	EC030							6	24	159
633	Areal Vegetation: EC030 Trees; STP: SM, VEG: Deciduous	EC030							7	24	160
634	Areal Vegetation: EC030 Trees; STP: SC, VEG: Deciduous	EC030							8	24	161
635	Areal Vegetation: EC030 Trees; STP: ML, VEG: Deciduous	EC030							9	24	162
636	Areal Vegetation: EC030 Trees; STP: CL, VEG: Deciduous	EC030							10	24	163
637	Areal Vegetation: EC030 Trees; STP: OL, VEG: Deciduous	EC030							11	24	164
638	Areal Vegetation: EC030 Trees; STP: CH, VEG: Deciduous	EC030							12	24	165
639	Areal Vegetation: EC030 Trees; STP: MH, VEG: Deciduous	EC030							13	24	166
640	Areal Vegetation: EC030 Trees; STP: OH, VEG: Deciduous	EC030							14	24	167
641	Areal Vegetation: EC030 Trees; STP: GW, VEG: Mixed Trees	EC030							1	50	188
642	Areal Vegetation: EC030 Trees; STP: GP, VEG: Mixed Trees	EC030							2	50	189
643	Areal Vegetation: EC030 Trees; STP: GM, VEG: Mixed Trees	EC030							3	50	190
644	Areal Vegetation: EC030 Trees; STP: GC, VEG: Mixed Trees	EC030							4	50	191
645	Areal Vegetation: EC030 Trees; STP: SW, VEG: Mixed Trees	EC030							5	50	192
646	Areal Vegetation: EC030 Trees; STP: SP, VEG: Mixed Trees	EC030							6	50	193
647	Areal Vegetation: EC030 Trees; STP: SM, VEG: Mixed Trees	EC030							7	50	194
648	Areal Vegetation: EC030 Trees; STP: SC, VEG: Mixed Trees	EC030							8	50	195
649	Areal Vegetation: EC030 Trees; STP: ML, VEG: Mixed Trees	EC030							9	50	196
650	Areal Vegetation: EC030 Trees; STP: CL, VEG: Mixed Trees	EC030							10	50	197
651	Areal Vegetation: EC030 Trees; STP: OL, VEG: Mixed Trees	EC030							11	50	198

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
652	Areal Vegetation: EC030 Trees; STP: CH, VEG: Mixed Trees	EC030							12	50	199
653	Areal Vegetation: EC030 Trees; STP: MH, VEG: Mixed Trees	EC030							13	50	200
654	Areal Vegetation: EC030 Trees; STP: OH, VEG: Mixed Trees	EC030							14	50	201
655	Areal Vegetation: EC030 Trees; STP: GW, VEG: Mangrove	EC030							1	19	239
656	Areal Vegetation: EC030 Trees; STP: GP, VEG: Mangrove	EC030							2	19	240
657	Areal Vegetation: EC030 Trees; STP: GM, VEG: Mangrove	EC030							3	19	241
658	Areal Vegetation: EC030 Trees; STP: GC, VEG: Mangrove	EC030							4	19	242
659	Areal Vegetation: EC030 Trees; STP: SW, VEG: Mangrove	EC030							5	19	243
660	Areal Vegetation: EC030 Trees; STP: SP, VEG: Mangrove	EC030							6	19	244
661	Areal Vegetation: EC030 Trees; STP: SM, VEG: Mangrove	EC030							7	19	245
662	Areal Vegetation: EC030 Trees; STP: SC, VEG: Mangrove	EC030							8	19	246
663	Areal Vegetation: EC030 Trees; STP: ML, VEG: Mangrove	EC030							9	19	247
664	Areal Vegetation: EC030 Trees; STP: CL, VEG: Mangrove	EC030							10	19	248
665	Areal Vegetation: EC030 Trees; STP: OL, VEG: Mangrove	EC030							11	19	249
666	Areal Vegetation: EC030 Trees; STP: CH, VEG: Mangrove	EC030							12	19	250
667	Areal Vegetation: EC030 Trees; STP: MH, VEG: Mangrove	EC030							13	19	251
668	Areal Vegetation: EC030 Trees; STP: OH, VEG: Mangrove	EC030							14	19	252
669	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: GW	EC040							1		205
670	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: GP	EC040							2		206
671	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: GM	EC040							3		207
672	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: GC	EC040							4		208
673	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: SW	EC040							5		209
674	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: SP	EC040							6		210
675	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: SM	EC040							7		211
676	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: SC	EC040							8		212
677	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: ML	EC040							9		213
678	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: CL	EC040							10		214
679	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: OL	EC040							11		215
680	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: CH	EC040							12		216
681	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: MH	EC040							13		217
682	Areal Vegetation: EC040 US-Cleared Way / Cut; STP: OH	EC040							14		218

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
683	Areal Urban: GB005 Airport / Airfield; STP: GW	BG005							1		18
684	Areal Urban: GB005 Airport / Airfield; STP: GP	BG005							2		19
685	Areal Urban: GB005 Airport / Airfield; STP: GM	BG005							3		20
686	Areal Urban: GB005 Airport / Airfield; STP: GC	BG005							4		21
687	Areal Urban: GB005 Airport / Airfield; STP: SW	BG005							5		22
688	Areal Urban: GB005 Airport / Airfield; STP: SP	BG005							6		23
689	Areal Urban: GB005 Airport / Airfield; STP: SM	BG005							7		24
690	Areal Urban: GB005 Airport / Airfield; STP: SC	BG005							8		25
691	Areal Urban: GB005 Airport / Airfield; STP: ML	BG005							9		26
692	Areal Urban: GB005 Airport / Airfield; STP: CL	BG005							10		27
693	Areal Urban: GB005 Airport / Airfield; STP: OL	BG005							11		28
694	Areal Urban: GB005 Airport / Airfield; STP: CH	BG005							12		29
695	Areal Urban: GB005 Airport / Airfield; STP: MH	BG005							13		30
696	Areal Urban: GB005 Airport / Airfield; STP: OH	BG005							14		31
697	Areal Urban: GB005 Airport / Airfield; STP: PT	BG005							15		32
698	Areal Urban: GB005 Airport / Airfield; STP: Evaporites	BG005							18		33
699	Areal Urban: GB015 US Apron / Hardstand; RST: Hard / Paved	GB015					1				742
700	Areal Urban: GB015 US Apron / Hardstand; RST: Loose / Unpaved	GB015					2				743
701	Areal Urban: GB015 US Apron / Hardstand; RST: Loose / Light	GB015					3				744
702	Areal Urban: GB015 US Apron / Hardstand; RST: Corduroy	GB015					4				745
703	Areal Urban: GB015 US Apron / Hardstand; RST: Grass / Sod (Soft)	GB015					5				746
704	Areal Urban: GB015 US Apron / Hardstand; RST: Natural	GB015					6				747
705	Areal Urban: GB015 US Apron / Hardstand; RST: Permanent	GB015					7				748
706	Areal Urban: GB015 US Apron / Hardstand; RST: Temporary	GB015					8				749
707	Areal Urban: GB035 Heliport; RST: Hard / Paved	GB035					1				742
708	Areal Urban: GB035 Heliport; RST: Loose / Unpaved	GB035					2				743
709	Areal Urban: GB035 Heliport; RST: Loose / Light	GB035					3				744
710	Areal Urban: GB035 Heliport; RST: Corduroy	GB035					4				745
711	Areal Urban: GB035 Heliport; RST: Grass / Sod (Soft)	GB035					5				746
712	Areal Urban: GB035 Heliport; RST: Natural	GB035					6				747
713	Areal Urban: GB035 Heliport; RST: Permanent	GB035					7				748
714	Areal Urban: GB035 Heliport; RST: Temporary	GB035					8				749
715	Areal Urban: GB075 Taxiway; RST: Hard / Paved	BG075					1				742
716	Areal Urban: GB075 Taxiway; RST: Loose / Unpaved	BG075					2				743
717	Areal Urban: GB075 Taxiway; RST: Loose / Light	BG075					3				744

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
718	Areal Urban: GB075 Taxiway; RST: Corduroy	BG075					4				745
719	Areal Urban: GB075 Taxiway; RST: Grass / Sod (Soft)	BG075					5				746
720	Areal Urban: GB075 Taxiway; RST: Natural	BG075					6				747
721	Areal Urban: GB075 Taxiway; RST: Permanent	BG075					7				748
722	Areal Urban: GB075 Taxiway; RST: Temporary	BG075					8				749
723	Areal Physiography: SA030 Exposed Bedrock	SA030									0
724	Transportation: AN010 Railroad	AB010									0
725	Transportation: AN050 Railroad Siding	AN050									0
726	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: GW	AP010							1		726
727	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: GP	AP010							2		727
728	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: GM	AP010							3		728
729	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: GC	AP010							4		729
730	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: SW	AP010							5		730
731	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: SP	AP010							6		731
732	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: SM	AP010							7		732
733	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: SC	AP010							8		733
734	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: ML	AP010							9		734
735	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: CL	AP010							10		735
736	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: OL	AP010							11		736
737	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: CH	AP010							12		737
738	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: MH	AP010							13		738
739	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: OH	AP010							14		739
740	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: PT	AP010							15		740
741	Transportation: AP010 Cart Track or AP050 US-Trail UK-Trail / Footpath; STP: Evaporites	AP010							18		741
742	Transportation: AP030 Road; RST: Hard / Paved	AP030					1				742
743	Transportation: AP030 Road; RST: Loose / Unpaved	AP030					2				743
744	Transportation: AP030 Road; RST: Loose / Light	AP030					3				744
745	Transportation: AP030 Road; RST: Corduroy	AP030					4				745
746	Transportation: AP030 Road; RST: Grass / Sod (Soft)	AP030					5				746
747	Transportation: AP030 Road; RST: Natural	AP030					6				747
748	Transportation: AP030 Road; RST: Permanent	AP030					7				748
749	Transportation: AP030 Road; RST: Temporary	AP030					8				749
750	VALUE INTENTIONALLY LEFT BLANK										0
751	VALUE INTENTIONALLY LEFT BLANK										0

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
752	VALUE INTENTIONALLY LEFT BLANK										0
753	VALUE INTENTIONALLY LEFT BLANK										0
754	VALUE INTENTIONALLY LEFT BLANK										0
755	VALUE INTENTIONALLY LEFT BLANK										0
756	VALUE INTENTIONALLY LEFT BLANK										0
757	Maritime: BB040 Breakwater / Groyne	BB040									0
758	Maritime: BB042 Mole	BB042									0
759	Maritime: BB140 Jetty	BB140									0
760	Maritime: BB190 Pier / Wharf	BB190									0
761	Transportation: BH070 Ford; BMC: Clay and Silt	BH070	1								0
762	Transportation: BH070 Ford; BMC: Silty Sands	BH070	2								0
763	Transportation: BH070 Ford; BMC: Sand and Gravel	BH070	3								0
764	Transportation: BH070 Ford; BMC: Gravel and Cobble	BH070	4								0
765	Transportation: BH070 Ford; BMC: Rocks and Boulders	BH070	5								0
766	Transportation: BH070 Ford; BMC: Bedrock	BH070	6								0
767	Transportation: BH070 Ford; BMC: Paved	BH070	7								0
768	Transportation: BH070 Ford; BMC: Peat	BH070	8								0
769	Transportation: BH070 Ford; BMC: Sand over mud	BH070	9								0
770	Transportation: BH070 Ford; BMC: Mixed qualities	BH070	10								0
771	Transportation: BH070 Ford; BMC: Sand	BH070	14								0
772	Transportation: GB055 Runway; RST: Hard / Paved	GB055					1				742
773	Transportation: GB055 Runway; RST: Loose / Unpaved	GB055					2				743
774	Transportation: GB055 Runway; RST: Loose / Light	GB055					3				744
775	Transportation: GB055 Runway; RST: Corduroy	GB055					4				745
776	Transportation: GB055 Runway; RST: Grass / Sod (Soft)	GB055					5				746
777	Transportation: GB055 Runway; RST: Natural	GB055					6				747
778	Transportation: GB055 Runway; RST: Permanent	GB055					7				748
779	Transportation: GB055 Runway; RST: Temporary	GB055					8				749
780	Transportation: GB055 Runway, RST: Asphalt / Asphalt Mix	GB055					9				742
781	Transportation: GB055 Runway, RST: Brick	GB055					10				742
782	Transportation: GB055 Runway, RST: Concrete	GB055					11				742
783	Transportation: Runway, RST: Composite Perm	GB055					12				742
784	Transportation: GB055 Runway, RST: Part Concrete and Part Asphalt	GB055					13				742
785	Transportation: GB055 Runway, RST: Bituminous	GB055					14				743
786	Transportation: GB055 Runway, RST: Clay	GB055					15				736

STGJ Code	Name	FACC Feature	BMC	BUD	DMT	FTC	RST	SIC	STP	VEG	WARSIM MLU
787	Transportation: GB055 Runway, RST: Composite Non Permanent	GB055					16				749
788	Transportation: GB055 Runway, RST: Coral	GB055					17				743
789	Transportation: GB055 Runway, RST: Graded	GB055					18				747
790	Transportation: GB055 Runway, RST: Ungraded	GB055					19				747
791	Transportation: GB055 Runway, RST: Gravel	GB055					20				743
792	Transportation: GB055 Runway, RST: Ice	GB055					21				742
793	Transportation: GB055 Runway, RST: Laterite	GB055					22				747
794	Transportation: GB055 Runway, RST: Macadam	GB055					23				742
795	Transportation: GB055 Runway, RST: Membrane	GB055					24				749
796	Transportation: Runway, RST: Mix in Place	GB055					25				742
797	Transportation: Runway, RST: Steel Planking	GB055					26				742
798	Transportation: GB055 Runway, RST: Sand	GB055					27				731
799	Transportation: GB055 Runway, RST: Snow	GB055					28				744
800	Areal Physiography: BH090 Land Subject to Inundation, STP: GW	BH090							1		222
801	Areal Physiography: BH090 Land Subject to Inundation, STP: GP	BH090							2		223
802	Areal Physiography: BH090 Land Subject to Inundation, STP: GM	BH090							3		224
803	Areal Physiography: BH090 Land Subject to Inundation, STP: GC	BH090							4		225
804	Areal Physiography: BH090 Land Subject to Inundation, STP: SW	BH090							5		226
805	Areal Physiography: BH090 Land Subject to Inundation, STP: SP	BH090							6		227
806	Areal Physiography: BH090 Land Subject to Inundation, STP: SM	BH090							7		228
807	Areal Physiography: BH090 Land Subject to Inundation, STP: SC	BH090							8		229
808	Areal Physiography: BH090 Land Subject to Inundation, STP: ML	BH090							9		230
809	Areal Physiography: BH090 Land Subject to Inundation, STP: CL	BH090							10		231
810	Areal Physiography: BH090 Land Subject to Inundation, STP: OL	BH090							11		232
811	Areal Physiography: BH090 Land Subject to Inundation, STP: CH	BH090							12		233
812	Areal Physiography: BH090 Land Subject to Inundation, STP: MH	BH090							13		234
813	Areal Physiography: BH090 Land Subject to Inundation, STP: OH	BH090							14		235

Appendix C
Vehicle Data, Fidelity 3 and 4

The following tables present the characterization data for the High-Mobility Tracked representative vehicle. Force coefficients are given only for a dry soil with 100 percent throttle. Additional surface_slippery and throttle settings would follow the same format.

Table C1
File Information

Title	M1A1
Date-Time of Creation	11/25/2002
Authors	Richmond, Ahlvin, Green
Developer	USAERDC
Certifier	Pending
NRMMII File Header	M1A1 ABRAMS TANK 3/07/01 - Use for WARSIM and JWARS
Version	2.6.7

Table C2
Platform Descriptors

Descriptor	Values	Units	Source	Created
Configuration				
Type	Tracked	none	NRMM	11/25/2002
Towing Trailer	No	none	NRMM	11/25/2002
Plow Blade Capable	Yes	none	NRMM	11/25/2002
Plow Power Reduction	1.0	none	NRMM	11/25/2002
Primary Use Code	null	none	NRMM	11/25/2002
Dimensional				
Gross Weight	57811.0	kg	NRMM	11/25/2002
Units	1.0	none	NRMM	11/25/2002
Unit Length	311.7	in.	NRMM	11/25/2002
Maximum Unit Width	143.8	in.	NRMM	11/25/2002
Unit Ground Clearance	17.0	in.	PM Ofc	1/1/1991
Push Bar Force	254902.0	lb	NRMM	11/25/2002
Push Bar Height	46.8	in.	NRMM	11/25/2002
Engine Power	1500.0	hp	NRMM	11/25/2002
Rotating Mass Factor1	1.1	none	NRMM	11/25/2002
Rotating Mass Factor2	0.0	none	NRMM	11/25/2002
Speed Caps				
On Road	72.0	kph	JANES	1/1/1998
Fording	8.0	kph	NRMM	11/25/2002
Swimming	0.0	kph	NRMM	11/25/2002
RMS Amplitude 0.0 in.	160.9[1]	kph	NRMM	11/25/2002
RMS Amplitude 1.6 in.	80.8	kph	NRMM	11/25/2002
RMS Amplitude 1.7 in.	61.0	kph	NRMM	11/25/2002
RMS Amplitude 1.9 in.	49.6	kph	NRMM	11/25/2002
RMS Amplitude 2.1 in.	39.8	kph	NRMM	11/25/2002
RMS Amplitude 2.3 in.	32.5	kph	NRMM	11/25/2002
RMS Amplitude 2.5 in.	30.1	kph	NRMM	11/25/2002
RMS Amplitude 2.6 in.	28.0	kph	NRMM	11/25/2002
RMS Amplitude 2.7 in.	25.6	kph	NRMM	11/25/2002
RMS Amplitude 2.8 in.	23.8	kph	NRMM	11/25/2002
RMS Amplitude 3.0 in.	21.4	kph	NRMM	11/25/2002
RMS Amplitude 3.4 in.	18.3	kph	NRMM	11/25/2002
RMS Amplitude 4.0 in.	15.1	kph	NRMM	11/25/2002
RMS Amplitude 4.5 in.	12.9	kph	NRMM	11/25/2002
RMS Amplitude 10.0 in.	11.3	kph	NRMM	11/25/2002
Obstacle Maneuver				
Max Vertical Obstacle	1.2	m	JANES	1/1/1998
Max Articulation Angle	0.0	deg	unknown	
Max Fording Depth	48.0	in.	NRMM	11/25/2002
Max Gradient	60.0	percent	JANES	1/1/1998

[1] Unrestrained.

Table C3
Obstacle Crossing Data

Minimum Clearance, in.	Max Force lb	Avg Force lb	Horizontal Depth, in.	Approach Angle, rad	Height in.
28.2	10871.1	641.9	3.15	1.95	5.88
15.37	28154.9	1686.8	15.75	1.95	5.88
-0.64	47131.3	1965.5	33.46	1.95	5.88
-9.99	99999.9	9999.9	45.46	1.95	5.88
28.2	10871.1	680	3.15	2.48	5.88
15.37	24149.8	1537.5	15.75	2.48	5.88
6.03	56291.4	2961.5	33.46	2.48	5.88
-0.29	78070	3926.4	45.46	2.48	5.88
28.2	10871.1	686.8	3.15	2.69	5.88
15.31	29939.8	1595.7	15.75	2.69	5.88
8.36	41876.1	3271.7	33.46	2.69	5.88
3.65	49963.9	4407	45.46	2.69	5.88
28.19	9976.4	713	3.15	2.86	5.88
16.46	21753.6	1508.1	15.75	2.86	5.88
13.7	27267.6	2796.6	33.46	2.86	5.88
13.49	34730.3	3742	45.46	2.86	5.88
29.76	5910.8	277.8	3.15	3.42	5.88
19.67	9949.9	1346.9	15.75	3.42	5.88
6.56	22431.4	2317.5	33.46	3.42	5.88
4.88	28949.1	3629.6	45.46	3.42	5.88
30.42	5400.8	88.3	3.15	3.6	5.88
22.73	16795.6	2083.6	15.75	3.6	5.88
9.05	19182.7	994.4	33.46	3.6	5.88
-0.16	48259.2	2682.9	45.46	3.6	5.88
31	3279.2	75.4	3.15	3.8	5.88
27.42	11345.6	1202.9	15.75	3.8	5.88
14.21	26517.9	2540.7	33.46	3.8	5.88
12.72	21319.9	1496.8	45.46	3.8	5.88
31	1479.2	0.3	3.15	4.33	5.88
30.43	3698.8	45.5	15.75	4.33	5.88
29.23	8237	271.9	33.46	4.33	5.88
27.86	12195.2	959.3	45.46	4.33	5.88
27.94	4718.6	266.1	3.15	1.95	29.88
15.25	13034.9	898.5	15.75	1.95	29.88
-0.64	27817.7	2690.5	33.46	1.95	29.88
-9.99	99999.9	9999.9	45.46	1.95	29.88
27.94	4718.6	282.2	3.15	2.48	29.88
15.25	19073.9	1366.5	15.75	2.48	29.88
6.03	49748.5	2850.5	33.46	2.48	29.88
3.5	55851	4053.9	45.46	2.48	29.88
27.94	4718.6	282.2	3.15	2.69	29.88
15.25	12721.6	1424.8	15.75	2.69	29.88
8.53	41304.3	2953.8	33.46	2.69	29.88
3.98	60671	3970.7	45.46	2.69	29.88
27.94	7977.1	385.4	3.15	2.86	29.88
16.82	13064.8	1359.8	15.75	2.86	29.88
13.7	25535.7	2907.6	33.46	2.86	29.88
13.61	28903	3746.4	45.46	2.86	29.88

Table C3 (Concluded)					
Minimum Clearance, in.	**Max Force lb**	**Avg Force lb**	**Horizontal Depth, in.**	**Approach Angle, rad**	**Height in.**
28.4	9945.6	841	3.15	3.42	29.88
15.15	9938.9	981.8	15.75	3.42	29.88
5.71	25444.3	2785.6	33.46	3.42	29.88
5.16	28955	3565.3	45.46	3.42	29.88
27.83	11629.9	818.6	3.15	3.6	29.88
17.62	17284	2405.5	15.75	3.6	29.88
5.3	47740.7	2782.6	33.46	3.6	29.88
-3.05	68377.7	3038.1	45.46	3.6	29.88
28.61	9496.4	316	3.15	3.8	29.88
21.95	19682.9	3260.1	15.75	3.8	29.88
12.67	25312.1	1819.2	33.46	3.8	29.88
7.79	25743	2543.9	45.46	3.8	29.88
29.28	9262.1	622.2	3.15	4.33	29.88
27.86	12214.6	964.4	15.75	4.33	29.88
24.98	14359.8	1256.1	33.46	4.33	29.88
22.82	20450.6	3497.6	45.46	4.33	29.88
27.85	10372.1	390.8	3.15	1.95	141.6
15.25	20363.2	1645.1	15.75	1.95	141.6
-0.64	33967.3	69475.5	33.46	1.95	141.6
-9.99	99999.9	99999.9	45.46	1.95	141.6
27.85	10372.1	408.1	3.15	2.48	141.6
15.25	26093.3	1889.4	15.75	2.48	141.6
6.03	48962.7	3253.1	33.46	2.48	141.6
4.81	64248.9	4275.7	45.46	2.48	141.6
27.85	10372.1	408.1	3.15	2.69	141.6
15.25	17225	1645.2	15.75	2.69	141.6
8.53	47709.2	2696.6	33.46	2.69	141.6
8.53	47592.8	3802.5	45.46	2.69	141.6
27.85	9918.5	484.6	3.15	2.86	141.6
16.82	12731.3	1740.6	15.75	2.86	141.6
13.69	25468.7	3180.8	33.46	2.86	141.6
13.58	28949.7	3863.3	45.46	2.86	141.6
25.71	9949.9	537	3.15	3.42	141.6
12.19	12340.9	1923.4	15.75	3.42	141.6
12.27	24259.6	3320.1	33.46	3.42	141.6
12.01	28954.7	4153.8	45.46	3.42	141.6
25.88	11649.9	662.1	3.15	3.6	141.6
7	17482.4	2525.1	15.75	3.6	141.6
3.88	47494.7	2846	33.46	3.6	141.6
3.02	47280.6	4483.2	45.46	3.6	141.6
25.88	8411.9	400.2	3.15	3.8	141.6
4.75	26218.9	1963.9	15.75	3.8	141.6
-6.91	36786.3	3515.6	33.46	3.8	141.6
-9.99	99999.9	9999.9	45.46	3.8	141.6
25.88	11094.4	433.4	3.15	4.33	141.6
11.27	24916.1	3672	15.75	4.33	141.6
-10.51	41128.5	6923.1	33.46	4.33	141.6
-99.99	99999.9	9999.9	45.46	4.33	141.6

Table C4
Obstacle Shock Data for 2.5 g Impact

Obstacle Shock Height 0.0 in.	1760 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 14.4 in.	704 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 15.0 in.	352 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 16.0 in.	211.2 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 17.0 in.	140.8 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 18.0 in.	123.2 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 20.0 in.	105.6 in. per sec	NRMM	11/25/2002
Obstacle Shock Height 100.0 in.	35.2 in. per sec	NRMM	11/25/2002

Table C5
Force Coefficients for On-Road Conditions at 100-Percent Throttle

Surface Condition	RoadType	Braking Coef	Motion Resistance Coef	Maximum Traction Coef	Minimum Traction Coef	c1	c2	c3
Dry	Superhighway	0.75000	0.03750	0.81208	0.05682	5.56624	-0.06087	5.69603
	Primary	0.75000	0.03750	0.81208	0.05682	5.56624	-0.06087	5.69603
	Secondary	0.75000	0.04500	0.81208	0.05682	5.56624	-0.06087	5.69603
Wet	Superhighway	0.45000	0.03750	0.50000	0.05615	7.60656	-0.08821	11.09034
	Primary	0.45000	0.03750	0.50000	0.05615	7.60656	-0.08821	11.09034
	Secondary	0.45000	0.04500	0.50000	0.05615	7.60656	-0.08821	11.09034

Table C6
Force Coefficients for Off-Road Conditions at 100-Percent Throttle Dry Conditions

Soil Types	Cone Index	Braking Coef	Motion Resistance Coef	Max Traction Coef	Min Traction Coef	c1	c2	c3
SC_GC	300	0.87020	0.06020	0.81208	0.06651	4.50969	-0.03114	4.81579
	200	0.87473	0.06473	0.81208	0.05553	5.54725	-0.06193	5.85202
	150	0.87957	0.06957	0.81208	0.05541	5.55813	-0.06226	5.85337
	100	0.89038	0.08038	0.81208	0.05764	5.35104	-0.05605	5.71674
	80	0.89750	0.08963	0.80787	0.05579	5.51992	-0.06113	5.88940
	50	0.88000	0.12567	0.75433	0.05533	5.80767	-0.06592	6.68318
	40	0.86325	0.16023	0.70303	0.05571	5.93993	-0.06725	7.21377
	30	0.81702	0.25582	0.56120	0.05710	6.63195	-0.07442	9.79037
	25	0.73952	0.41677	0.32275	0.05534	13.52165	-0.14930	27.18063
	20	0.60834	0.68984	0.00000	0.00000	0.00000	0.00000	0.00000
	10	0.34598	1.23600	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.21481	1.50907	0.00000	0.00000	0.00000	0.00000	0.00000
CH_MH_OH	300	0.87020	0.06020	0.81208	0.06651	4.50969	-0.03114	4.81579
	200	0.87473	0.06473	0.81208	0.05553	5.54725	-0.06193	5.85202
	150	0.87957	0.06957	0.81208	0.05541	5.55813	-0.06226	5.85337
	100	0.89038	0.08038	0.81208	0.05764	5.35104	-0.05605	5.71674
	80	0.89750	0.08963	0.80787	0.05579	5.51992	-0.06113	5.88940
	50	0.88000	0.12567	0.75433	0.05533	5.80767	-0.06592	6.68318
	40	0.86325	0.16023	0.70303	0.05571	5.93993	-0.06725	7.21377

(Continued)

Table C6 (Concluded)								
Soil Types	Cone Index	Braking Coef	Motion Resistance Coef	Max Traction Coef	Min Traction Coef	c1	c2	c3
CH_MH_OH	30	0.81702	0.25582	0.56120	0.05710	6.63195	-0.07442	9.79037
	25	0.73952	0.41677	0.32275	0.05534	13.52165	-0.14930	27.18063
	20	0.60834	0.68984	0.00000	0.00000	0.00000	0.00000	0.00000
	10	0.34598	1.23600	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.21481	1.50907	0.00000	0.00000	0.00000	0.00000	0.00000
ML_MLCL_CL_OL	300	0.85708	0.06020	0.79688	0.05557	5.56451	-0.06188	6.01792
	200	0.86613	0.06473	0.80140	0.05566	5.54257	-0.06144	5.96469
	150	0.87379	0.06957	0.80422	0.06591	4.53530	-0.03211	4.89766
	100	0.86709	0.08038	0.78671	0.05546	5.60905	-0.06269	6.14052
	80	0.86163	0.08963	0.77200	0.05569	5.64698	-0.06288	6.32569
	50	0.84274	0.12567	0.71707	0.05610	5.82420	-0.06489	6.97668
	40	0.82804	0.16023	0.66781	0.05520	6.24263	-0.07190	8.09914
	30	0.80317	0.25582	0.54735	0.05692	6.75221	-0.07606	10.22096
	25	0.80633	0.41677	0.38956	0.05643	9.59620	-0.11007	18.14623
	20	0.84915	0.68984	0.15931	0.05173	75.09254	0.59965	-170.69690
	10	0.93480	1.23600	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.97762	1.50907	0.00000	0.00000	0.00000	0.00000	0.00000
SM_SMSC_GM_GMGC	300	0.87708	0.07020	0.80688	0.06605	4.51958	-0.03168	4.86684
	200	0.88473	0.07473	0.81140	0.05708	5.36632	-0.05684	5.72048
	150	0.88957	0.07957	0.81208	0.05742	5.40270	-0.05696	5.84335
	100	0.88709	0.09038	0.79671	0.05557	5.56530	-0.06190	6.01989
	80	0.88163	0.09963	0.78200	0.05545	5.62606	-0.06293	6.19883
	50	0.86274	0.13567	0.72707	0.05827	5.52445	-0.05742	6.56300
	40	0.84804	0.17023	0.67781	0.05565	6.05058	-0.06858	7.65265
	30	0.82317	0.26582	0.55735	0.05704	6.63810	-0.07446	9.88008
	25	0.82633	0.42677	0.39956	0.05422	10.41360	-0.12337	19.05483
	20	0.86915	0.69984	0.16931	0.05180	203.01370	0.95159	-259.89570
	10	0.95480	1.24600	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.99762	1.51907	0.00000	0.00000	0.00000	0.00000	0.00000
SP_SW_GP_GW	300	0.68260	0.14500	0.60096	0.05530	6.86024	-0.08023	9.53762
	200	0.68260	0.14500	0.60096	0.05530	6.86024	-0.08023	9.53762
	150	0.68260	0.14500	0.60096	0.05530	6.86024	-0.08023	9.53762
	100	0.68260	0.14500	0.60096	0.05530	6.86024	-0.08023	9.53762
	80	0.68260	0.14500	0.60096	0.05530	6.86024	-0.08023	9.53762
	50	0.67163	0.14500	0.58999	0.05603	6.80641	-0.07835	9.59348
	40	0.64663	0.14500	0.56499	0.05712	6.77896	-0.07616	9.86588
	30	0.61440	0.14500	0.53276	0.05424	7.87263	-0.09434	12.08048
	25	0.59397	0.14500	0.51233	0.05426	8.24775	-0.09891	13.00215
	20	0.56897	0.14500	0.48732	0.05614	8.09551	-0.09381	13.22639
	10	0.49130	0.14500	0.40966	0.05409	10.74102	-0.12655	19.03272
	5	0.41363	0.14500	0.33199	0.05552	13.86709	-0.15173	26.98427
Pt	300	0.78639	0.05406	0.79733	0.05528	5.51815	-0.06135	5.92361
	200	0.79679	0.05992	0.80187	0.05541	5.49301	-0.06076	5.87239
	150	0.80921	0.06705	0.80717	0.05557	5.46347	-0.06005	5.81370
	100	0.84235	0.08723	0.81208	0.05702	5.31505	-0.05573	5.63724
	80	0.87447	0.11161	0.81208	0.05514	5.49099	-0.06091	5.77340
	50	0.80371	0.41114	0.45758	0.05518	8.50573	-0.10298	14.30679
	40	0.82371	0.47114	0.41758	0.05711	8.61652	-0.10075	15.39444
	30	0.84371	0.53114	0.37758	0.05442	11.39000	-0.13620	20.86971
	25	0.85371	0.56114	0.35758	0.05435	12.37838	-0.14605	23.05366
	20	0.86371	0.59114	0.33758	0.05465	13.85879	-0.15894	26.34801
	10	0.88371	0.65114	0.29758	0.05390	19.78164	-0.20875	37.17551
	5	0.89371	0.68114	0.27758	0.05236	30.58932	-0.28605	52.47930

Table C7
Frozen Water Force Coefficients for Ice and Snow Variations

Frozen Water Type	Frozen Water Type Resistance Coefficient	Frozen Water Type Max Tractive Force Limit	Frozen Water Type Min Tractive Force Limit	Tractive Force vs. Speed (TFS) Coefficient b0	TFS Coefficient b1	TFS Coefficient b2
Ice Cover None	0.0525	0.1	0.048	0.7992295	0.12295	-48.6585
Ice Cover Snow	0.0525	0.16718	0.04746	36.61823	0.473875	-125.469
Snow Density Hardpacked	0.0525	0.27978	0.05323	17.28976	-0.17938	33.8842
Snow Density Normal -Soil Strength Normal	0.05297	0.37824	0.05641	8.427331	-0.0939	15.3102
Snow Density Soft –Soil Strength Soft	0.05434	0.37824	0.05641	8.427331	-0.0939	15.3102

Table C8
Force Coefficients for Snow at Varying Depths with Varying Soil Strengths Underneath

Cone Index for Coefficient for Snow Depth by Density: y Cone Index: Snow Density Normal - Soil Strength Soft	Snow Density for Coefficient for Snow Depth by Density: Snow Density Normal	Snow Resistance Coefficient, Density 1, Depth 1	Snow Resistance Coefficient, Density 1, Depth 2	Snow Resistance Coefficient, Density 1, Depth 3	Snow Resistance Coefficient, Density 1, Depth 4	Snow Resistance Coefficient, Density 1, Depth 5
300	0.05	0.05297	0.05401	0.05573	0.05728	0.0592
300	0.1	0.05327	0.05493	0.05772	0.06022	0.06332
300	0.2	0.05357	0.05591	0.05982	0.06332	0.06767
300	0.3	0.05357	0.05591	0.05982	0.06332	0.06767
300	0.4	0.05327	0.05493	0.05772	0.06022	0.06332
300	0.5	0.0525	0.0525	0.0525	0.0525	0.0525
100	0.05	0.05434	0.05521	0.0568	0.05828	0.06014
100	0.1	0.05572	0.0571	0.05965	0.06203	0.06502
100	0.2	0.05801	0.05989	0.06339	0.06668	0.07083
100	0.3	0.05993	0.06171	0.06509	0.06829	0.07237
100	0.4	0.06155	0.0627	0.06494	0.0671	0.06988
100	0.5	0.06293	0.06293	0.06293	0.06293	0.06293
80	0.05	0.05462	0.05547	0.05704	0.0585	0.06035
80	0.1	0.05622	0.05757	0.06008	0.06244	0.06541
80	0.2	0.05892	0.06074	0.06418	0.06743	0.07155
80	0.3	0.0612	0.06293	0.06624	0.0694	0.07343
80	0.4	0.06318	0.0643	0.06648	0.06859	0.07132
80	0.5	0.06491	0.06491	0.06491	0.06491	0.06491

(Continued)

Table C8 (Concluded)						
Cone Index for Coefficient for Snow Depth by Density: y Cone Index: Snow Density Normal - Soil Strength Soft	**Snow Density for Coefficient for Snow Depth by Density: Snow Density Normal**	**Snow Resistance Coefficient, Density 1, Depth 1**	**Snow Resistance Coefficient, Density 1, Depth 2**	**Snow Resistance Coefficient, Density 1, Depth 3**	**Snow Resistance Coefficient, Density 1, Depth 4**	**Snow Resistance Coefficient, Density 1, Depth 5**
40	0.05	0.0571	0.05784	0.05926	0.06063	0.07721
40	0.1	0.06064	0.06181	0.06408	0.06627	0.06908
40	0.2	0.06682	0.0684	0.07147	0.07445	0.0783
40	0.3	0.07232	0.0738	0.07672	0.07956	0.08327
40	0.4	0.07737	0.07832	0.0802	0.08205	0.08449
40	0.5	0.08206	0.08206	0.08206	0.08206	0.08206
20	0.05	0.1146	0.11594	0.1186	0.12124	0.12473
20	0.1	0.16303	0.16515	0.16937	0.17356	0.1791
20	0.2	0.36704	0.37158	0.38061	0.3896	0.40151
20	0.3	0.49271	0.49695	0.50542	0.51385	0.52504
20	0.4	0.61101	0.61371	0.6191	0.62448	0.63164
20	0.5	0.72402	0.72402	0.72402	0.72402	0.72402

Appendix D Comparison of NRMM and STNDMob

This appendix compares NRMM II.6.8 (ERDC Version) and STNDMob 3.2 (Level 2, Fidelity Degree 3).

a. *Objective*: Is the implementation of STNDMob representative of NRMM predictions?

b. *Approach*:

- Formulate specific subquestions to investigate
- Identify associated parameters to be tested
- Develop pass/fail criteria
- Design experiments/trials
- Analyze results

#1. Is STNDMob 3.2 in agreement with NRMM 2.6.8 for the given current functionality of STNDMob?

#2. Is STNDMob 3.2 in agreement with NRMM 2.6.8 regardless of functionality?

c. *Parameters*

Question #1 -- Design a NRMM terrain file that contains only the terrain parameters STNDMob considers and predict vehicle speed.

Question #2 – Design a NRMM terrain file that contains data from various parts of the world and predict vehicle speed (Fort Hood, Germany, Korea, Saudi Arabia, Kuwait).

d. Pass/Fail Criteria

Criterion 1 -- STNDMob predicts within 3 mph for 90 percent of the cases for the given terrain and representative vehicle set given.

Criterion 2 -- STNDMob predicts within a mean absolute difference of 3 mph for 100 percent of the cases for the given terrain and representative vehicle set.

e. Scope

Table D1
Vehicle Bundles and Representative Vehicles

Vehicle Bundle	Representative Vehicle
High-Mobility Track	M1A1
Medium-Mobility Track	M270-MLRS
Low-Mobility Track	M60-AVLB
High-Mobility Wheeled	M1084
Medium-Mobility Wheeled	M985
Low-Mobility Wheeled	M917
High-Mobility Wheeled w/trailer	M1084-M1094
Medium-Mobility Wheeled w/trailer	M985-M989
Low-Mobility Wheeled w/trailer	M911-M747
Amphibious Combat Vehicle Tracked	M113A2
Amphibious Combat Vehicle Wheeled	LAV3
Light ATV (unmanned)	Kawasaki ATV

f. Terrain

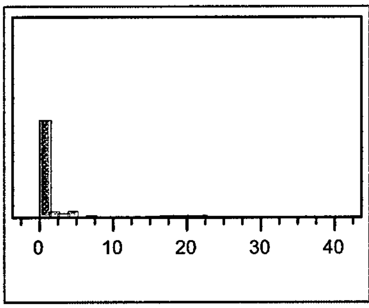
Include a custom-built terrain set that uses the current state of functionality for STNDMob and include terrain sets for Fort Hood, TX, Germany, Korea, Saudi Arabia, and Kuwait.

Analysis of Question #1

Is STNDMob 3.2 in agreement with NRMM 2.6.8 for the given current functionality of STNDMob?

Bin 1: High-Mobility Tracked (M1A1)

NRMM#1



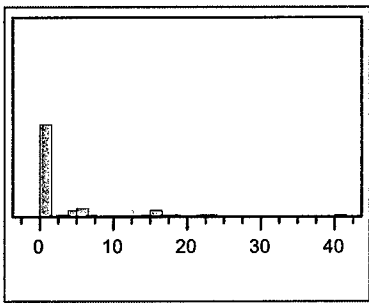
Quantiles

maximum	100.0%	41.603
	99.5%	41.602
	97.5%	39.367
	90.0%	27.423
quartile	75.0%	18.071
median	50.0%	2.038
quartile	25.0%	0.000
	10.0%	0.000
	2.5%	0.000
	0.5%	0.000
minimum	0.0%	0.000

Moments

Mean	9.157
Std Dev	11.880
Std Error Mean	0.329
Upper 95% Mean	9.803
Lower 95% Mean	8.512
N	1304.000
Sum Weights	1304.000

STD3#1



Quantiles

maximum	100.0%	41.603
	99.5%	41.603
	97.5%	40.393
	90.0%	27.892
quartile	75.0%	16.581
median	50.0%	3.970
quartile	25.0%	0.000
	10.0%	0.000
	2.5%	0.000
	0.5%	0.000
minimum	0.0%	-1.000

Moments

Mean	9.383
Std Dev	11.879
Std Error Mean	0.329
Upper 95% Mean	10.028
Lower 95% Mean	8.737
N	1304.000
Sum Weights	1304.000

Terrain file built to test emerging functionality of STNDMob for variations in

Cross-Country

- Slope
- Soil Type
- Obstacle Crossing
- Obstacle Shock
- Vegetation Maneuver
- Slipperiness
- Surface Roughness
- Limited Braking

On-Road

- Slope
- Soil Type (trails)
- Surface Type

Mean absolute deviation (MAD) is the average of all the absolute values of the deviations between the NRMM II.6.8 predictions and the STNDMob 3.2.0.0 predictions. The "percent less than 3 mph" is self-explanatory. The number following the "#" sign indicates which bin was evaluated.

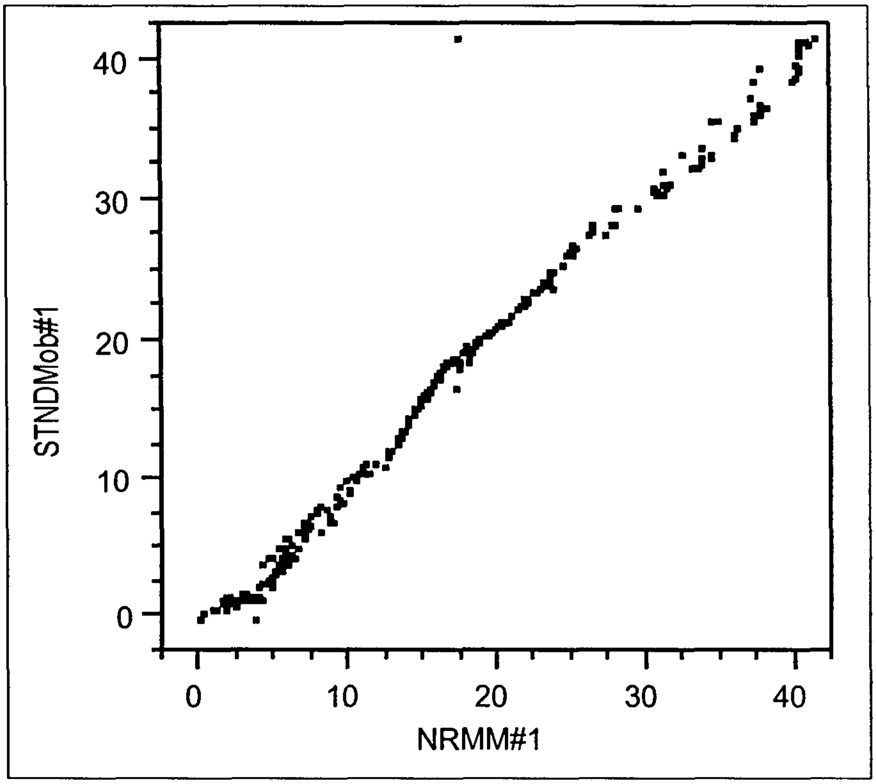


Figure D1. Bin 1, M1A1: MAD 0.6 mph: percent less than 3 mph, 99.8 percent

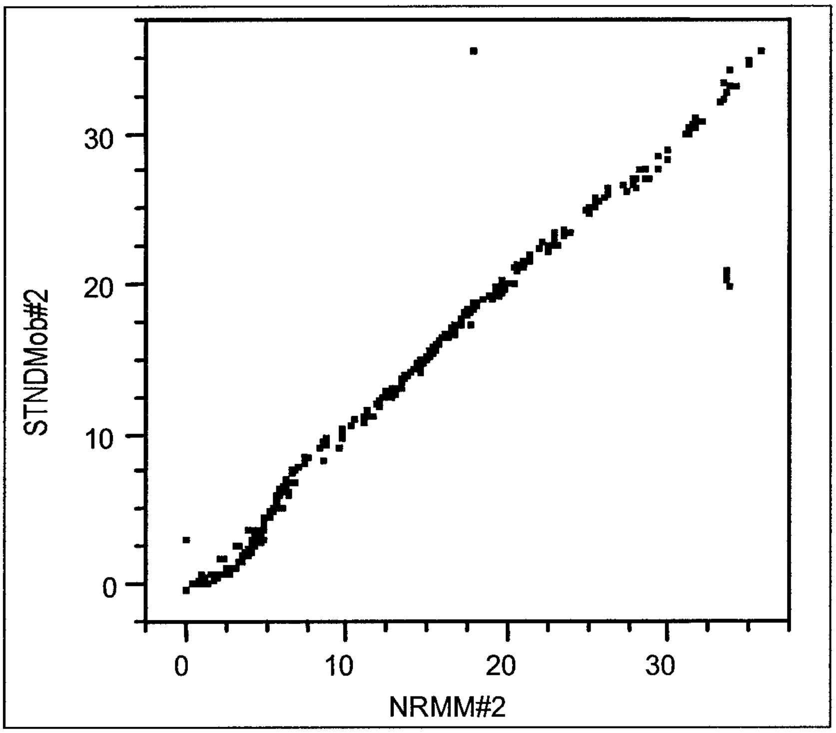


Figure D2. Bin 2, M270-MLRS: MAD 0.5 mph: percent less than 3 mph, 98.9 percent

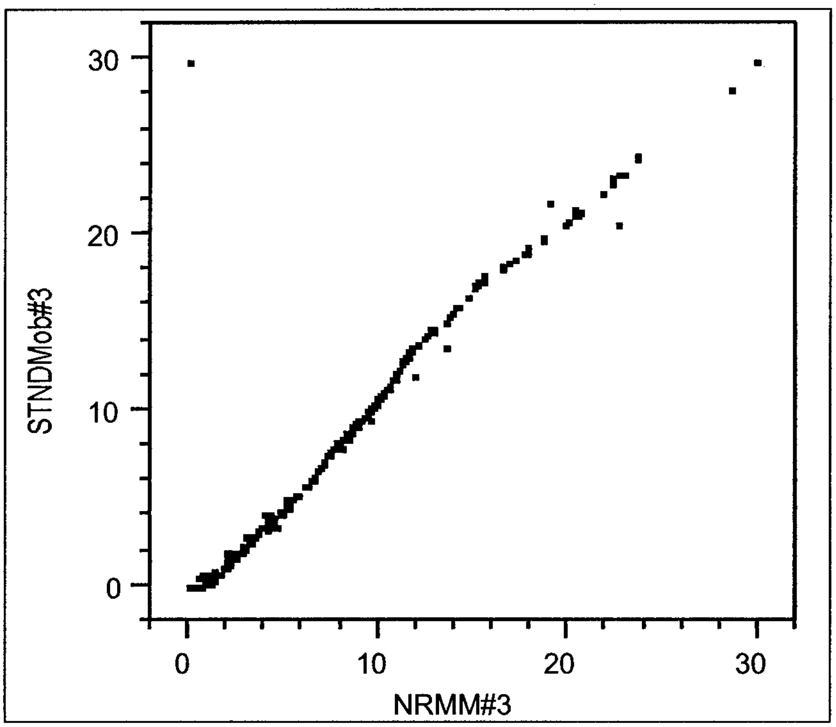


Figure D3. Bin 3, M60-AVLB: MAD 0.5 mph: percent less than 3 mph, 99.9 percent

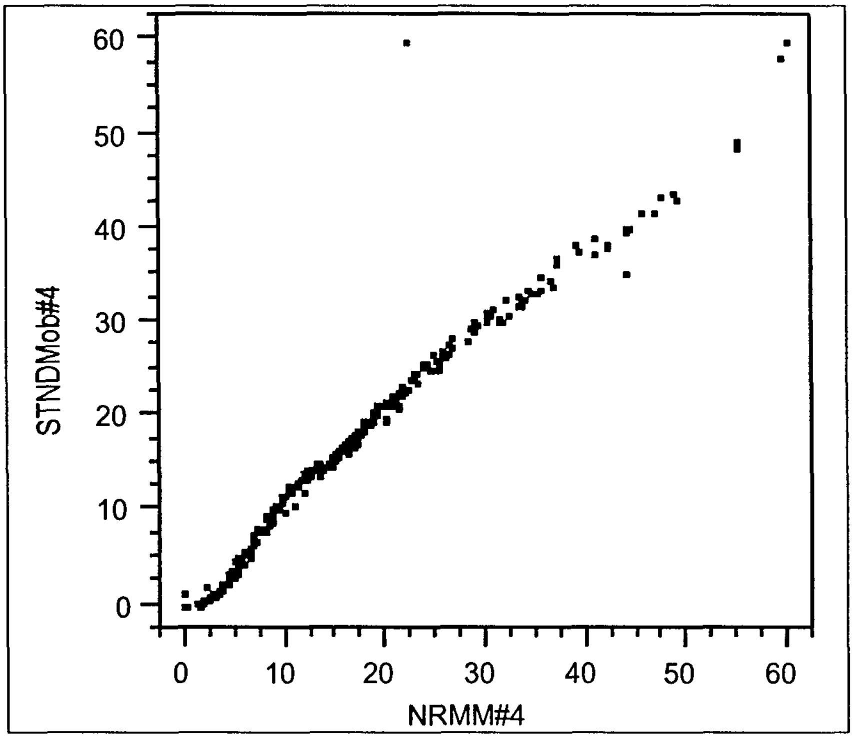


Figure D4. Bin 4, MTV: MAD 0.7 mph: percent less than 3 mph, 97.5 percent

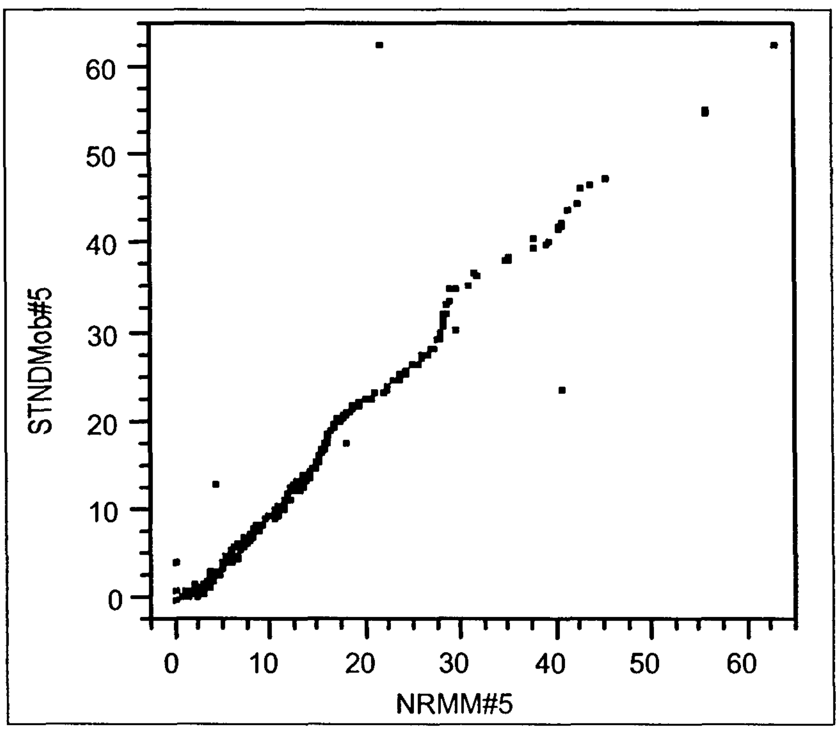


Figure D5. Bin 5, M985: MAD 0.8 mph, percent less than 3 mph, 93.3 percent

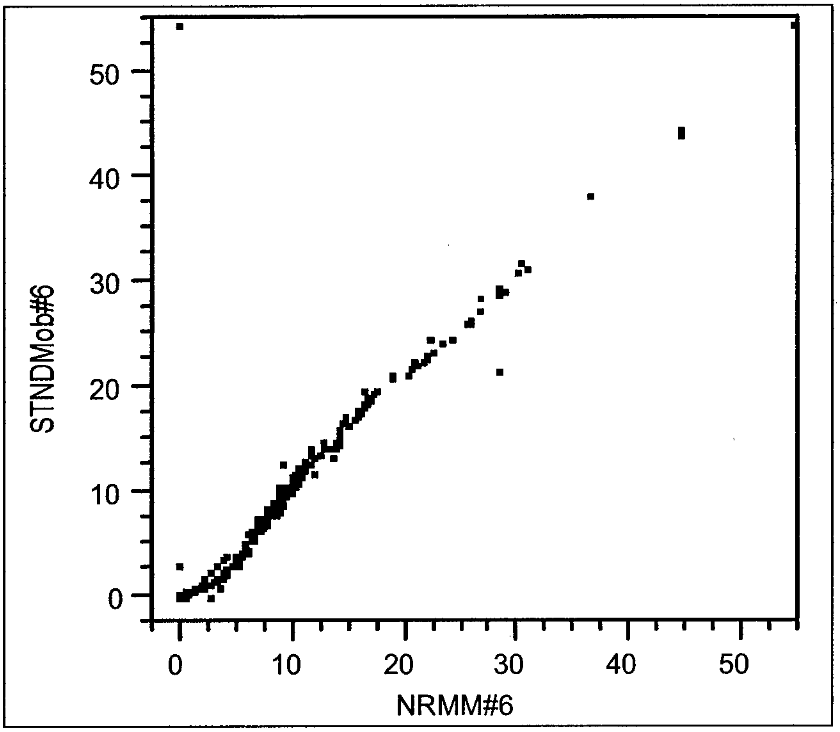


Figure D6. Bin 6, M917: MAD 0.4 mph, percent less than 3 mph 99.5 percent

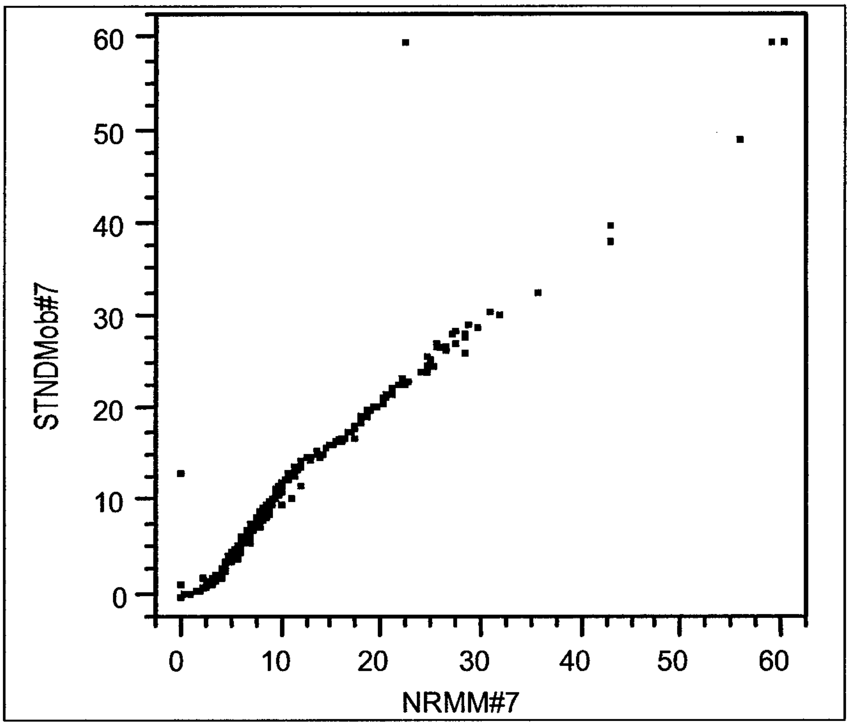


Figure D7. Bin 7, M1084-M1094, MAD 0.5 mph, percent less than 3 mph 99.5 percent

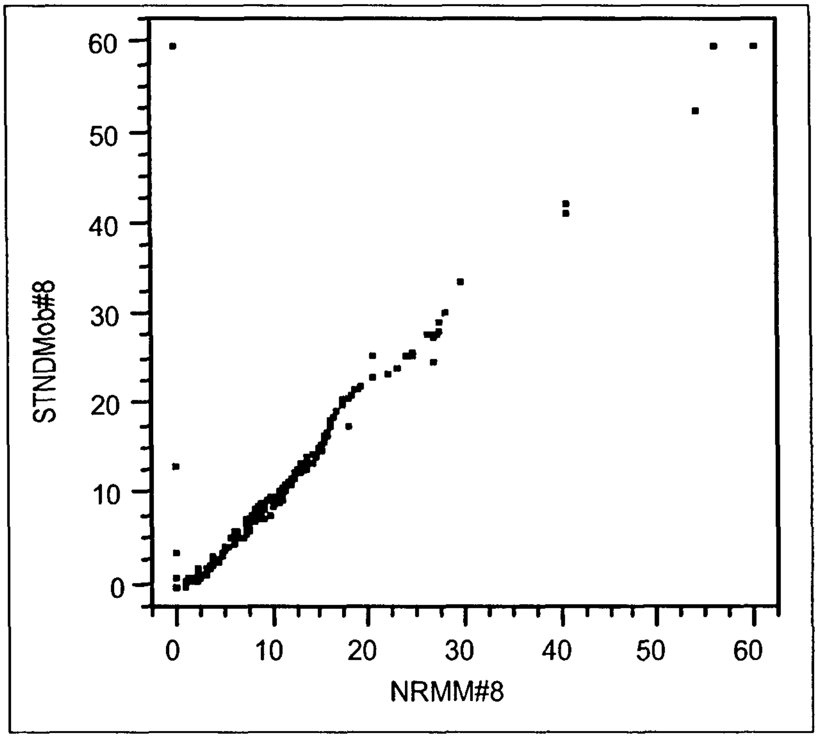


Figure D8. Bin 8, M985-M989, MAD 0.4 mph, percent less than 3 mph, 97.6 percent

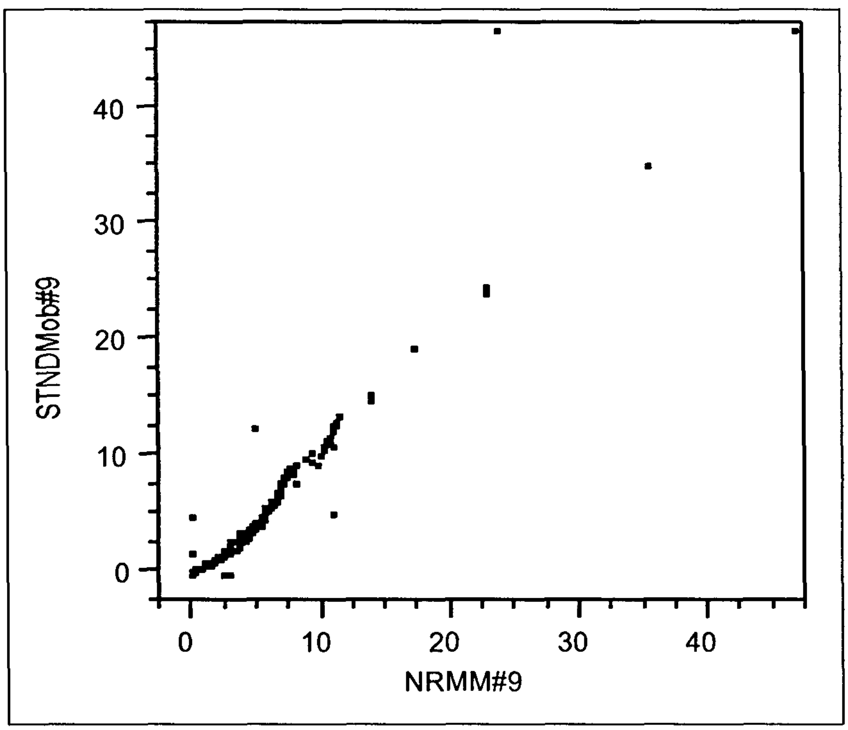


Figure D9. Bin 9, M911-M747, MAD 0.3 mph, percent less than 3 mph, 99.5 percent

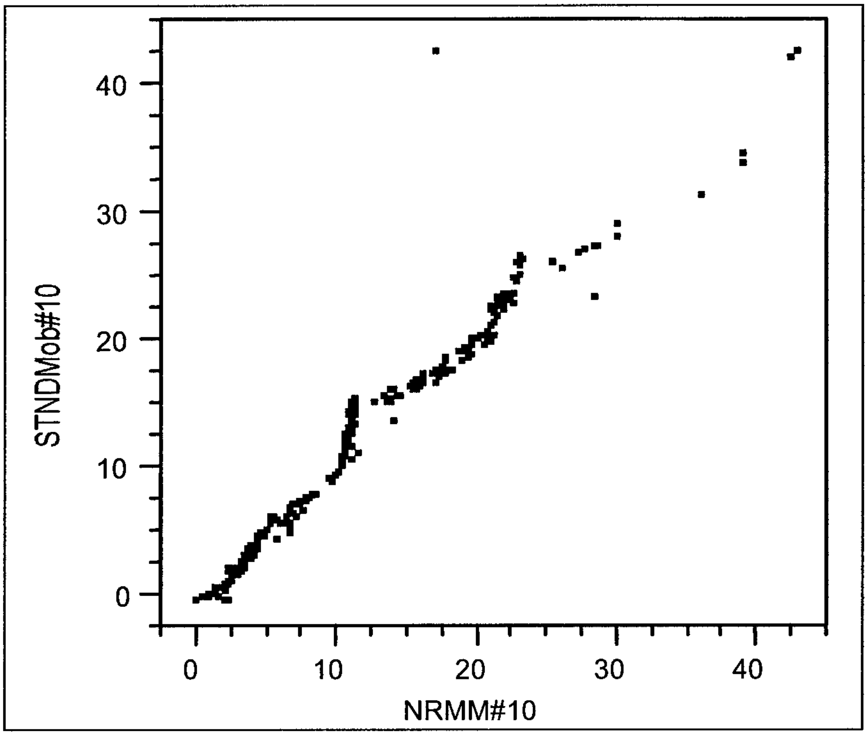


Figure D10. Bin 10, M113A2, MAD 0.7 mph, percent less than 3 mph, 94.9 percent

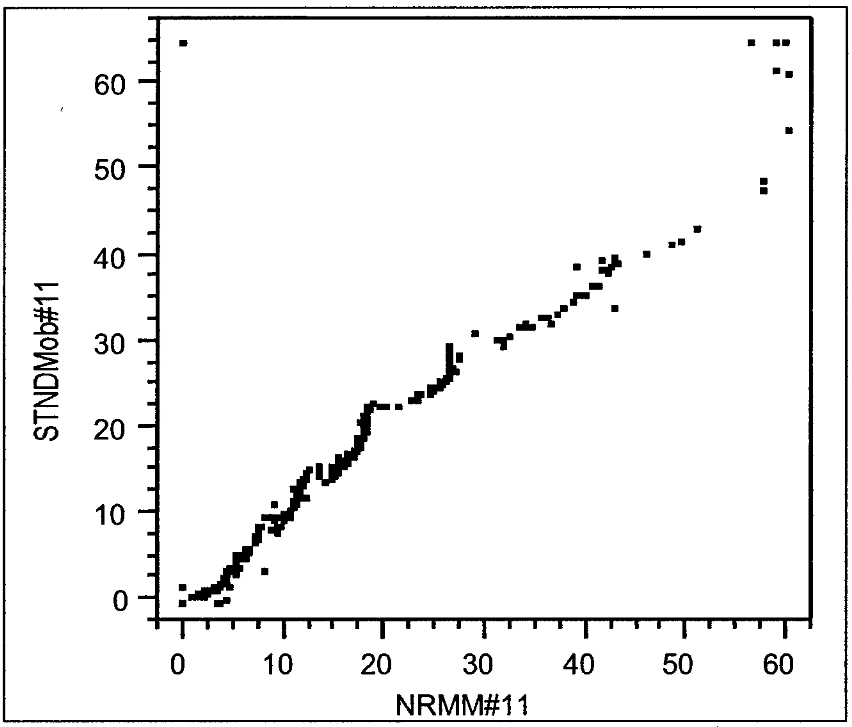


Figure D11. Bin 11, LAV3: MAD 0.9 mph, percent less than 3 mph, 92.5 percent

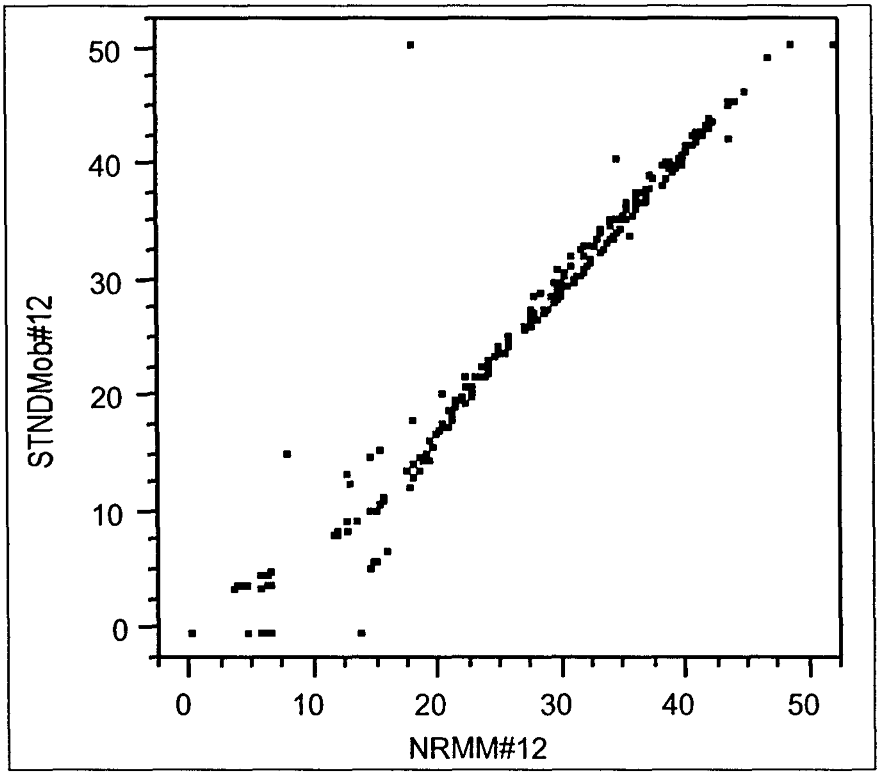


Figure D12. Bin 12, Kawasaki ATV: MAD 1.2 mph, percent less than 3 mph, 90 percent

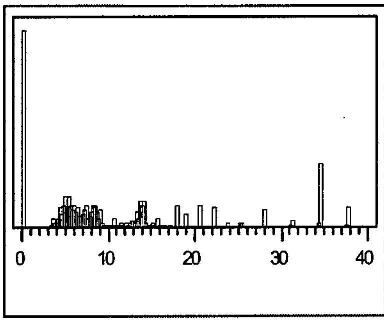
Since STNDMob 3.2 predictions for all cases met the pass/fail criteria, it is in agreement with NRMM II.6.8. Other criteria may offer different results.

Analysis of Question # 2

Is STNDMob 3.2 in agreement with NRMM 2.6.8 regardless of functionality?

Bin 1, High-Mobility Tracked, M1A1

NRMM#1



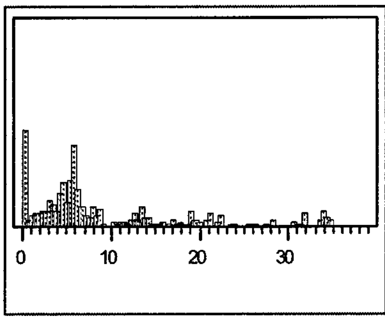
Quantiles

maximum	100.0%	39.400
	99.5%	37.700
	97.5%	36.100
	90.0%	31.100
quartile	75.0%	17.900
median	50.0%	8.600
quartile	25.0%	5.000
	10.0%	0.000
	2.5%	0.000
	0.5%	0.000
minimum	0.0%	0.000

Moments

Mean	12.32
Std Dev	10.33
Std Error Mean	0.08
Upper 95% Mean	12.49
Lower 95% Mean	12.16
N	14845.00
Sum Weights	14845.00

STDG#1



Quantiles

maximum	100.0%	38.400
	99.5%	36.277
	97.5%	34.000
	90.0%	29.000
quartile	75.0%	18.100
median	50.0%	6.600
quartile	25.0%	4.100
	10.0%	0.900
	2.5%	0.000
	0.5%	0.000
minimum	0.0%	0.000

Moments

Mean	11.31
Std Dev	10.14
Std Error Mean	0.08
Upper 95% Mean	11.47
Lower 95% Mean	11.14
N	14845.00
Sum Weights	14845.00

Terrain File Built from Fort Hood, Germany, Korea, Saudi Arabia, Kuwait: TU = 14,485

Cross-Country

- Slope
- Soil Type
- Obstacle Crossing
- Obstacle Shock
- Vegetation Maneuver
- Slipperiness
- Surface Roughness
- Full Braking
- Visibility

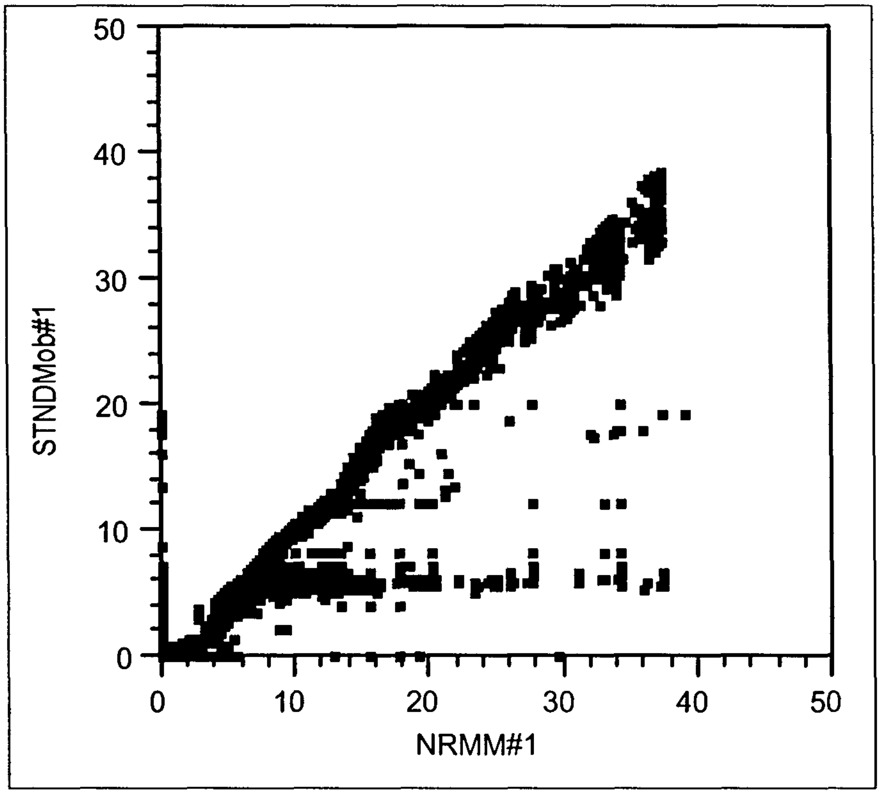


Figure D13. Bin 1, M1A1: MAD 1.6 mph, percent less than 3 mph, 87.9 percent

Major identified differences occur because NRMM averages the speeds over an array of obstacles as a prediction or determines that it is faster to travel around obstacles, rather than the resulting speed of crossing a single obstacle as implemented in STNDMob. Thus, those terrain units that are randomly placed (IOST = 1) and have an obstacle spacing (OBS) greater than 100 ft (arbitrary) will be eliminated from consideration. This leaves only 2,733 of the original 14,485 terrain units.

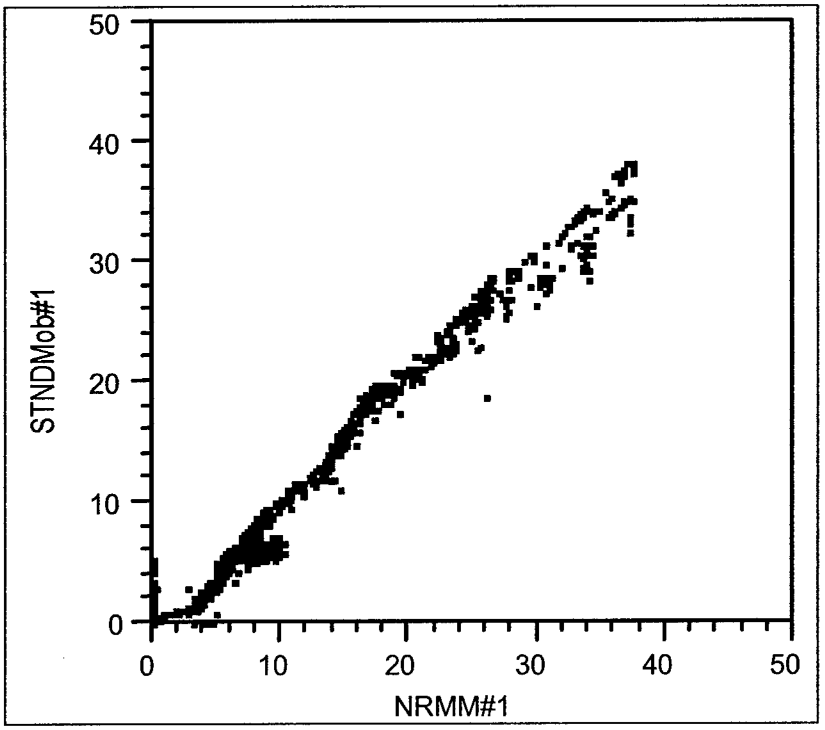


Figure D14. Bin 1, M1A1: MAD 1.2 mph, percent less than 3 mph, 94.2 percent

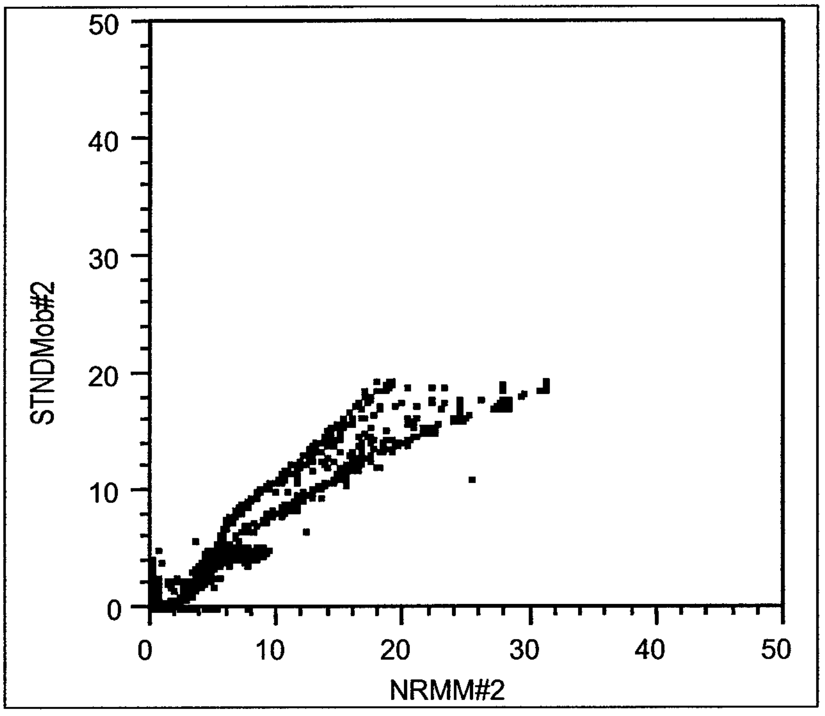


Figure D15. Bin 2, M270-MLRS: MAD 1.5 mph, percent less than 3 mph 87.2 percent

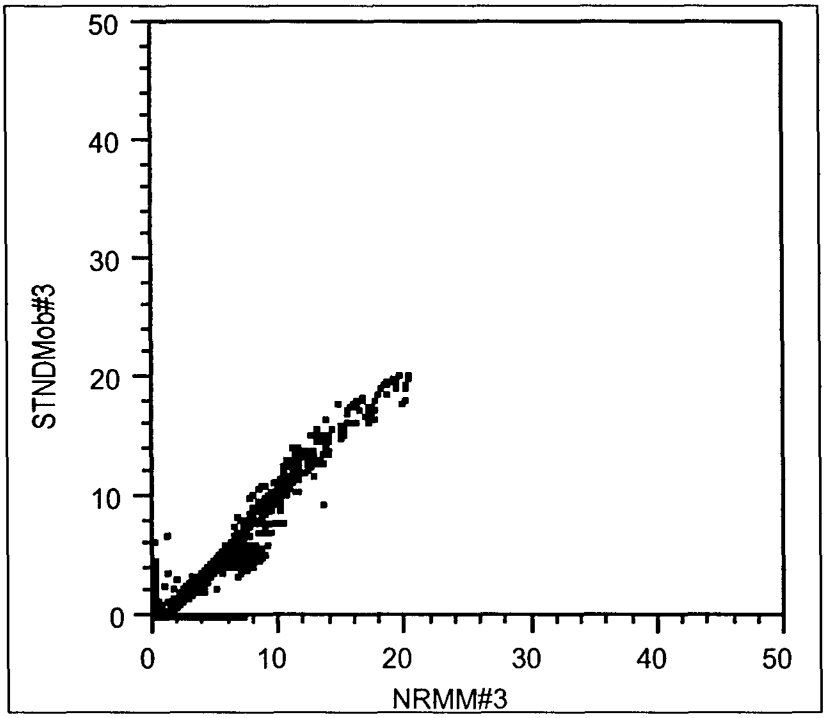


Figure D16. Bin 3, M60-AVLB: MAD 1.1 mph, percent less than 3 mph, 93.5 percent

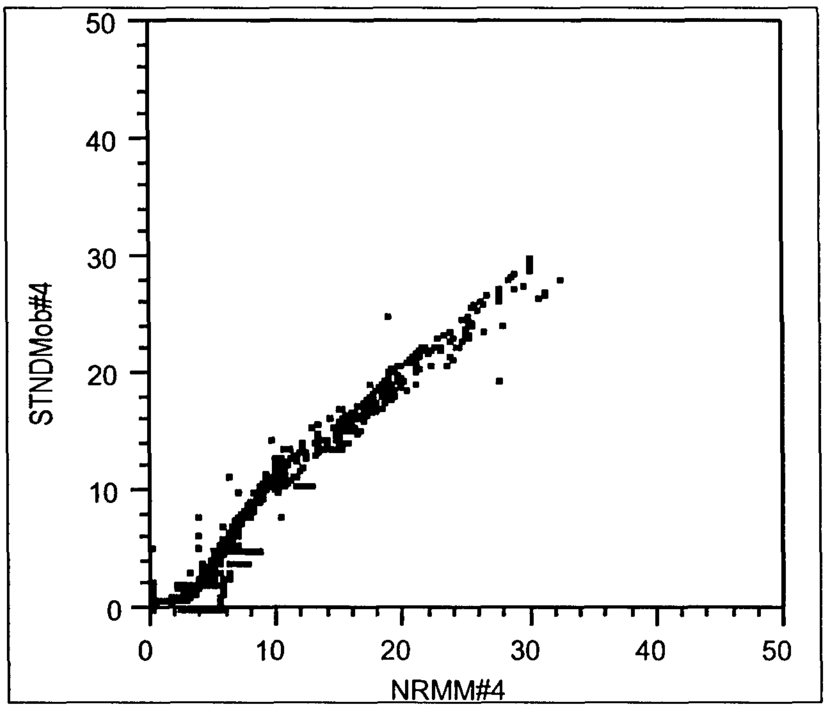


Figure D17. Bin 4, M1084-M1094: MAD 0.86 mph, percent less than 3 mph, 95.9 percent

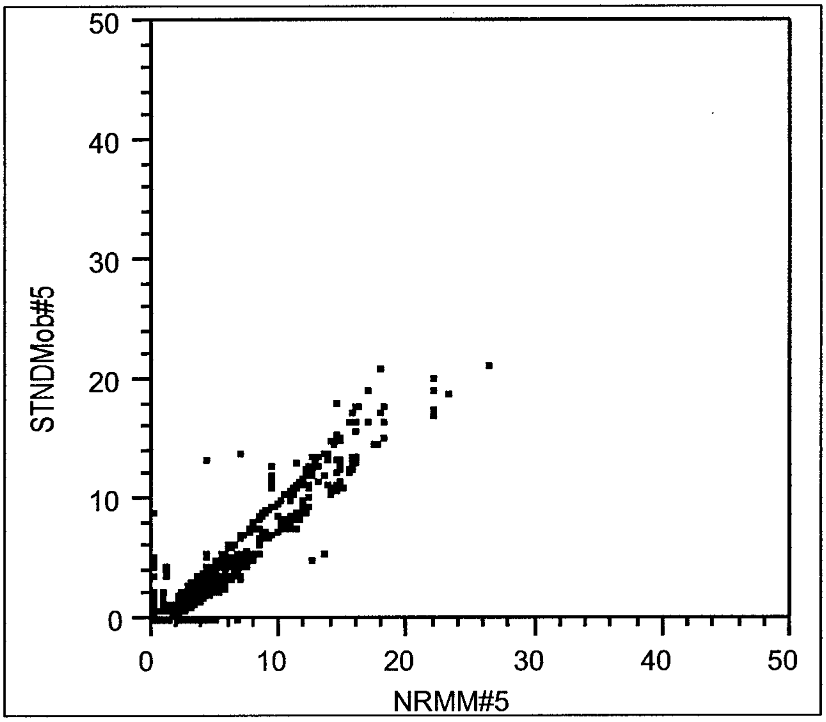


Figure D18. Bin 5, M985: MAD 0.9 mph, percent less than 3 mph, 93.6 percent

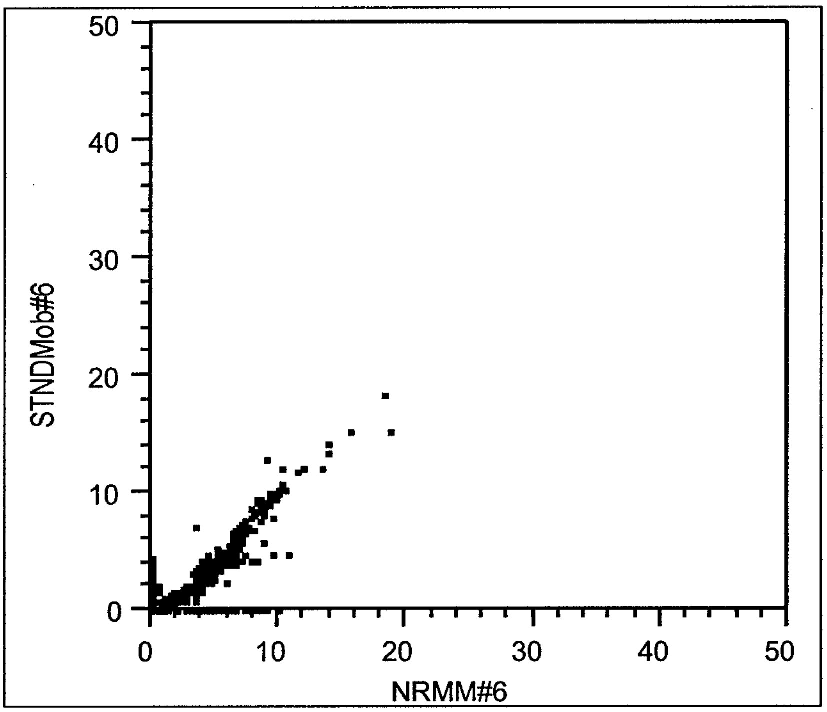


Figure D19. Bin 6, M917: MAD 1.1 mph, percent less than 3 mph, 85.6 percent

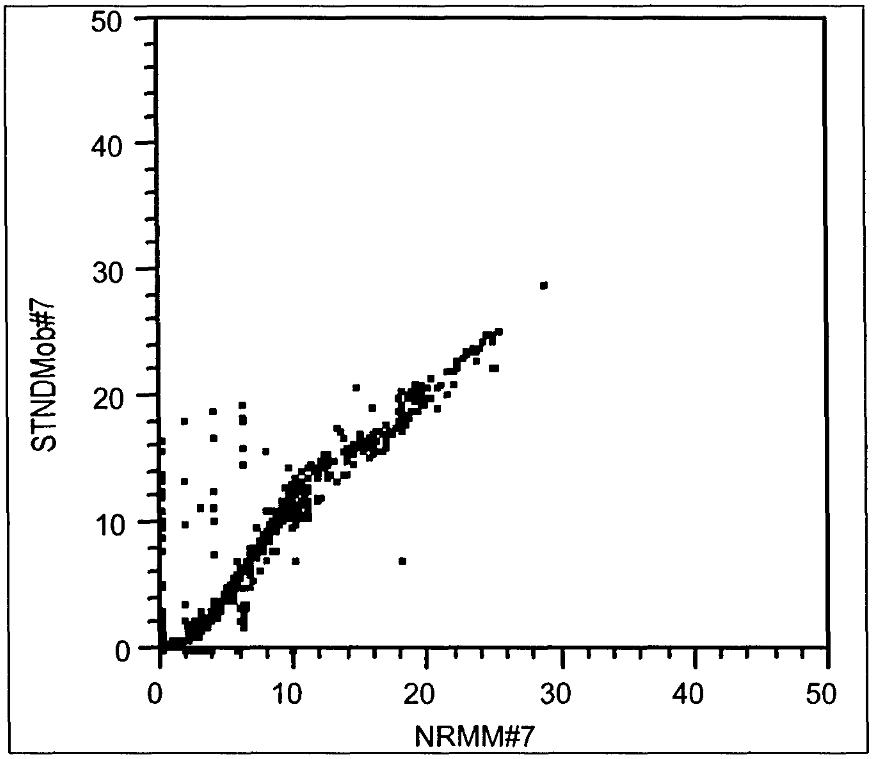


Figure D20. Bin 7, M1084-M1094: MAD 0.86 mph, percent less than 3 mph, 96.6 percent

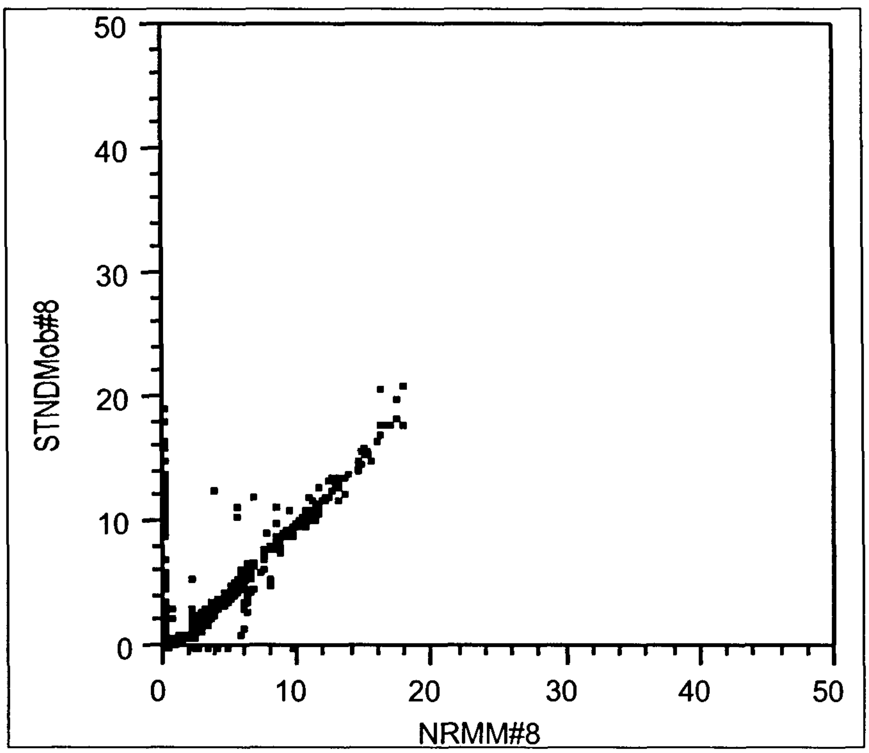


Figure D21. Bin 8, M911-M747: MAD 0.56 mph, percent less than 3 mph, 97.5 percent

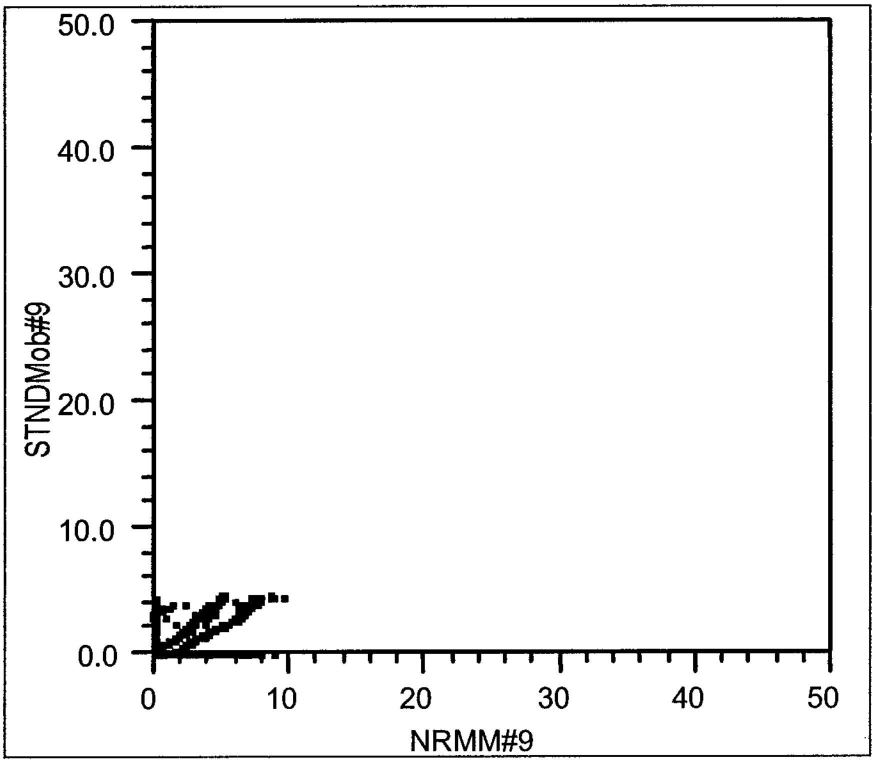


Figure D22. Bin 9, M911-M747: MAD 0.63 mph, percent less than 3 mph, 93.1 percent

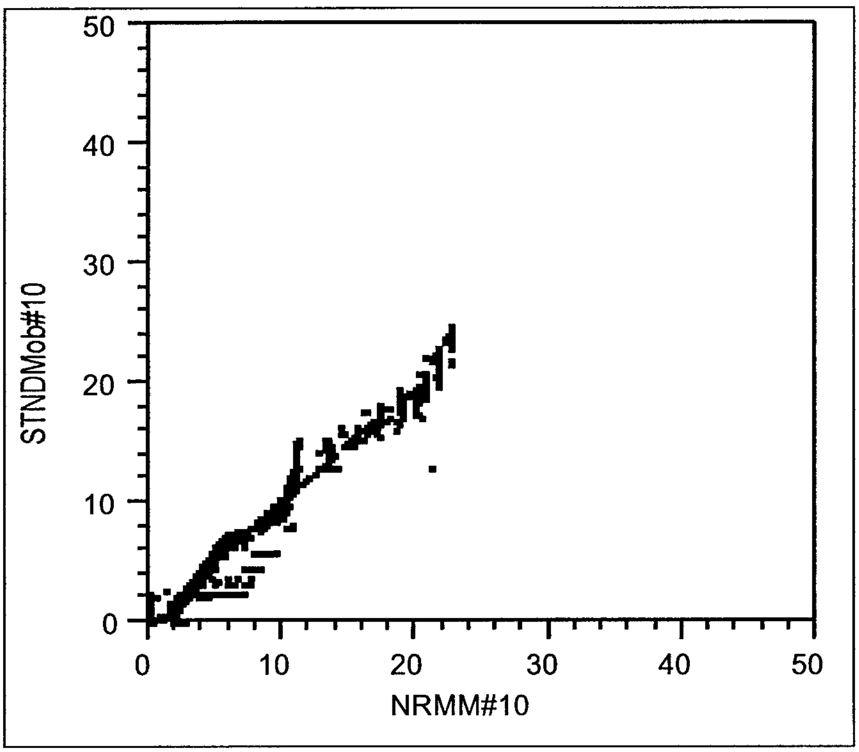


Figure D23. Bin 10, M113A2: MAD 1.0 mph, percent less than 3 mph, 94.4 percent

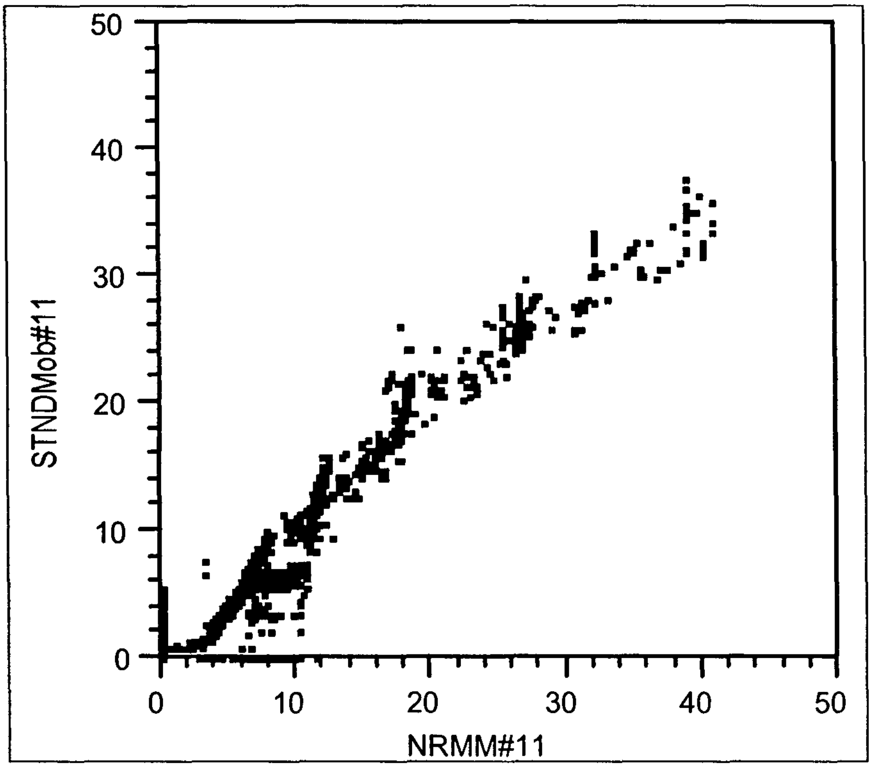


Figure D24. Bin 11, LAV3: MAD 1.3 mph, percent less than 3 mph, 85.1 percent

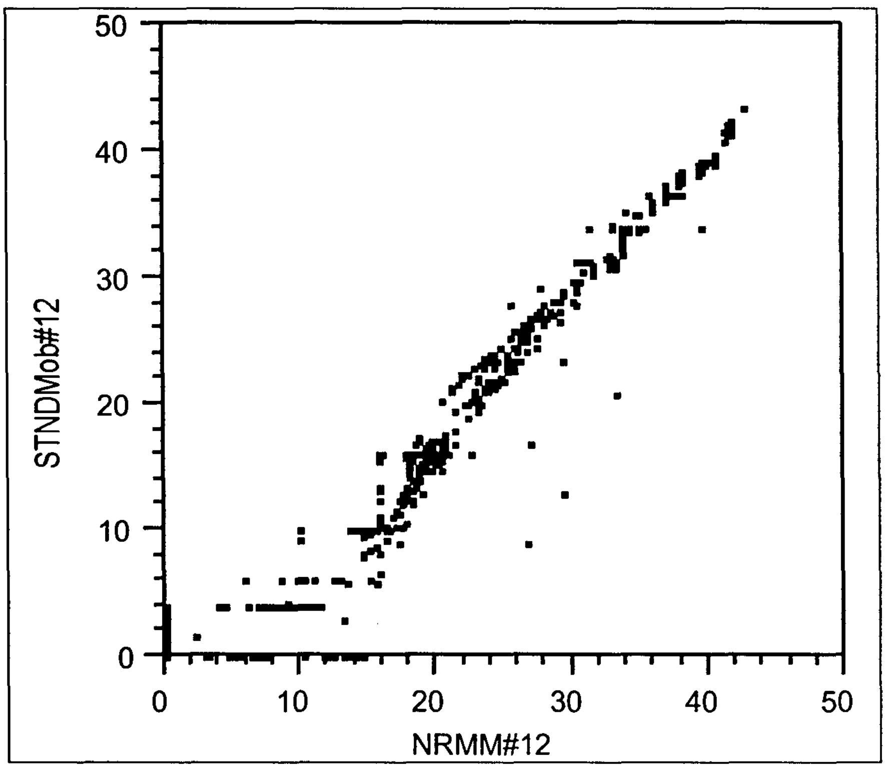


Figure D25. Bin 12, Kawasaki ATV: MAD 1.6 mph, percent less than 3 mph, 72.9 percent

This is a less than satisfactory match between the NRMM II and STNDMob 3.2 predictions for Bin 12. Since the ATV is much smaller and has a high acceleration potential, NRMM is predicting substantially higher speeds between obstacles within 100 ft of one another. Therefore, for this vehicle, all terrain units whereby the obstacle spacing is greater than 50 ft were eliminated. This leaves 1265 terrain units. The changes to the comparison are shown in Figure D26.

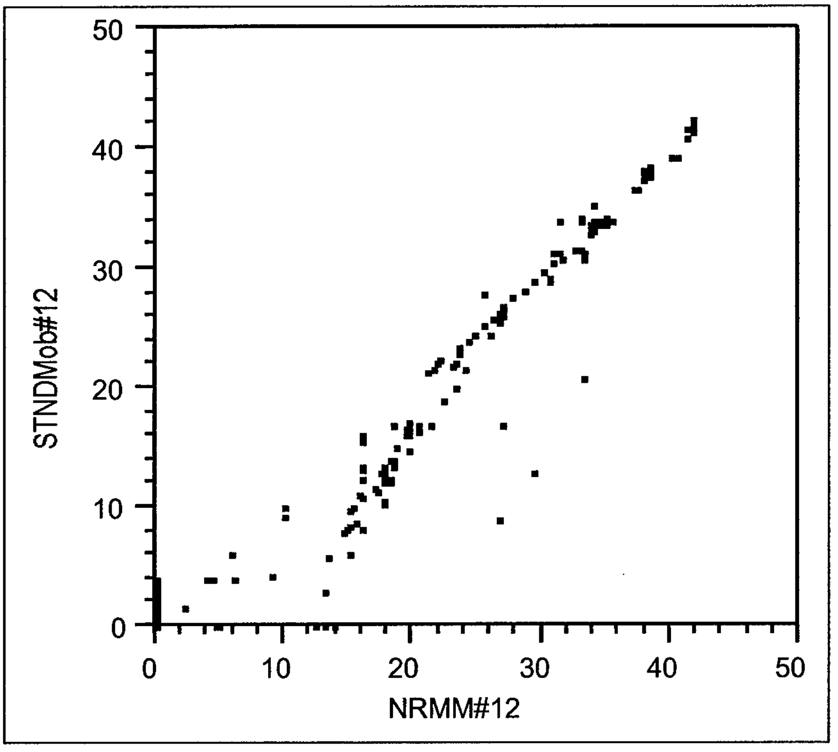


Figure D26. Modified Bin 12, Kawasaki ATV: MAD 1.0 mph, percent less than 3 mph, 84.7 percent

Thus, with a fair comparison of how STNDMob 3.2 and NRMM II.6.8 model vehicle-obstacle interaction, 8 of the 12 representative vehicles predicted (67 percent) met the pass/fail criteria. Had the percent less than 3 mph been relaxed to 85 percent, then 11 of 12 representative vehicles predicted (92 percent) would have met the pass/fail criteria with the last just missing the mark.

Summary

From the results of this comparison, it can be stated with some degree of statistical confidence that for all 12 representative vehicles, STNDMob 3.2 and NRMM II.6.8 are in agreement when the terrain considered does not go beyond the capability for STNDMob 3.2 to model the interaction. When the terrain data set was expanded to include what NRMM II.6.8 can fully model, STNDMob 3.2 was in agreement for 67 percent of the vehicles for the criteria stated.

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14. ABSTRACT
Mobility implementation in military models and simulations (M&S) currently is tailored primarily for specific models, leading to inconsistency between models. To assist decision-makers in analysis, acquisition, and training activities, it is necessary to provide and promote consistency among the models.

The NATO Reference Mobility Model (NRMM), Version II, is the Army Battle Command, Simulation and Experimentation Directorate, standard for single vehicle ground movement representation. This report describes the development of an NRMM-based Standard Mobility (STNDMob) Application Programming Interface (API) as a means of readily achieving higher fidelity movement representation by incorporating terrain-limited speeds into M&S.

As described in the report, the STNDMob API, Version 3, includes descriptions of two derivative models: the low-resolution (Level 1) and the medium-resolution (Level 2) capabilities of STNDMob within the tactical/entity fidelity. Each level of resolution has two degrees of fidelity. These levels of resolution are an implementation of the physical models for steady-state speed conditions. As a whole, STNDMob can be classified as a service module that provides vehicle speeds to a vehicle routing service/planner.

(Continued)

15. SUBJECT TERMS

Combat model	Maneuver	Movement
Ground vehicle	Mobility model	NRMM
	Modeling standards	Vehicle traction

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		114	

14. ABSTRACT (Concluded).

Included in the report are descriptions of the input/output data, algorithm process and supporting equations, and example data. Appendixes provide supporting data descriptions, software documentation, and a comparison of STNDMob to NRMM.