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Construction Engineering Research Laboratory

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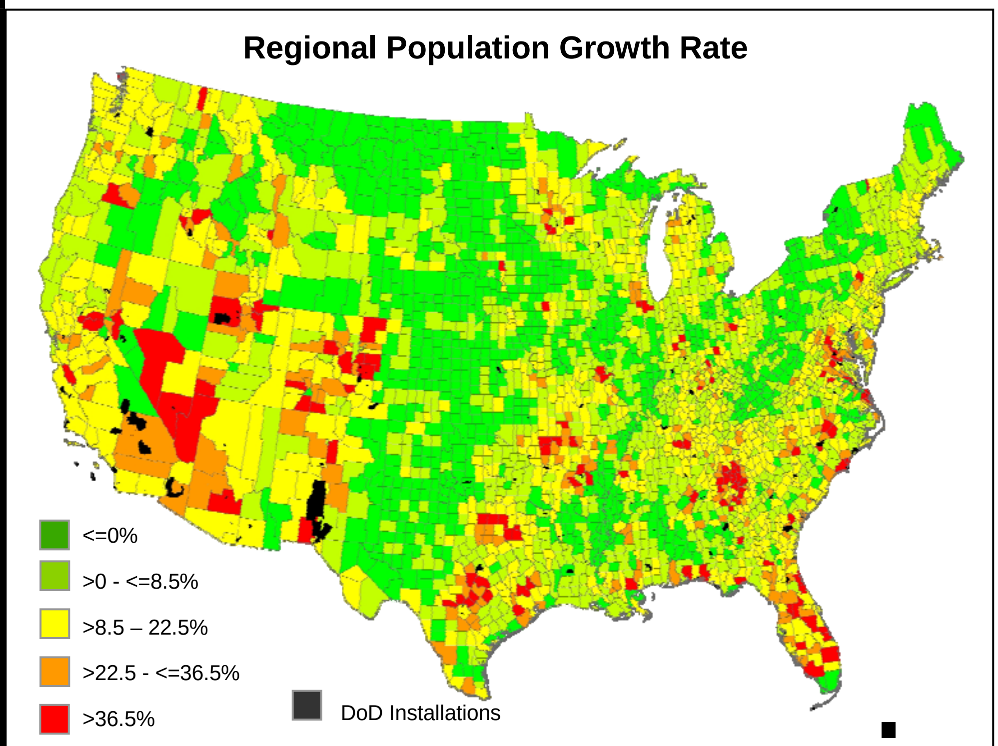
A Comparison of Regional Vulnerability Factors for Department of Defense (DoD) Installations

Elisabeth M. Jenicek, Natalie R.D. Myers, Brad Boesdorfer, and Donald F. Fournier

September 2006



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A Comparison of Regional Vulnerability Factors for Department of Defense (DOD) Installations

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ABSTRACT: A key concern for Department of Defense (DoD) installations is their ability to sustain, and sometimes change or expand, their mission activities. Optimal use of installations in the face of changing missions, closures, and realignments requires an understanding of each installation's capabilities. Regional competition for land, transportation, energy, water, and other resources may put an installation's ability to perform essential activities at risk. This research adapted the Sustainable Installation Regional Resource Assessment (SIRRA) methodology to consider primary military mission as a weighting factor in determining vulnerability to a set of sustainability issues, and to identify the most vulnerable installations within each DoD service, and to determine those installations that would benefit from further study and intervention.

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Conversion Factors

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

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

**Système International d'Unités* ("International System of Measurement"), commonly known as the "metric system."

Preface

This study was conducted for the Office of the Chief of Engineers (OCE), Headquarters, U.S. Army Corps of Engineers (HQUSACE) under RDTE SERDP Project CS-1257, and Project T233FF, "FF Training Range sustainability"; Work Unit L74711, "FF Environmental Stewardship." The SERDP technical reviewer was Dr. Robert Holst, SERDP Conservation Program Manager. The technical monitors were Dr. Michael Case, Program Manager, Office of Technical Directors, and William Goran, Director of Special Projects, Construction Engineering Research Laboratory (CERL).

The work was performed by the Energy Branch (CF-E) and the Business Processes Branch the CF-N of the Facilities Division (CF), CERL. The CERL Principal Investigator was Elisabeth M. Jenicek. Thomas J. Hartranft is Chief, CF-E, Donald K. Hicks is Chief, CF-N, and L. Michael Golish is Chief, CF. The associated Technical Directors are Michael Case and William Goran. Part of this work was done by Donald Fournier of the University of Illinois at Urbana-Champaign under contract number DACA88-99-D-002, Delivery Order 0031, and by Natalie Myer and Brad Boesdorfer of the PERTAN Group, contract number DACA42-01-D-0002, Delivery Order 11. The Acting Director of CERL is Dr. Ilker R. Adiguzel.

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

1 Introduction

Background

One of the key concerns for Department of Defense (DoD) installations is their ability to sustain, and sometimes change or expand, their mission activities. Optimal use of installations in the face of changing missions, closures, and realignments requires an understanding of each installation's capabilities. Regional competition for land, transportation, energy, water, and other resources may put an installation's ability to perform essential activities at risk. It is critical that we understand those factors that impact an installation's ability to maintain its mission.

Over the last several decades, the population and amount of developed land around most U.S. cities and military installations have grown significantly. Economic expansion driven by the presence of DoD installations spurs development of new suburban communities while services such as utilities and housing offered by cities attract installations toward urban areas. As a result, many installations are now at the fringe or in the midst of large urbanized or urbanizing areas.

Land transformations near military installations affect how military lands are managed. For example, loss of habitat "outside the fence-line" can increase the importance of threatened and endangered species habitat inside the installation boundary; an addition of soldiers on an installation can deplete critical water resources for both the installation and surrounding community; and growing residential neighborhoods adjacent to the "fence-line" can limit flight patterns and range usage for DoD training. These pressures may limit the military's use of land-, air-, and sea-space and are defined as "encroachment" issues. Encroachment issues stress an installations' sustainability and/or threaten its viability to complete mission assignments. Installations often find themselves not only in competition for scarce regional resources, such as land for growth, water supply, air space, and radio/communication frequency spectrum, but they are also affected by stricter regulations for air and water quality standards, erosion control requirements, and wetland impacts. As a result, installations and their sustainability face a number of uncertainties, up to and including closure.

Sustainability is the foundation of the DoD's strategy to address both present and future needs while strengthening community partnerships that improve an installation's ability to organize, equip, train, and deploy as part of a joint force. The Strategic Environmental Research and Development Program (SERDP) is the DoD's corporate environmental science and technology program (SERDP Program Office 2004). SERPD specifically focuses on identifying and developing environmental technologies that relate directly to defense mission accomplishment and encroachment issues. This research adapts one such technology, the Sustainable Installation Regional Resource Assessment (SIRRA) methodology, by considering primary military mission as a weighting factor in determining vulnerability to a set of sustainability issues.

Objective

The objective of this work was to identify the most vulnerable installations within each DoD service and to determine those installations that would benefit from further study and intervention by characterizing resources and stresses in the region surrounding an installation. The specific objective of this study was to use environmental research and sustainment indices to define and describe a methodology to identify installations whose mission sustainment has potential problems. The method identifies the potential for encroachment issues at 308 DoD installations by ranking the regions around installations for vulnerability to sustainability issues.

Approach

This research initiative is based on previous work at CERL in the area of encroachment and sustainability indicator development, under the Sustainability, Encroachment, and Room-to-Maneuver (SERM) research program, which is part of the Fort Future initiative. As such, this work is a natural outgrowth of the SERM initiative. It represents an application of analysis techniques—developed in the SERM initiative—to stationing and installation realignment.

Mode of Technology Transfer

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

http://www.cecer.army.mil

2 Sustainable Installations Regional Resource Assessment

Planners for DoD installations face increasingly complex challenges, due to rapid land use changes, stakeholder involvement in planning processes, and transforming Defense forces, technologies, and global circumstances. In response to these issues, the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL initiated several projects that are included in the SERM project grouping. These research efforts are all designed to provide tools, data, expertise, and processes that help the DoD sustain and evolve mission operations, both military and civil works. The concept for SERM emerged from exploratory research initiated at CERL during the 1997-1998 timeframe. The purpose of SERM is to provide Defense planners with greater flexibility and ability to evaluate complex issues, and to access "the right information at the right time" to enhance their planning outcomes while addressing current and future planning problems. SIRRA is one of the projects developed under SERM.

Regional resource assessment provides the opportunity to incorporate the broader perspective of regional issues into the concept of installation sustainability and its implications to mission sustainment. SIRRA is a process of characterizing regions containing installations based on a set of indicators grouped into several issues (Jenicek, Fournier et al. 2004). SIRRA uses uniform assessments with a broad set of indicators covering the range of issues that may affect military installations and their locality. The determined indicator(s) may be used to express the relative ranking of installations based on single measures (or groups of measures) that define an issue. This standardized approach enables the use of national level data to evaluate the regional aspects of the installation setting. This provides a heightened awareness of long-term issues that could threaten mission sustainment.

This methodology was first developed and presented in the ERDC/CERL Technical Report TR-02-27, *An Assessment of Encroachment Mitigation Techniques for Army Lands* (Deal et al. October 2002) and further developed in the ERDC/CERL Special Report SR-02-12 *Sustainable Installation Risk Assessment and Stationing Implications* (Fournier et al. September 2002). SIRRA Version 1a was released in July 2004. Its capabilities are described in the ERDC/CERL TR-04-9 *The Sustainable Installations Regional Resource Assessment (SIRRA) Capability* (Jenicek et al., July 2004).

Regional Resource Assessment Framework and Metrics

Assessing installation or watershed sustainability is complex and requires the evaluation of a combination of indicators that are related to both exogenous and endogenous factors. These factors may not really lend themselves to prioritization, but present an indication of issues that may need to be addressed in installation or watershed planning and management. The effects of demographic change, community growth and sprawl, and regional economic vitality present levels of exogenous resource issues that may be a threat to continued mission sustainment or watershed vitality. Issues associated with installation mission, management, and cultural and natural histories define endogenous risk. The framework developed here looks outside the installation and is based on exogenous indicators that could be determined with data sets available nation-wide. Some indicators were deemed so critical that they were retained despite the lack of a national data set. Assessing levels of regional resource and environmental stress or demands entails developing a set of indicators or indices that can provide reliable information about the level and type of a given resource. The resource can vary from availability of clean water to the amount of vehicular traffic congestion in the region, the latter being an indicator of potential air and water pollution and water from non-point sources and the ability of military members residing off-post to quickly mobilize.

Overview of Indicator Development

An "indicator" is a piece of information that reflects what is happening in a larger system. It allows observers to see the big picture by looking at a smaller part of it. Indicators are often quantitative measures such as physical or economic data. For example, traditional indicators such as inflation and unemployment rates are used for making economic decisions. Indicators are widely used as a tool for monitoring progress and to simplify, quantify, and communicate complex issues. Multiple indicators are sometimes aggregated into an index, usually for comparison across locations or to indicate change over time. Indicators are often used as the feedback mechanism to inform policy changes intended to improve the situation being measured. Their intent in the SERM analysis cycle is to provide the baseline information about the region in which the installation resides and illuminate key issues which may be a current or future threat to mission sustainment, mission realignments, or regional environmental health. These provide the starting point for regional planning and impact amelioration. Because the process of measuring focuses attention on the impact, it makes a great deal of difference what is measured and how it relates to what we wish to measure.

Developing indicators is a six-step process (Maclaren 1996):

1. Define and conceptualize the goals for which indicators are needed.

2. Identify the target audience, the associated purpose for which indicators will be used, and the relative number of indicators needed.
3. Choose an appropriate indicator framework.
4. Define indicator selection criteria.
5. Identify a set of potential indicators and evaluate them against the selection criteria.
6. Choose a final set of indicators and test their effectiveness.

As noted above, the goal of the indicators is to define and highlight regional issues that may define current or future encroachment and resource issues or potential future impacts. The encroachment and mission sustainment issue areas that have been defined by the Senior Readiness Oversight Council are:

- endangered species and critical habitat
- unexploded ordinance and munitions
- frequency encroachment
- maritime sustainability
- airspace restrictions
- air quality
- airborne noise
- urban growth.

Many of these issues are associated with external aspects: what is located and what happens outside the fence line. Incompatible residential and commercial development of land close to military installations can affect the ability of an installation to carry out its mission. Such development also threatens public safety because accidents sometimes occur in areas surrounding an installation. The economic health of a community is affected if military operations and missions must relocate because of urban encroachment.

The target audience for the indicators and the regional resource assessment are decisionmakers and planners who need broadly based information to inform their processes of determining future stationing, base realignments, and installation sustainability actions. Regional and local planners must also be included if encroachment amelioration is to be successful.

A framework for developing a set of indicators is necessary for every indicator effort. The choice of framework must meet users' needs and priorities. A number of frameworks have been identified and used. These frameworks provide a starting point for any organization embarking on a sustainability effort.

Virginia MacLaren (Maclaren 1996) reviews four general frameworks for use in organizing sustainability indicators: domain-based, goal-based, sectoral, or causal frameworks. She adds a fifth type, known as issue-based, and a combination framework, which uses two or more of the other frameworks.

A *domain-based framework* is based on the three key dimensions of sustainability: environment, economy, and society. Indicators are identified for each dimension. This framework is effective at ensuring that the key dimensions of sustainability are covered. A weakness of this framework is that indicators are not linked to sustainability goals. An example of the domain-based framework is the Sustainable Seattle effort.

A *goal-based framework* is predicated on the development of organization sustainability goals. Indicators are then created for each goal. A benefit of this framework is that there are fewer indicators. A weakness is that it does not capture linkages among the dimensions of sustainability. Examples of goals are basic human needs, social well-being, economic prosperity, and carrying capacity. The United Kingdom's Local Government Management Board (LGMB) employed this kind of framework.

A *sectoral framework* may tie indicators to different sectors of a governing entity. This framework makes it easier to assign responsibilities for problems or results revealed by indicators. A drawback to using this framework is the resulting compartmentalization that often masks linkages between domains.

A *causal framework* is useful in explaining changes in indicators or whether policy interventions are effective. A drawback to this framework is that it implies simple linkages between stressors and conditions that may be very complex. This oversimplification can confuse the issues and lead to erroneous perceptions.

An *issue-based framework* may be popular because it addresses visible problems. A weakness of this framework is that it lacks explicit linkages to policy and presents a "shotgun" approach to developing indicators. Some examples of issues are urban sprawl, solid waste management, crime and safety, job creation, and industrial pollution.

The difficulty in selecting indicators is not a lack of measures but rather the overwhelming number of potentially useful indicators. The International Institute for Sustainable Development selected the following criteria based on indicator literature and practical experience with performance measurement (IISD 2000):

- *Relevance*. Can the indicator be associated with one or several issues around which key policies are formulated? The indicator must be linked to critical decisions and policies.

- *Simplicity*. Can the information be presented in an easily understandable, appealing way to the target audience? Complex issues and calculations should yield clearly presentable and understandable information.
- *Validity*. Is the indicator a true reflection of the facts? Was the data collected using scientifically defensible measurement techniques? Is the indicator verifiable and reproducible? Methodological rigor is needed to make the data credible.
- *Temporality*. Is time-series data available, reflecting the trend of the indicator over time? Several data points are needed to visualize the direction the community or region may be going in the near future.
- *Measurability*. Is the data quantifiable — something that can be measured directly or can be counted? Data must be based on tangible information.
- *Availability and Affordability of Data*. Is good quality data available at a reasonable cost or is it feasible to initiate a monitoring process that will make it available in the future?
- *Expansiveness*. Is the indicator about a narrow or broad issue? Indicators that aggregate information on broader issues are preferred. For example, forest canopy temperature is a useful indicator of forest health and is preferable to measuring other indicators to come to the same conclusion.
- *Sensitivity*. Can the indicator detect a small change in the system? Determine whether small or large changes are relevant for monitoring.
- *Reliability*. Will you arrive at the same result if you make two or more measurements of the same indicator? Others should reach the same conclusions based on the indicator.

SIRRA Indicator Framework

The research team developed a SIRRA framework based on the process, framework, and criteria considerations described above. This framework is both issue-based and domain-based. It addresses many aspects of installation sustainability from a regional perspective. Using a combined framework offers the advantage of being able to draw on the strengths of the two frameworks while downplaying their weaknesses (Maclaren 1996). This framework enables a relatively easy assessment of the potential resource issues in a region and highlights the issues within that region that an installation or range may be experiencing. The indicators show where the issues lie and highlight potential long-term sustainability implications.

Issue		
	Indicator	**Data**
	Indicator	**Data**
	Indicator	**Data**
Threatened and Endangered Species		
	# of TES in state	**Fish and Wildlife Service**
	Species at risk	**Journal of American Water Resources Association**
	Federally listed TES by Ecoregion	**NatureServe**
	TES of Concern	**NatureServe**

Figure 1. Regional resource assessment framework.

Figure 1 shows the regional resource assessment framework of issues and indicators, including an example of the issue-indicator relationship. Each indicator measures a different dimension of potential risk or stress. Comparison across installations of values for an individual indicator can give a measure of relative stress along one dimension. Each issue has several indicators and sometimes a combination of several indicators, or indices. Organizing the indicators by sustainability issue area allows the user to determine the issues that are relevant for their particular analysis and to consider only those.

The research team has developed a set of regional resource assessment indicators based on the process, framework, and criteria considerations described above. To help determine installation sustainability, our indicators are a combination of issue-based and domain-based. Using a combination framework has the advantage of being able to draw on the strength of the two frameworks while downplaying their weaknesses (Maclaren 1996). This framework enables a relatively easy assessment of the potential resource issues in a region and highlights the issues within that region an installation may be experiencing. The indicators show the status of the issues and highlight potential long-term sustainability implications.

Sustainability Issues

The selected sustainability issues are based on regional resource issues outside the installation boundaries. The associated indicators were developed based on criteria discussed in the next section. Community growth increases the contiguity between outside development and the installation or range. This contiguity increases the likelihood of incompatibility of land use between military missions and nearby urban development resulting in conflicts. The issues have been generated to apply to military installations, but a subset of these issues and indicators would also apply to watersheds, political boundaries, energy grids, etc. Water and energy resources are impacted by regional growth and related consumption and contamination. Regional types of energy use and their sources affect energy security and availability. Based on the criteria, the research team developed a set of 10 sustainability issue areas with a total of 54 indicators. The sustainability issue areas are: Air Quality, Airspace, Energy, Urban Development, TES, Locational, Water, Economic, Quality of Life, and Transportation.

The SIRRA Set of Indicators

Indicators with the potential for assessing these regional resources within the 10 issue areas were selected based on these requirements:

- the availability at a uniform scale nation-wide to ensure uniformity in comparisons
- records for multiple time periods to enable the evaluation of change
- preparation by a reputable source, such as a government agency or professional data vendor, and accompanied by metadata for quality assurance
- provision in a digital format, to accelerate data gathering and preparation for analysis
- the ability to be converted to geographic information system (GIS) format.

The 10 sustainability issue areas, with their corresponding indicators, represent a broad spectrum of topics related to resource availability and development. The 54 indicators provide a wide variety of information about population, economics, land development and usage, water availability and watershed health, natural disasters, infrastructure, air pollution, airspace availability, regional energy, and regional quality of life. Indicator data is from a variety of sources such as the U.S. Geological Survey (USGS) for seismicity information, the U.S. Environmental Protection Agency (USEPA) for air quality data and water supply characterization, the U.S. Fish and Wildlife Service (USFWS) and NatureServe for endangered species data, the U.S. Census Bureau for population statistics, and the U.S. Department of Energy for energy related data.

Appendix A includes the metadata documentation for each indicator, and provides the logic for indicator selection along with data sources, method of calculation, and assessment criteria. Since most of these are national data sets and were chosen due to their availability at the national level, incorporating them into GIS format for mapping provided a ready pictorial view of the sustainability issues. Table 1 lists the SIRRA indicators broken out by sustainability issue area, and also shows the data source and the data resolution level. All 54 indicators were used in this study.

Table 1. Matrix of SIRRA indicators broken out by issue area.

Issue	Indicator	Data Source	Data Level
Air Quality Sustainability			
AQ1	Criteria Pollutant Non-Attainment	EPA/EIA	County
AQ2	Noise Sensitivity	US Census Bureau	Installation
Airspace Sustainability			
AS1	SUA, Fighter Range	FAA	Installation
AS2	SUA, Bomber Range	FAA	Installation
AS3	Terminal Airspace	FAA	Installation
AS4	MTR, Fighter Range	FAA	Installation
AS5	MTR, Bomber Range	FAA	Installation
Energy Sustainability			
EN1	Electrical Grid Congestion	NERC	NERCSub
EN2	Electrical Reserve Margin	NERC	NERCReg
EN3	Renewable Energy - Wind	NREL	Solargridunit
EN4	Renewable Energy - Solar	NREL	Windgridunit
EN5	Renewable Energy - Biomass	NREL	State
EN6	Electrical Price Structure (Dereg)	EIA	State
EN7	Net metering	Green Power network	State
Urban Development Sustainability			
UD1	Regional population density	US Census Bureau	County
UD2	Incr. Regional Growth Rate	US Census Bureau	County
UD3	Regional population growth	US Census Bureau	County
UD4	Regional Land Urbanization	NLCD	Installation
UD5	State smart growth plans	APA web site	State
UD6	Joint Land Use Study (JLUS)	JLUS Office	Installation
UD7	Proximity to MSA	US Census Bureau	Installation
TES Sustainability			
TE1	# TES in state	FWS	State
TE2	Species at Risk	JAWRA	watershed
TE3	Federally Listed TES by Ecoregion	NatureServe	Ecoregion
TE4	TES of Concern	NatureServe	Ecoregion
Locational Sustainability			
LO1	Federally declared floods	FEMA database	County
LO2	Seismic Zones	USGS maps	Zone
LO3	Weather-related damage	NWS/NOAA	State
LO4	Federally declared disasters	FEMA database	County
LO5	Tornadoes	NOAA	County

Issue	Indicator	Data Source	Data Level
Water Sustainability			
WA1	Level of Development	JAWRA	Watershed
WA2	Ground Water Depletion	JAWRA	Watershed
WA3	Flood Risk	JAWRA	Watershed
WA4	Low Flow Sensitivity	JAWRA	Watershed
WA5	Water Quality	JAWRA	Watershed
Economic Sustainability			
EC1	DoD Local Employment	www.bea.gov (REIS)	County
EC2	Job Availability/unemployment	Bureau Labor Statistics	County
EC3	Housing Affordability	US Census Bureau	County
EC4	Poverty	US Census Bureau	County
EC5	Avg Hsg Value of New Construction	US Census Bureau	County
EC6	Housing Permits Issued	US Census Bureau	County
QOL Sustainability			
QL1	Crime Rate	NACJD	County
QL2	Housing Availability	US Census Bureau	County
QL3	Rental Availability	US Census Bureau	County
QL4	Healthcare Availability	HHS	County
QL5	Educational Attainment	US Census Bureau	County
QL6	Commute Times	US Census Bureau	County
Transportation Sustainability			
TR1	Capacity of Comml Airports	TAF System	Installation
TR2	Airport Suitability-C5	FAA	Installation
TR3	Airport Suitability-C141	FAA	Installation
TR4	Railroad Capacity	FRA	County
TR5	Proximity to Interstate	IRRIS	Installation
TR6	Roadway Congestion	2002 Urban Mobility & FHWA	State
TR7	Traffic Volume	TTI & FHWA	State

3 Methodology

Analysis Concept

SIRRA has proven to be a useful and successful sustainability screening tool and has been used in the past to assess installations in a decision support function (Fournier, Deal et al. 2002). SIRRA version 1a was released in July 2004 using National data sets organized in a web-based analysis tool. The SIRRA methodology was reviewed by the individual DoD services before release. SIRRA data is derived from validated national sources, compiled in a consistent format, and covers a wide array of sustainability topics. SIRRA quantifies the state or condition of sustainability indicators and provides sustainability ratings for single indicators. However, it does not currently provide sustainability ratings based on an index, that is, a group of indicators. To meet the objective to rank the general sustainability of all DoD installations, this report generates a set of sustainability ratings based on multiple indicators with the capability to illustrate minor differences between DoD installations and regions of the country.

The SIRRA sustainment ratings contained in version 1a categorize indicator measures in three ratings as follows: sustainable, moderately sustainable, or unsustainable. The current SIRRA sustainment ratings were adjusted to have a finer resolution to highlight differences between a large number of installations within various regional settings. These ratings are not yet available on the SIRRA web site. This study characterizes indicator measures in five sustainment ratings:

1. Very low vulnerability
2. Low vulnerability
3. Moderate vulnerability
4. Vulnerable
5. High vulnerability.

Note that these ratings are not absolute in all cases as some are relative to a norm or mean. Also, note that not all indicators are broken out into five categories and some remain with three as the data did not lend itself to the finer scale.

Analysis Methodology

The analysis methodology consists of initially characterizing and weighting sustainment issues at DoD installations using the SIRRA system. The full set of the original 48 indicators from SIRRA 1a, plus an additional six indicators, were used for this evaluation. The set of indicators is listed in Table 1 and also contained in Appendix A with metadata documentation.

The indicator weighting scheme relates the regional issues to specific missions or functions of an installation. For example, a storage depot facility is affected less by housing availability issues and affected more by inter-state transportation availability for the movement of its goods; while an expeditionary facility is affected greatly by housing availability for its soldiers and affected minimally by inter-state transportation availability. Both housing and transportation availability are considered sustainment issues that contribute to regional encroachment, but the weight given to each type of installation for those indicators is different. The regional sustainability ranking approach provides a weighted summary of assessment indicators that determine an overall mission sustainment or vulnerability rating for that region hosting the given installation. These weighted assessments can then be used as a screening tool to assess installations where additional studies, planning, and actions are recommended to ensure continued mission accomplishment.

The following steps were followed to accomplish this:

1. *Compile data for 54 SIRRA indicators in the regions surrounding 308 DoD installations.*
   Appendix A of this report includes the SIRRA metadata. Indicator data values were extracted from the revised SIRRA database, updated from the version 1a contained on the web-based analysis tool that is available online at URL:
   https://ff.cecer.army.mil/ff/sirramx.do

   The query results in several "not-available" data values—specifically for water sustainment indicators in Alaska and Hawaii where the data source does not report conditions in these areas. To assure these "not-available" data values neither hurt or help installations, these values were entered as "moderately sustainable" or the rating was interpolated from the surrounding nearby regions. The table in Appendix B reports all data values for the SIRRA indicators in regions surrounding the installations used in the analysis. Appendix B also provides the installation mission classifications.

2. *Assign numbers to 54 SIRRA indicator sustainability ratings into five categories of sustainability—where 1 represents very low vulnerability and 5 represents high vulnerability.*

   The metadata in Appendix A includes the sustainment rating thresholds for the SIRRA indicators. Once sustainment ratings are determined, they were assigned numbers. This allowed an indicator to be weighted and scored based on its criticality to mission.

   - very low vulnerability = 1
   - low vulnerability = 2
   - moderate vulnerability = 3
   - vulnerable = 4
   - high vulnerability = 5

3. *Assign weights to 54 SIRRA indicators based on four DoD missions. A weight of 1 is applied to a low importance indicator, 2 to indicators of average importance, and 3 to indicators of major importance.*

   For each mission/installation type a different set of indicators are important. If an indicator is of major significance to a specific mission, its value is multiplied by 3. If an indicator is of average significance to a specific mission, its sustainment rating is multiplied by 2. If an indicator is of lesser significance to a specific mission, its sustainment rating is multiplied by 1. Appendix C contains the matrix characterizing indicators by missions used in this report.

4. *Assign the primary mission/function to each installation.*

   Each installation is assigned a *primary* function or mission—expeditionary, training and ranges, industrial, and administrative support. Definitions of these missions follow:

   - *Expeditionary*: Includes all installations (land, air, sea) that train and project forces—airbases with active runways, maneuver installations, naval air facilities, and selected training installations.
   - *Training and Ranges*: These include non-expeditionary training installations, remote ranges, and reserve component training sites.
   - *Industrial*: These include storage installations, arsenals, depots, industrial facilities, ammo plants, shipyards, and ocean terminals.
   - *Administrative Support*: These include command, control, and administrative support installations; medical treatment facilities; non-maneuver type training; professional development installations; and RDT&E oriented locations.

   Characterizations of these missions were determined based on judgment of overall activities present on the installation. Installations often perform more than one task and characterizing the function in a single term is often difficult. Installations' official missions often compose a unique paragraph description. Generalizations of missions are used within this analysis. Appendix B includes a complete list of assigned installation missions.

5. *Sum the sustainability ratings to arrive at an overall sustainability score or index that characterizes a level of encroachment potential or sustainment jeopardy.* To arrive at a final sustainment/vulnerability score for the region around an installation, multiply indicator ratings by respective weights identified by mission criteria. These weighted indicator ratings are then summed to arrive at a total installation sustainability vulnerability score. The higher the score, the more vulnerable the installation is considered or the more stress experienced due to encroachment issues. The lower the score, the less vulnerable the installation is to encroachment and key issue stresses. Appendixes C, D, and E provide the final Vulnerability Score for each installation region.

Using this method, lower scores represent more sustainable or less vulnerable installations. In other words, low scores represent few regional risks for that particular mission. Understanding the mathematics, if an indicator is of lesser importance, the weights rank it positively (x 1). If an indicator is a key determinant, the weights will rank it relatively positively if it is a good rating (1 x 3) and highly negatively if it is a poor weighting (5 x 3). Indicators of average importance act similarly to key indicators only not as significantly (x 2 vs. x 3).

Testing Example

Is an urban area most suitable for an expeditionary or administrative support mission?

expeditionary = 5 x 3 = 15

administrative support = 5 x 1 = 5

Warning! Users must be careful in comparing sustainability scores of installations/regions with differing mission. Because of the set-up of the weights, majority of expeditionary mission indicators are multiplied by 3, where majority of administrative support mission indicators are multiplied by 1. Therefore, expeditionary mission installations will naturally have a higher vulnerability score compared to administrative support mission installations. Users should note the range of possible sustainability scores for each mission and compare where an installation falls within that scale to compare two or more installations of differing missions. The different mission weightings highlight the fact that expeditionary installations tend to be larger, produce more impacts, and be subjected to more environmental issues. Table 2 lists the range of possible scores by mission type.

Table 2. Possible sustainability score ranges by mission.

Mission	Score Ranges
Expeditionary Forces Facilities	135 – 675*
Training Facilities and Ranges	84 – 420
Industrial Facilities	92 – 460
Administrative Support Facilities	87 – 435

* Range determined by taking the sum of all weights (for a given mission) multiplied by 1 and then by 5.

4 Results

Regional Sustainability Scores

Figure 2 shows the resulting rankings of all 308 DoD installations' mission Vulnerability Scores for the regions, which ranged from 169 to 454.

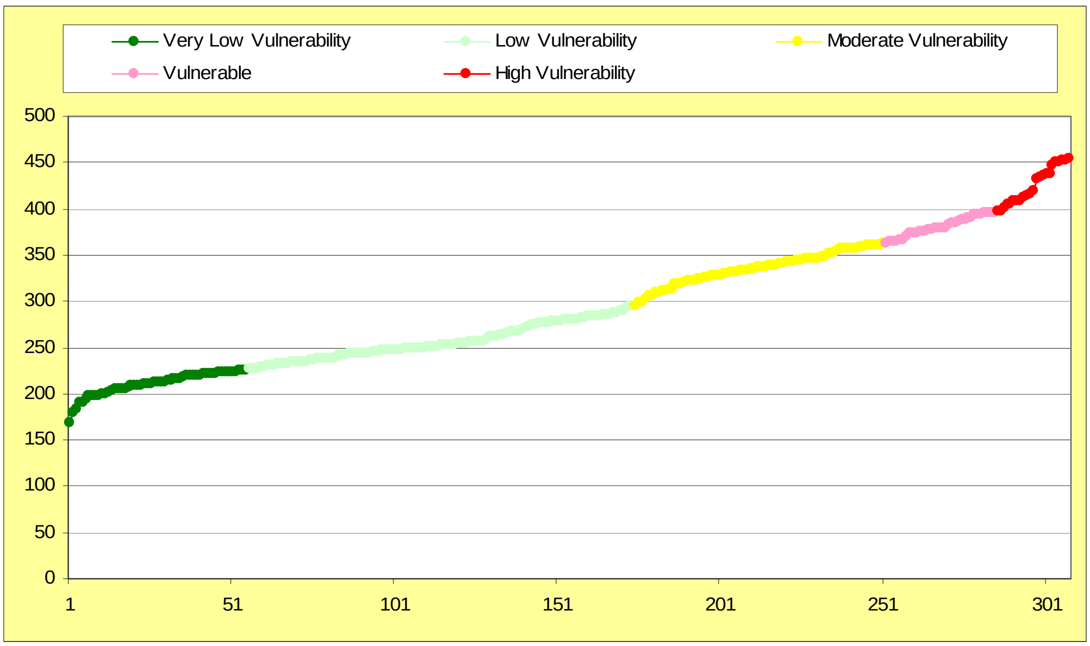


Figure 2. DoD vulnerability scores.

Possible overall sustainability scores range from 84 to 675, where 84 represents lowest vulnerability and 675 represents the maximum vulnerability. Table 3, below, lists the range of scores and their statistics. Table 4 lists the ranges for the various vulnerability classifications.

Table 3. Statistics of Scores.

Statistical Analysis	Score
Median	280
Average	294.2
Standard Deviation	68.1
Lowest Score	169
Highest Score	454

Table 4. Ranges of vulnerability based on statistics.

Vulnerability Range	Definition
Very Low Vulnerability	Less that 1 Std Dev below Mean (< 226.1)
Low Vulnerability	Between 1 Std Dev below Mean and Mean (226.1 – 294.2)
Moderate Vulnerability	Between 1 Std Dev above Mean and Mean (294.2 – 362.3)
Vulnerable	Between 1 Std Dev above Mean and 1.5 Std Dev above Mean (362.3 – 396.3)
High Vulnerability	Above 1.5 Std Dev above Mean (> 396.3)

Discussion

Installations with the highest vulnerability tended to be expeditionary installations located in or near large metropolitan areas or in either California or Hawaii. Installations in areas rated the least vulnerable tended to be non-expeditionary training or administrative facilities located in rural areas or settings in the lesser populated areas. Also, administrative and industrial facilities were not negatively impacted by being located in or near metropolitan areas.

All locations have some issues of sustainability creating vulnerabilities as shown by the fact that the lowest rating score was still significantly higher than the lowest possible score. Also, the highest scored region was a good deal less than the maximum possible score indicating that installation settings do vary and that not all of the indicators are high for any given location.

The range of scores was fairly linear across the range except for either extreme. The regions with the highest vulnerability have a fairly steep rise in scores, indicating that vulnerabilities were worsening en masse. The same is true for regions rated least vulnerable, the indicators tended to get much better as a whole.

5 Interpreting the Results

Scoring Implications

The vulnerability scores presented here represent a generic evaluation of the potential for encroachment issues and general sustainability of any given setting for a DoD installation. The ranking methodology is meant to be a screening tool. It is not a final, definitive evaluation of the sustainability of any given installation's location and region. Further detailed studies specific to an installation and its region are required. In other words, this study screened for certain issues and identified installations in regions where the set of indicators and mission weightings were considered to have potential problems.

For example, an installation may show poor water quality within its region and thus be rated high in terms of vulnerability. However, in practice the installation may use its own potable water system with its own sources—making its actual vulnerability rating to this issue of sustainability "low" instead of "high." The methodology of this report is exogenous to an installation and does not factor in site specific conditions. As a national level screening tool, the information represents entire counties, watersheds, and ecoregions and this data will not always agree with local data sources for specific towns or managed units within a county, watershed, or ecoregion.

There are trade-offs between using this standardized approach, which allows the use of national-level data to evaluate regional aspects of the installation setting, and one that uses installation specific data. The best recommendation is to examine the indicators that are most important and to seek additional information to better understand the rating. Any decision relevant to a specific installation or location should always be informed by more than SIRRA. This report (and appendixes) is a helpful screening tool that organizes these numerous exogenous sustainability data and provides relative characterizations of installations based on that information.

Understanding Options for Sustainment Mitigation

The characterization process results in a list of installations that may soon be experiencing or are already experiencing impacts on mission and readiness due to exogenous forces in the region. Any decision on how to proceed should be based on the characterization and any known sustainability issues endogenous to the installation. An installation facing sustainability encroachment issues has essentially five courses of action. Table 5 lists general guidelines for determining mitigation strategies for a given installation. Each progressive step of action includes the previous step, so, if step 5 is recommended, so are the actions in steps 2-4. The best sustainment mitigation strategy is often a combination of options.

Very Low Vulnerability: There are limited concerns, however, continuous monitoring is the recommended action for those installations rated as having a very low vulnerability. Indicators illustrate that the region and the installation mission are currently in fairly good harmony. This action includes a need to continue monitoring the installation and updating the sustainment assessment as new information is made available. Temporal changes in indicators will provide a measure of how the situation is evolving and, eventually, identify when "no action" is no longer viable.

Low Vulnerability: Installations that are experiencing select pressures and need immediate action in a selected sustainment issue may require mitigation in that particular issue. Examples of select pressures are U.S. Endangered Species Act (USESA) compliance, local community concerns, or a private landowner lawsuit.

Moderate Vulnerability: Installations characterized with moderate vulnerability may be struggling with some sustainability issues. They may require long-term efforts in regional planning that rely on external jurisdictions for enabling real change within the region. This action is valuable for building connections with neighbors, exposing positive installation efforts to the public, establishing zoning to ensure military compatible land uses, and awakening local area responsibility for ecosystem sustainability. Programs that support this action include Joint Land Use Studies (JLUS), USDA programs that keep farm land actively farming, and regional transportation studies and plans. In other words, moderately vulnerable installations should collaborate with local governments to ensure a future for both the installation and local communities.

Table 5. Vulnerability sustainment mitigation.

Vulnerability Score	Vulnerability Range	Interpretation of Scores
169 – 226	Very Low Vulnerability	Limited concerns; continue to monitor
226 – 294	Low Vulnerability	Concerns may require mitigation
294 – 362	Moderate Vulnerability	Concerns likely to require mitigation and proactive coordination with regional stakeholders
362 – 396	Vulnerable	Significant concern(s) to address and resolve
396 – 454	High Vulnerability	Many significant concerns to address and resolve

Vulnerable: Installations considered vulnerable should initiate an assessment of on-site activities for how they reach beyond the fence line, maximizing effective use of existing lands, and ensuring long-term sustainability. These are accomplished by characterizing the installation assets, understanding how those assets meet the current mission, and predicting what might be needed in the future. This action should generally be implemented at all installations, yet is recommended for those installations considered Vulnerable.

High Vulnerability: Installations classified as highly vulnerable should actively work with local governments to develop sustainable solutions for their region. This refers to controlling land use actions outside the fence through mechanisms such as conservation easements and land purchase. Other mitigations may include technology infusion, codes and standards, and market approaches. It assumes the potential for short-term, concrete action to mitigate severe on-post issues while the longer-term efforts are being negotiated. It should not be assumed that pursuing this option will *de facto* be beneficial. Success depends on sufficient understanding of the issues and the availability of appropriate off-post partners. It also depends on the ability to develop and implement mitigation strategies, the ability to identify suitable land for easement acquisition or other land control options, and that fact that these options must be affordable.

Using Appendix E

Appendix E is attached as a Microsoft Excel workspace (AppendixE.xls). The workspace provides the 54 individual, weighted indicator vulnerability scores, a total weighted issue area vulnerability score for the 10 issues, and the final weighted vulnerability scores for all 308 installations. As previously stated, the higher the score the more vulnerable the installation is considered or the more stress it incurs due to development and encroachment issues. The lower the score, the less vulnerable the installation is to environmental and key issue stresses. When opening Appendix E workspace, be certain that all macros remain enabled. Once open, the workspace contains two worksheets—MAIN Page and SIRRA Indicators. These are identifiable by tabs located in the bottom, left corner of the workspace.

The MAIN Page holds all weighted vulnerability scores. SIRRA Indicators is a reference worksheet. Users may refer to this worksheet for a quick reference of indicator identifiers, source, and data level (i.e., users may recollect that AQ1 represents Criteria Pollutant Non-Attainment data from the USEPA at the county level).

Appendix E provides users the ability to analytically identify potential sustainability problems for any given installation as well as view vulnerability ratings in relation to other installations. Data columns include installation name, state, service branch, MACOM, and mission; total weighted vulnerability score; and, individual issue area weighted vulnerability score. Check boxes located above the issue area column headings may be checked to reveal or unchecked to hide a break-down of individual indicator vulnerability scores. For example, checking the “AQ” box reveals AQ1 and AQ2 rating columns. Removing the checkmark collapses these columns. Users may sort the MAIN Page columns using the Microsoft Excel sort function for several analyses including a ranking of all installations by vulnerability score and a ranking of installations by state, branch, MACOM, mission, issue area, or indicator.

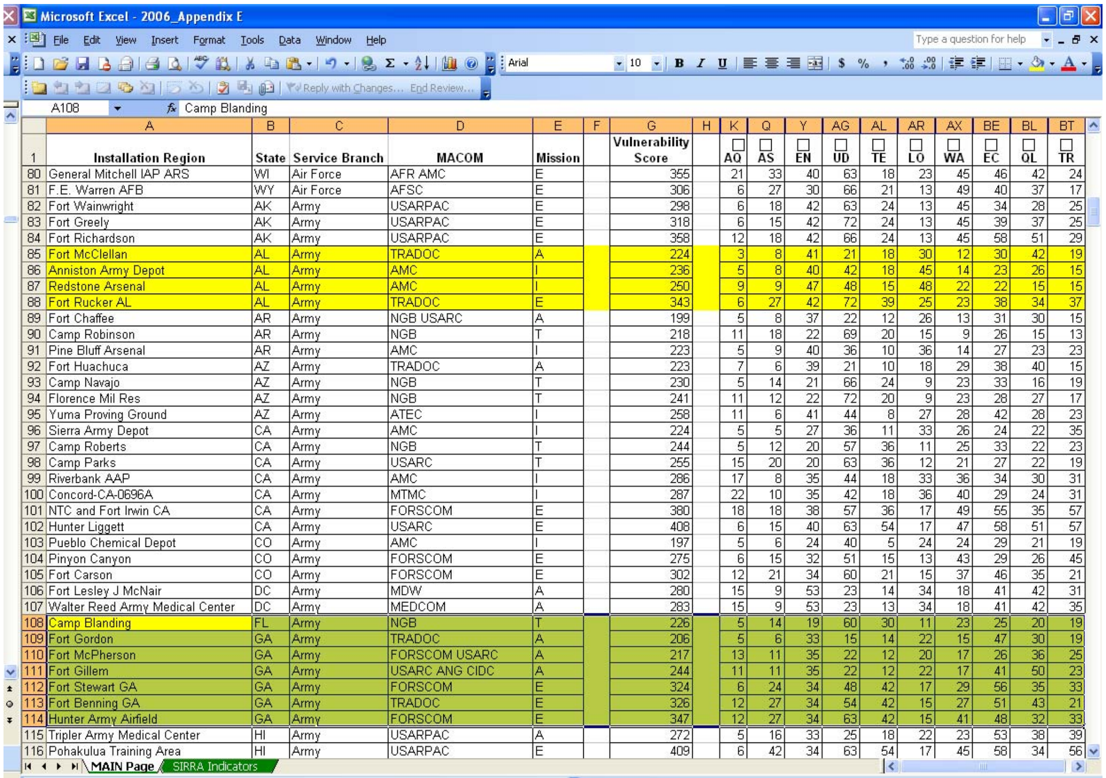
The “Vulnerability Scores” are the sum of all 54 indicator vulnerability scores weighted by mission. Individual issue area vulnerability scores are the sum of all indicators within that issue weighted by mission. Overall, these sustainability assessments are intended to be used as a screening tool to identify installations for which additional studies, planning, and actions may be recommended to ensure continued viability and sustainability. To go beyond this initial screening, users are advised to review the indicators that led to a high or low sustainability score and judge the score based on local knowledge. Example applications of the data follow.

Scenario 1

As an Army Forces Command planner, you are curious as to the viability of adding a training range to an existing installation located within the Southeast region of the United States (the Southeast region is defined by Alabama, Georgia, Florida, North Carolina, and South Carolina). You wish to identify Army installations in the Southeast capable of supporting an additional training range.

Step 1: Using the Microsoft Excel sorting function, sort the “MAIN Page” data by Service Branch (column C), then by State (column B), and then by Vulnerability Score (column G), in ascending order. (Figure 3)

These steps produce a grouping of Army installations by state and ranked by Vulnerability Scores. In other words, it becomes clear which Army installations have the lowest vulnerability ratings in each respective state.



	A	B	C	D	E	G	K	Q	Y	AG	AL	AR	AX	BE	BL	BT
1	Installation Region	State	Service Branch	MACOM	Mission	Vulnerability Score	AQ	AS	EN	UD	TE	LO	WA	EC	QL	TR
80	General Mitchell IAP ARS	WI	Air Force	AFR AMC	E	355	21	33	40	63	18	23	45	46	42	24
81	F.E. Warren AFB	WY	Air Force	AFSC	E	306	6	27	30	66	21	13	49	40	37	17
82	Fort Wainwright	AK	Army	USARPAC	E	298	6	18	42	63	24	13	45	34	28	25
83	Fort Greely	AK	Army	USARPAC	E	318	6	15	42	72	24	13	45	39	37	25
84	Fort Richardson	AK	Army	USARPAC	E	358	12	18	42	66	24	13	45	58	51	29
85	Fort McClellan	AL	Army	TRADOC	A	224	3	8	41	21	18	30	12	30	42	19
86	Anniston Army Depot	AL	Army	AMC	I	236	5	8	40	42	18	45	14	23	26	15
87	Redstone Arsenal	AL	Army	AMC	I	250	9	9	47	48	15	48	22	22	15	15
88	Fort Rucker AL	AL	Army	TRADOC	E	343	6	27	42	72	39	25	23	38	34	37
89	Fort Chaffee	AR	Army	NGB USARC	A	199	5	8	37	22	12	26	13	31	30	15
90	Camp Robinson	AR	Army	NGB	T	218	11	18	22	69	20	15	9	26	15	13
91	Pine Bluff Arsenal	AR	Army	AMC	I	223	5	9	40	36	10	36	14	27	23	23
92	Fort Huachuca	AZ	Army	TRADOC	A	223	7	6	39	21	10	18	29	38	40	15
93	Camp Navajo	AZ	Army	NGB	T	230	5	14	21	66	24	9	23	33	16	19
94	Florence Mil Res	AZ	Army	NGB	T	241	11	12	22	72	20	9	23	28	27	17
95	Yuma Proving Ground	AZ	Army	ATEC	I	258	11	6	41	44	8	27	28	42	28	23
96	Sierra Army Depot	CA	Army	AMC	I	224	5	5	27	36	11	33	26	24	22	35
97	Camp Roberts	CA	Army	NGB	T	244	5	12	20	57	36	11	25	33	22	23
98	Camp Parks	CA	Army	USARC	T	255	15	20	20	63	36	12	21	27	22	19
99	Riverbank AAP	CA	Army	AMC	I	286	17	8	35	44	18	33	36	34	30	31
100	Concord-CA-0696A	CA	Army	MTMC	I	287	22	10	35	42	18	36	40	29	24	31
101	NTC and Fort Irwin CA	CA	Army	FORSCOM	E	380	18	18	38	57	36	17	49	55	35	57
102	Hunter Liggett	CA	Army	USARC	E	408	6	15	40	63	54	17	47	58	51	57
103	Pueblo Chemical Depot	CO	Army	AMC	I	197	5	6	24	40	5	24	24	29	21	19
104	Pinyon Canyon	CO	Army	FORSCOM	E	275	6	15	32	51	15	13	43	29	26	45
105	Fort Carson	CO	Army	FORSCOM	E	302	12	21	34	60	21	15	37	46	35	21
106	Fort Lesley J McNair	DC	Army	MDW	A	280	15	9	53	23	14	34	18	41	42	31
107	Walter Reed Army Medical Center	DC	Army	MEDCOM	A	283	15	9	53	23	13	34	18	41	42	35
108	Camp Blanding	FL	Army	NGB	T	226	5	14	19	60	30	11	23	25	20	19
109	Fort Gordon	GA	Army	TRADOC	A	206	5	6	33	15	14	22	15	47	30	19
110	Fort McPherson	GA	Army	FORSCOM USARC	A	217	13	11	35	22	12	20	17	26	36	25
111	Fort Gillem	GA	Army	USARC ANG CIDC	A	244	11	11	35	22	12	22	17	41	50	23
112	Fort Stewart GA	GA	Army	FORSCOM	E	324	6	24	34	48	42	17	29	56	35	33
113	Fort Benning GA	GA	Army	TRADOC	E	326	12	27	34	54	42	15	27	51	43	21
114	Hunter Army Airfield	GA	Army	FORSCOM	E	347	12	27	34	63	42	15	41	48	32	33
115	Tripler Army Medical Center	HI	Army	USARPAC	A	272	5	16	33	25	18	22	23	53	38	39
116	Pohakulua Training Area	HI	Army	USARPAC	E	409	6	42	34	63	54	17	45	58	34	56

Figure 3. Screen capture of Appendix E resulting from Step 1 of Scenario 1. Army installations located in the southeast have been highlighted.

Step 2: Identify sustainability issue areas critical to a training mission.

The vulnerability rating is based on 10 issue areas weighted by current missions, yet, the relevance of an issue changes depending on the specific missions or functions of an installation. For example, a storage depot facility is impacted less by soldier quality of life issues and impacted more by transportation availability for the movement of its goods. A radar bomb scoring range is impacted greatly by air space and noise indicators and less by energy and water availability. Thus, it is necessary to acknowledge how critical issue areas were weighted according to the installation's current mission. For this example one should assume for the type of training being added, critical issue areas include AQ and QL (air quality and quality of life, respectively).

Step 3: Highlight installations within the Southeast region—Alabama, Georgia, Florida, North Carolina, and South Carolina —having a moderate vulnerability rating or better in all critical issue areas (e.g., 1, 2, or 3). Obtain vulnerability ratings by dividing indicator vulnerability scores by its respective weight. (e.g., divide AQ1 vulnerability scores by 3 for all expeditionary forces facilities, by 2 for all training facilities, etc.)

These installations include: Redstone Arsenal, AL.

Step 4: Review the indicators that led to a high or low sustainability score and interpret the score based on local knowledge.

The results of Step 3 identified one viable installation for the addition of a training range in the Southeast United States. Users are advised to review this result and interpret scores based on local knowledge. For example, Fort Benning, GA was eliminated primarily due to a poor threatened and endangered species (TE) rating. However, local knowledge reveals that Fort Benning is currently proactively addressing threatened and endangered species issues through participation in the SERDP Ecosystem Management Program (SEMP). In this instance the high TE vulnerability rating would be of less concern and the installation could be considered viable.

Scenario 2

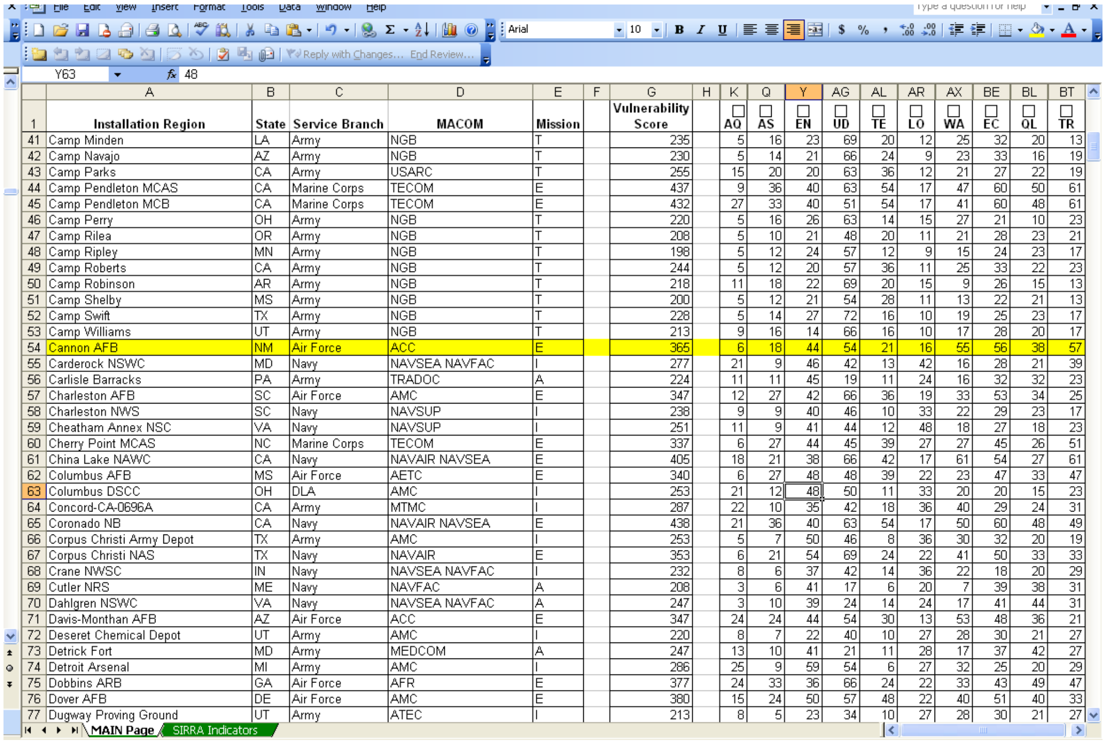
A realignment proposal has been made at Cannon AFB, NM, to relocate the 1st Armored Division, Artillery Brigade, Maneuver Battalion, Support Battalion, and Aviation Unit to Cannon AFB. You wish to ensure that the Cannon AFB region has sufficient infrastructure to support this proposal. You want to know if Cannon AFB can sustain the additional missions and if not, what actions need to be taken to ensure sustainability.

Step 1: Using Microsoft Excel sorting function, sort the MAIN Page data by Installation (column A) ascending alphabetically (Figure 4).

Cannon AFB should appear in row 54 and show a final vulnerability score of 365. A vulnerability score of 365 indicates that Cannon AFB is currently vulnerable to encroachment issues.

Step 2: Identify sustainability issues critical to the 1st Armored Division, Artillery Brigade, Maneuver Battalion, Support Battalion, and Aviation Unit missions.

Overall, Cannon AFB is vulnerable to encroachment issues. However, its most vulnerable issues may not be relevant to the proposed missions. It is necessary to assess whether “vulnerable” is the proper designation for Cannon AFB given its functions. The user should assume for the missions being added that critical issue areas include AS, EN, TE, WA, and TR (airspace, energy, threatened and endangered species, water, and transportation respectively).



1	Installation Region	State	Service Branch	MACOM	Mission	Vulnerability Score	AQ	AS	EN	UD	TE	LO	WA	EC	QL	TR
41	Camp Minden	LA	Army	NGB	T	235	5	16	23	69	20	12	25	32	20	13
42	Camp Navajo	AZ	Army	NGB	T	230	5	14	21	66	24	9	23	33	16	19
43	Camp Parks	CA	Army	USARC	T	255	15	20	20	63	36	12	21	27	22	19
44	Camp Pendleton MCAS	CA	Marine Corps	TECOM	E	437	9	36	40	63	54	17	47	60	50	61
45	Camp Pendleton MCB	CA	Marine Corps	TECOM	E	432	27	33	40	51	54	17	41	60	48	61
46	Camp Perry	OH	Army	NGB	T	220	5	16	26	63	14	15	27	21	10	23
47	Camp Rilea	OR	Army	NGB	T	208	5	10	21	48	20	11	21	28	23	21
48	Camp Ripley	MN	Army	NGB	T	198	5	12	24	57	12	9	15	24	23	17
49	Camp Roberts	CA	Army	NGB	T	244	5	12	20	57	36	11	25	33	22	23
50	Camp Robinson	AR	Army	NGB	T	218	11	18	22	69	20	15	9	26	15	13
51	Camp Shelby	MS	Army	NGB	T	200	5	12	21	54	28	11	13	22	21	13
52	Camp Swift	TX	Army	NGB	T	228	5	14	27	72	16	10	19	25	23	17
53	Camp Williams	UT	Army	NGB	T	213	9	16	14	66	16	10	17	28	20	17
54	Cannon AFB	NM	Air Force	ACC	E	365	6	18	44	54	21	16	55	56	38	57
55	Carderock NSWC	MD	Navy	NAVSEA NAVFAC	I	277	21	9	46	42	13	42	16	28	21	39
56	Carlisle Barracks	PA	Army	TRADOC	A	224	11	11	45	19	11	24	16	32	32	23
57	Charleston AFB	SC	Air Force	AMC	E	347	12	27	42	66	36	19	33	53	34	25
58	Charleston NWS	SC	Navy	NAVSUP	I	238	9	9	40	46	10	33	22	29	23	17
59	Cheatham Annex NSC	VA	Navy	NAVSUP	I	251	11	9	41	44	12	48	18	27	18	23
60	Cherry Point MCAS	NC	Marine Corps	TECOM	E	337	6	27	44	45	39	27	27	45	26	51
61	China Lake NAWC	CA	Navy	NAVAIR NAVSEA	E	405	18	21	38	66	42	17	61	54	27	61
62	Columbus AFB	MS	Air Force	AETC	E	340	6	27	48	48	39	22	23	47	33	47
63	Columbus DSCC	OH	DLA	AMC	I	253	21	12	48	50	11	33	20	20	15	23
64	Concord-CA-0696A	CA	Army	MTMC	I	287	22	10	35	42	18	36	40	29	24	31
65	Coronado NB	CA	Navy	NAVAIR NAVSEA	E	438	21	36	40	63	54	17	50	60	48	49
66	Corpus Christi Army Depot	TX	Army	AMC	I	253	5	7	50	46	8	36	30	32	20	19
67	Corpus Christi NAS	TX	Navy	NAVAIR	E	353	6	21	54	69	24	22	41	50	33	33
68	Crane NWSC	IN	Navy	NAVSEA NAVFAC	I	232	8	6	37	42	14	36	22	18	20	29
69	Cutler NRS	ME	Navy	NAVFAC	A	208	3	6	41	17	6	20	7	39	38	31
70	Dahlgren NSWC	VA	Navy	NAVSEA NAVFAC	A	247	3	10	39	24	14	24	17	41	44	31
71	Davis-Monthan AFB	AZ	Air Force	ACC	E	347	24	24	44	54	30	13	53	48	36	21
72	Deseret Chemical Depot	UT	Army	AMC	I	220	8	7	22	40	10	27	28	30	21	27
73	Detrick Fort	MD	Army	MEDCOM	A	247	13	10	41	21	11	28	17	37	42	27
74	Detroit Arsenal	MI	Army	AMC	I	286	25	9	59	54	6	27	32	25	20	29
75	Dobbins ARB	GA	Air Force	AFR	E	377	24	33	36	66	24	22	33	43	49	47
76	Dover AFB	DE	Air Force	AMC	E	380	15	24	50	57	48	22	40	51	40	33
77	Dugway Proving Ground	UT	Army	ATEC	I	213	8	5	23	34	10	27	28	30	21	27

Figure 4. Screen capture of Appendix E resulting from Step 1 of Scenario 2. Cannon AFB has been highlighted.

Step 3: Highlight the critical issues having a high (4) or very high (5) vulnerability rating (e.g., highlight if AS rates above 60, EN rates above 48, TE rates above 48, WA rates above 52, or TR rates above 68).

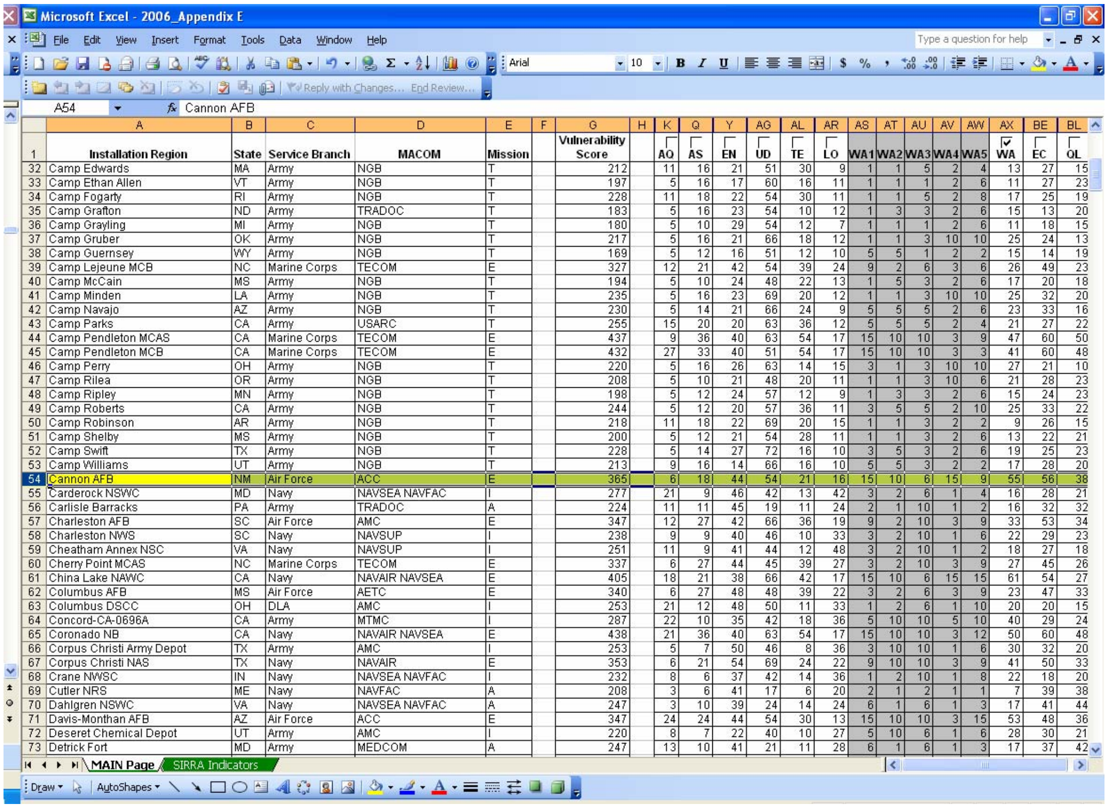
High vulnerability issue areas include water (WA).

Step 4: Check the column heading of WA issues. This opens individual indicator ratings for water issues. Next, highlight indicators having a high (4) or very high (5) vulnerability rating (e.g., highlight if WA1 rates above 12, WA2 rates above 8, WA3 rates above 8, WA4 rates above 12, or WA5 rates above 12) See Figure 5.

High vulnerability indicators include WA1 and WA2, and WA4 (level of development, groundwater depletion, and low flow sensitivity respectively).

Step 5: Review the indicators that led to a high or low sustainability score and interpret the score based on local knowledge.

The results of Step 4 identified water availability problems in the region that may conflict with the proposed additional missions and accompanying personnel.



	Installation Region	State	Service Branch	MACOM	Mission	Vulnerability Score	AQ	AS	EN	UD	TE	LO	WA1	WA2	WA3	WA4	WA5	WA	EC	QL
32	Camp Edwards	MA	Army	NGB	T	212	11	16	21	51	30	9	1	1	5	2	4	13	27	15
33	Camp Ethan Allen	VT	Army	NGB	T	197	5	16	17	60	16	11	1	1	1	2	6	11	27	23
34	Camp Fogarty	RI	Army	NGB	T	228	11	18	22	54	30	11	1	1	5	2	8	17	25	19
35	Camp Grafton	ND	Army	TRADOC	T	183	5	16	23	54	10	12	1	3	3	2	6	15	13	20
36	Camp Grayling	MI	Army	NGB	T	180	5	10	29	54	12	7	1	1	1	2	6	11	18	15
37	Camp Gruber	OK	Army	NGB	T	217	5	16	21	66	18	12	1	1	3	10	10	25	24	13
38	Camp Guernsey	WY	Army	NGB	T	169	5	12	16	51	12	10	5	5	1	2	2	15	14	19
39	Camp Lejeune MCB	NC	Marine Corps	TECOM	E	327	12	21	42	54	39	24	9	2	6	3	6	26	49	23
40	Camp McCain	MS	Army	NGB	T	194	5	10	24	48	22	13	1	5	3	2	6	17	20	18
41	Camp Minden	LA	Army	NGB	T	235	5	16	23	69	20	12	1	1	3	10	10	25	32	20
42	Camp Navajo	AZ	Army	NGB	T	230	5	14	21	66	24	9	5	5	5	2	6	23	33	16
43	Camp Parks	CA	Army	USARC	T	255	15	20	20	63	36	12	5	5	5	2	4	21	27	22
44	Camp Pendleton MCAS	CA	Marine Corps	TECOM	E	437	9	36	40	63	54	17	15	10	10	3	9	47	60	50
45	Camp Pendleton MCB	CA	Marine Corps	TECOM	E	432	27	33	40	51	54	17	15	10	10	3	3	41	60	48
46	Camp Perry	OH	Army	NGB	T	220	5	16	26	63	14	15	3	1	3	10	10	27	21	10
47	Camp Rilea	OR	Army	NGB	T	208	5	10	21	48	20	11	1	1	3	10	6	21	28	23
48	Camp Ripley	MN	Army	NGB	T	198	5	12	24	57	12	9	1	3	3	2	6	15	24	23
49	Camp Roberts	CA	Army	NGB	T	244	5	12	20	57	36	11	3	5	5	2	10	25	33	22
50	Camp Robinson	AR	Army	NGB	T	218	11	18	22	69	20	15	1	1	3	2	2	9	26	15
51	Camp Shelby	MS	Army	NGB	T	200	5	12	21	54	28	11	1	1	3	2	6	13	22	21
52	Camp Swift	TX	Army	NGB	T	228	5	14	27	72	16	10	3	5	3	2	6	19	25	23
53	Camp Williams	UT	Army	NGB	T	213	9	16	14	66	16	10	5	5	3	2	2	17	28	20
54	Cannon AFB	NM	Air Force	ACC	E	365	6	18	44	54	21	16	15	10	6	15	9	55	56	38
55	Carderock NSWC	MD	Navy	NAVSEA NAVFAC	I	277	21	9	46	42	13	42	3	2	6	1	4	16	28	21
56	Carlisle Barracks	PA	Army	TRADOC	A	224	11	11	45	19	11	24	2	1	10	1	2	16	32	32
57	Charleston AFB	SC	Air Force	AMC	E	347	12	27	42	66	36	19	9	2	10	3	9	33	53	34
58	Charleston NWS	SC	Navy	NAVSUP	I	238	9	9	40	46	10	33	3	2	10	1	6	22	29	23
59	Cheatham Annex NSC	VA	Navy	NAVSUP	I	251	11	9	41	44	12	48	3	2	10	1	2	18	27	18
60	Cherry Point MCAS	NC	Marine Corps	TECOM	E	337	6	27	44	45	39	27	3	2	10	3	9	27	45	26
61	China Lake NAWC	CA	Navy	NAVAIR NAVSEA	E	405	18	21	38	66	42	17	15	10	6	15	15	61	54	27
62	Columbus AFB	MS	Air Force	AETC	E	340	6	27	48	48	39	22	3	2	6	3	9	23	47	33
63	Columbus DSCC	OH	DLA	AMC	I	253	21	12	48	50	11	33	1	2	6	1	10	20	20	15
64	Concord-CA-0696A	CA	Army	MTMC	I	287	22	10	35	42	18	36	5	10	10	5	10	40	29	24
65	Coronado NB	CA	Navy	NAVAIR NAVSEA	E	438	21	36	40	63	54	17	15	10	10	3	12	50	60	48
66	Corpus Christi Army Depot	TX	Army	AMC	I	253	5	7	50	46	8	36	3	10	10	1	6	30	32	20
67	Corpus Christi NAS	TX	Navy	NAVAIR	E	353	6	21	54	69	24	22	9	10	10	3	9	41	50	33
68	Crane NWSC	IN	Navy	NAVSEA NAVFAC	I	232	8	6	37	42	14	36	1	2	10	1	8	22	18	20
69	Cutler NRS	ME	Navy	NAVFAC	A	208	3	6	41	17	6	20	2	1	2	1	1	7	39	38
70	Dahlgren NSWC	VA	Navy	NAVSEA NAVFAC	A	247	3	10	39	24	14	24	6	1	6	1	3	17	41	44
71	Davis-Monthan AFB	AZ	Air Force	ACC	E	347	24	24	44	54	30	13	15	10	10	3	15	53	48	36
72	Deseret Chemical Depot	UT	Army	AMC	I	220	8	7	22	40	10	27	5	10	6	1	6	28	30	21
73	Detrick Fort	MD	Army	MEDCOM	A	247	13	10	41	21	11	28	6	1	6	1	3	17	37	42

Figure 5. Screen Capture of Appendix E resulting from Step 4 of Scenario 2. Cannon AFB has been highlighted and water indicators are displayed.

To ensure sustainability, actions addressing water availability need to be taken. Further analysis will be required to determine the extent of vulnerability that these indicators pose to Cannon AFB sustainability under the proposed realignment. This analysis results in identifying *possible* conflicts. It does not provide installation-specific assessments. For example, the scenario identifies ground water sources within the watershed as insufficient. However, it does not know if Cannon AFB uses its own water source; that would decrease the relevance of this rating. Use of local knowledge and understanding of indicator measures (found in indicator metadata) are critical to the application of this analysis.

6 Conclusions

The outcome of using the SIRRA methodology to rank DoD installation regions has provided a prioritized list of installations that require further analysis and evaluation. Of the 308 installations included in the analysis, the results indicate that 57 (about 19 percent) of the installations are located in regions that are Vulnerable or have High Vulnerability. Another 77 of the installations were located in regions rated as Moderately Vulnerable. The remaining 174 (56 percent) of the installations were located in regions rated as having Low or Very Low Vulnerability.

This use of the SIRRA tool demonstrates how a Web-based decision support framework can be applied to regions surrounding military installations. This approach used the SIRRA information, databases, and index models coupled with GIS capabilities for system-wide assessments. This specialized application of SIRRA added an indicator weighting scheme, based on the installation mission, to the methodology extant on the SIRRA web-based analysis tool. This report represents the first tier of a multi-tiered approach that allows use of various levels of models and tools based on scientific needs, user ability, and available resources. The framework supports decisionmaking flexibly, allowing individual applications of the information.

The SIRRA methodology allows USACE Division and District planners and project managers, regulators, and operation and maintenance managers involved with system-wide studies such as installation studies, ecosystem restoration, and resource reallocation studies to obtain a first-cut evaluation of an installation using national data sets. SIRRA provides an assessment tool for the U.S. Army Corps of Engineers that contains a significant new capability to apply national data sets in an installation context that addresses sustainability support to the military mission on a regional scale. It provides data and analysis to support efforts toward sustainable management of national resources. The SIRRA-based installation analysis capability provides an information link that increases the effectiveness of partnering with other agencies and private stakeholders. The installation-based screening tool may also reduce costs associated with determining installations that need further study.

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Acronyms and Abbreviations

Term	Spellout
AADT	Annual Average Daily Traffic per Lane
AEC	U.S. Army Environmental Center
AFB	Air Force Base
ANSI	American National Standards Institute
APA	American Planning Association
AVMT	annual vehicle miles traveled
CERL	Construction Engineering Research Laboratory
CO	carbon monoxide
DA	Department of the Army
DC	direct current
DO	Dissolved Oxygen
DoD	Department of Defense
DOI	Department of Interior
EIA	Energy Information Administration
EO	Executive Order
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ES	Electrical System
ESRI	Environmental Systems Research Institute, Inc.
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHA	Federal Housing Authority
FHWA	Federal Highway Administration
FY	fiscal year
GIS	geographic information system
HQ	headquarters
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HUC	hydrologic unit code
ID	Identification
IRRIS	Intelligent Road/Rail Information Server
ITC	Installation Training Capacity
JAWRA	Journal of American Water Resources Association
JLUS	Joint Land Use Study
MSA	Metropolitan Statistical Areas
NAAQS	National Attainment Air Quality Standards
NACJD	National Archive of Criminal Justice Data
NAVFAC	Naval Facilities Engineering Command
NEMIS	National Emergency Management Information System
NERC	North American Electricity Reliability Council
NLCD	National Land Use Data

Term	Spellout
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NWS	National Weather Service
OCE	Office of the Chief of Engineers
OMB	Office of Management and Budget
ORD	Operational Requirements Document
PDF	Portable Document Format
PM	particulate matter
PO	purchase order
QOL	Quality of Life
RCI	Roadway Congestion Index
RDTE	Research, Development, Test, and Evaluation
REIS	U.S. Department of Commerce, Bureau of Economic Analysis
SAR	Search and Rescue
SERM	Sustainability, Environment, and Room to Maneuver
SI	Systeme Internationale
SIRRA	Sustainable Installations Regional Resource Assessment
SR	Special Report
SWWRP	System-Wide Water Resources Program
TAF	Terminal Aerodrome Forecasts
TES	threatened and endangered species
TNC	The Nature Conservancy
TR	Technical Report
TTI	Travel Time Index
URL	Universal Resource Locator
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center
USC	United States Code
USCB	U.S. Census Bureau
USDOA	U.S. Department of Agriculture
USDOC	U.S. Department of Commerce
USDOE	U.S. Department of Energy
USDOI	U.S. Department of the Interior
USDOJ	U.S. Department of Justice
USDOL	U.S. Department of Labor
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USESA	U.S. Endangered Species Act
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WWW	World Wide Web

Appendix A: SIRRA Metadata

Contents

Sustainability Issue: Air Quality

Indicator: **Criteria Pollutant Non-Attainment (AQ1)**
Variables: Six Principal Air Pollutants (also referred to as criteria pollutants): Nitrogen Dioxide (NO_2), Ozone (O_3), Sulfur Dioxide (SO_2), Particulate Matter (PM), Carbon Monoxide (CO), and Lead (Pb)
Scale: County
Year: 2004
Data Sources:

USEPA. (2005). *Green Book Nonattainment Areas for Criteria Pollutants.* Office of Air and Radiation/Office of Air Quality Planning and Standards. Washington, DC. (Nonattainment Status for Each County by Year), available through URL: http://www.epa.gov/oar/oaqps/greenbk/anay.html

USEPA. (2004). *The Particle Pollution Report: Current Understanding of Air Quality and Emissions through 2003.* Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division. Washington, DC, available through URL: http://www.epa.gov/airtrends/

Logic: The Clean Air Act provides the principal framework for national, state, tribal, and local efforts to protect air quality. Under the Clean Air Act, EPA establishes air quality standards to protect public health by setting National Attainment Air Quality Standards (NAAQS) for the six principal pollutants that are considered harmful to public health and the environment and ensuring that these air quality standards are met (in cooperation with the state, tribal, and local governments) through national standards and strategies to control air pollutant emissions from vehicles, factories, and other sources (USEPA 2004). EPA has set national air quality standards for six principal air pollutants (also referred to as criteria pollutants): nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), and lead (Pb). Four of these pollutants (CO, Pb, NO_2, and SO_2) result primarily from direct emissions from a variety of sources. PM results from direct emissions, but is also commonly formed when emissions of nitrogen oxides (NOx), sulfur oxides (SOx), ammonia, organic compounds, and other gases react in the atmosphere. Ozone is not directly emitted but is formed when NOx and volatile organic compounds (VOCs) react in the presence of sunlight (USEPA 2004).

EPA tracks trends in air quality based on actual measurements of pollutant concentrations in the ambient (outside) air at monitoring sites across the country. State, tribal, and local government agencies as well as some Federal agencies, including the EPA, operate monitoring stations.

Air quality is important to military operations in non-attainment areas of EPA ambient air quality. The standards for the six criterion pollutants will have added restrictions on emissions from military operations. Gaining compliance for these regulations may cause financial strain on the DoD. Being located in a nonattainment zone is a strong indicator that the military may face restrictions on the amounts of certain emissions they can release (including mobility emissions) as part of the region's plan for coming into attainment. Information concerning what affects each criterion is available from the EPA at http://www.epa.gov. In summary, each criterion is vulnerable to change. Thus, the data should be updated regularly and the age of the data should be carefully noted in any analysis.

Additionally, the data reflects county level data where different values are reported for the same county in the same year in some cases. Thus, knowledge of the local area and its efforts need to be considered especially in large acreage counties.

Replicable: Each year EPA examines changes in levels of these ambient pollutants and their precursor emissions over time and summarizes the current air pollution status (USEPA 2005). The updates are available for download at:

http://www.epa.gov/air/oaqps/greenbk/anay.html.

Directions: Download *NonAttainment Status for Each County by Year* for all U.S. counties from the EPA Green Book at http://www.epa.gov/air/oaqps/greenbk/anay.html (EPA 2005). Import the *Classification* data into a GIS program and join it with county boundary files to create a GIS air quality attainment status indicator layer.

Indicator Measure: Emission status indicates whether or not a U.S. County is in attainment of EPA air quality emission standards for the six criteria pollutants. The EPA designates a classification rating for each criteria depending on the non-attainment status—extreme, severe, serious, moderate, marginal, primary, subpart 1, and section 185A (USEPA 2005). Different values may be reported for the same county in the same year in some cases. In this case, the worst value is indicated (USEPA 2004).

The emission ratings were grouped into the following classifications.

Very Low Vulnerability	(1):	Attainment
Low Vulnerability	(2):	Primary, Section 185A, Subpart 1, Incomplete Data, Not Classified, and Other Violations
Moderate Vulnerability	(3):	Marginal and Moderate Violations
Vulnerable	(4):	Serious and Severe Violations
High Vulnerability	(5):	Non-attainment and Extreme Violations

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the region around the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Region Around Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Noise Sensitivity (AQ2)**
Variables: Environmental Noise Sensitivity
Scale: Installation
Year: 2000
Data Sources:

U.S. Bureau of the Census, Department of Commerce. (2000). *Incorporated Places/Census Designated Places*. Compiled and edited by Geography Division. Washington, DC, available through URL: http://www.census.gov/geo/www/cob/pl2000.html

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Logic: Lower noise levels will result in improved quality of life for both military personnel and the residents of the region surrounding military installations. Fewer noise problems helps to ensure that military personnel are well-trained, will remain in the military, and will be able to carry out missions with greater effectiveness and reduced losses. The training and testing capability impacts include loss of training hours, rescheduling training and testing, modifying training procedures, and the consequences of inadequate training. An effective and proactive noise management program greatly improves effective military operations as well as relations with the surrounding community (USDA 2002).

The U.S. military has articulated goals of: (1) protecting the ability of personnel to train as they fight by working to limit civilian encroachment into areas exposed to high levels of military noise; (2) protecting people who live near military training areas from unhealthy levels of noise from military operations; and (3) protecting military families.

Every installation has its own style of keeping noise complaint logs, and there is no central repository—making it difficult to track noise complaints by installation. Noise researchers often generate noise contours surrounding a noise source to spatially represent noise levels (Westervelt 2004). A method similar to this is used to characterize noise sensitivity. Yet, this method may not easily be used to explore circumstance patterns. Missing from this data is the situational patterns that affect noise. For instance, topography, climate, community activity, and community value all impact noise—large mountains or buildings absorb sounds, high humidity slows the travel of sound, additional noises tend to go unnoticed or are "blocked-out" in high sound areas, social contexts react differently to differing sound types, etc. Therefore small noises may generate a big impact and large noises may generate no complaints depending on the surrounding environment. Because of these concerns, it is important to use local knowledge and applicable supplemental analysis in interpreting the noise sensitivity classifications for a particular environment.

Replicable: It is recognized that noise complaints have a direct relationship with population concentrations. Theoretically, noise complaints have a greater chance of occurring near civilian development. Any section of an installation located within or near a civilian population is considered sensitive or vulnerable to noise complaints. Therefore, this indicator may be updated every 10 years as the U.S. Census updates the *Incorporated Places/Census Designated Places* GIS compatible maps available online at http://www.census.gov/geo/www/cob/pl2000.html

Directions: Download *Incorporated Places/Census Designated Places* GIS compatible shapefile for all of the United States from the U.S. Census Bureau at http://www.census.gov/geo/www/cob/pl2000.html. Note, the U.S. Census makes no population requirements for incorporated or designated places—all populations are indicated within the shapefile. Make sure the average population per square mile is attached in the attribute table of each place. Import the data into a GIS program and create 3-mile buffers around all places. Join the place and buffer shapefiles with installation boundary files to create a GIS noise sensitivity indicator layer.

Indicator Measure: Because military installations are often of a significant size, what goes on within one area of the installation may not affect what goes on within another area. Thus, only the area of the installation located in or within 3 miles of an incorporated or designated place is classified as noise sensitive. As noted earlier, the size of the population affected also makes a difference. Therefore, the installation area in or within 3 miles of an incorporated or designated place is multiplied by the population per square mile of the specified place. The result is an estimated population affected by possible installation generated noise. The following vulnerability thresholds were defined under expert guidance from Army Corps of Engineers, Construction Engineering Research Laboratory (CERL).

Very Low Vulnerability	(1):	<=50,000 affected persons
Low Vulnerability	(2):	>50,000-<=100,000 affected persons
Moderate Vulnerability	(3):	>100,000-<=150,000 affected persons
Vulnerable	(4):	>150,000-<=200,000 affected persons
High Vulnerability	(5):	>200,000 affected persons

Rules: Installations are possibly located within 3 miles of two or more incorporated or designated places. Therefore, the estimated population sensitive to noise is calculated on each place and summed to establish a total estimated population sensitive to noise. The total estimated population sensitive to noise is then subject to the same metric noted above.

Sustainability Issue: Airspace

Indicator: **Proximity to Special Use Airspace, Fighter Range (AS1)**
Variables: Warning Area, Military Operations Area, Restricted Area, and Controlled Firing Area Special Use Airspace (SUA)
Scale: Installation
Year: 2005
Data Sources:

U.S. Air Force. (2005). *Air Force Link. Factsheets: Aircraft*. Washington, DC
http://www.af.mil/factsheets/

Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation. (2002). *Safety Advisor, Regulation No. 1*. Frederick, MD
http://www.aopa.org/asf/publications/sa02.pdf

Digital Aeronautical Flight Information File (DAFIF), National Imagery and Mapping Agency. (2005). *DAFIF Edition 6*. Bethesda, MD
https://164.214.2.62/products/digitalaero/index.cfm

Logic: Airspace structure is complex. The Federal Aviation Administration regulates aircraft based on altitudes as well as through the development of special use airspace (SUA). SUAs were developed to advise pilots of an activity or surface area that dictates special rules or notices and may possibly be hazardous. There are five main types of SUAs (prohibited areas, restricted areas, warning areas, military operations areas, and alert areas) and several secondary types (national security areas, military training routes, air defense identification zones, controlled firing areas, local airport advisory areas, and parachute jump areas). Descriptions of commonly referred to SUAs follow (AOPA 2002).

Prohibited areas are established for security reasons or for national welfare. They are permanently "off limits." An example of a prohibited area is the White House, or Camp David.

Restricted areas, though not entirely prohibited to flight activity, are areas in which unauthorized penetration is not only illegal, but also extremely dangerous. Restricted areas generally contain operations that do not mix well with aircraft such as artillery firing, guided missiles, or aerial gunnery.

Warning areas are airspace over domestic or international water that extend beyond shore. Warning areas are advisory in nature and alert pilots that they may be entering areas of hazardous activity.

Military operations areas (MOA) separate high-speed military traffic from other traffic. Although no one is prohibited from entering MOAs, they are cautioned to keep a watchful eye out for military operations such as aerial refueling, air combat training, and formation flying.

Alert areas are airspace in which an unusual type of aerial activity or dense pilot training takes place. They advise pilots of possible aerial conflicts, but have no special rules.

National security areas are established over areas that require increase security.

Military training routes are one-way high-speed routes for military traffic.

Controlled firing areas allow military activity such as artillery fire that is suspended when radar detects approaching aircraft.

SUAs primarily used by the military include warning areas, MOAs, restricted areas, and controlled firing areas. This indicator provides a measurement of special use airspace available to fighter aircraft. Availability is measured by the aircrafts unrefueling range as defined by the U.S. Air Force (Air Force 2005). Having available airspace is typically a necessity for military training. If access is inadequate, then it is a strong indicator of pressures on the future use and vulnerability of airspace, leading to greater demands and limitations on military development and missions. This would then place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

It is important to note that although this indicator describes availability of fighter aircraft training airspace, not all installations make use of training airspace. Ideally, installations are prepared for transformations to any mission. However, it may not be realistic. It is important to use local knowledge of an installation's current and future mission requirements when interpreting this indicator.

Replicable: This indicator could be replicated annually based on information updated in the DAFIF System (DAFIF 2005).

Directions: Download the SUA file from the DAFIF System at https://164.214.2.62/products/digitalaero/index.cfm (DAFIF 2005). This file includes boundary files for six SUA designations—warning (W), military operation (M), alert (A), restricted (R), prohibited (P), controlled firing area, and national security (T). Delete prohibited, alert, and national security SUAs for the purposes of this indicator. Import the remaining SUA boundary files into a GIS program to create a Proximity to Special Use Airspace, Fighter Range indicator layer. Create buffers at 35, 70, 105, and 140 mile intervals around the SUAs to form vulnerability-rating classifications.

Indicator Measure: This indicator provides insight into an installation's fighter aircraft SUA access. Classifications were defined based on fighter aircraft capabilities as recommended by Air Force Headquarters (Air Force 2005).

Very Low Vulnerability	(1):	Within a designated SUA or Within 35 miles of a SUA
Low Vulnerability	(2):	Greater than 35 miles but Less than 70 miles of a SUA
Moderate Vulnerability	(3):	Greater than 70 miles but Less than 105 miles of a SUA
Vulnerable	(4):	Greater than 105 miles but Less than 140 miles of a SUA
High Vulnerability	(5):	Greater than 140 miles of a SUA

Rules: Installations typically have only one SUA located within 35 to 140 miles. However, several installations do have two or more SUAs located within 35 to 140 miles. In this instance, the region around an installation takes on the SUA classification of the lowest vulnerability. For instance, if an installation has an SUA located within 35 miles and another SUA located within 105 miles, the region would be classified as very low vulnerability.

Indicator: **Proximity to Special Use Airspace, Bomber Range (AS2)**
Variables: Warning Areas, Military Operations Areas, Restricted Areas, and Controlled Firing Area Special Use Airspace (SUA)
Scale: Installation
Year: 2005
Data Sources:

U.S. Air Force. (2005). *Air Force Link. Factsheets: Aircraft*. Washington, DC, available through URL: http://www.af.mil/factsheets/

Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation. (2002). *Safety Advisor, Regulation No. 1*. Frederick, MD, available through URL: http://www.aopa.org/asf/publications/sa02.pdf

Digital Aeronautical Flight Information File (DAFIF), National Imagery and Mapping Agency. (2005). *DAFIF Edition 6*. Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm.

Logic: Airspace structure is complex. The Federal Aviation Administration regulates aircraft based on altitudes as well as through the development of special use airspace (SUA). SUAs were developed to advise pilots of an activity or surface area that dictates special rules or notices and may possibly be hazardous. There are five main types of SUAs (prohibited areas, restricted areas, warning areas, military operations areas, and alert areas) and several secondary types (national security areas, military training routes, air defense identification zones, controlled firing areas, local airport advisory areas, and parachute jump areas). Descriptions of commonly referred to SUAs follow (AOPA 2002).

Prohibited areas are established for security reasons or for national welfare. They are permanently “off limits.” An example of a prohibited area is the White House, or Camp David.

Restricted areas, though not entirely prohibited to flight activity, are areas in which unauthorized penetration is not only illegal, but also extremely dangerous. Restricted areas generally contain operations that do not mix well with aircraft such as artillery firing, guided missiles, or aerial gunnery.

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SUAs primarily used by the military include warning areas, MOAs, restricted areas, and controlled firing areas. This indicator provides a measurement of special use airspace available to bomber aircraft. Availability is measured by the aircrafts unrefueling range as defined by the U.S. Air Force (Air Force 2005). Having available airspace is typically a necessity for military training. If access is inadequate, then it is a strong indicator of pressures on the future use and vulnerability of airspace, leading to greater demands and limitations on military development and missions.

This would then place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

It is important to note that although this indicator describes availability of bomber aircraft training airspace, not all installations make use of training airspace. Ideally, installations are prepared for transformations to any mission. However, it may not be realistic. It is important to use local knowledge of an installation's current and future mission requirements when interpreting this indicator.

Replicable: This indicator could be replicated annually based on information updated in the DAFIF System (DAFIF 2005).

Directions: Download the SUA file from the DAFIF System (DAFIF 2005)at https://164.214.2.62/products/digitalaero/index.cfm. This file includes boundary files for six SUA designations—warning (W), military operation (M), alert (A), restricted (R), prohibited (P), controlled firing area, and national security (T). Delete prohibited, alert, and national security SUAs for the purposes of this indicator. Import the remaining SUA boundary files into a GIS program to create a Proximity to Special Use Airspace, Bomber Range indicator layer. Create buffers at 70, 140, 210, and 280 mile intervals around the SUAs to form vulnerability-rating classifications.

Indicator Measure: This indicator provides insight into an installation's bomber aircraft SUA access. Classifications were defined based on bomber aircraft capabilities as recommended by Air Force Headquarters (Air Force 2005).

Very Low Vulnerability	(1):	Within a designated SUA or Within 70 miles of a SUA
Low Vulnerability	(2):	Greater than 70 miles but Less than 140 miles of a SUA
Moderate Vulnerability	(3):	Greater than 140 miles but Less than 210 miles of a SUA
Vulnerable	(4):	Greater than 210 miles but Less than 280 miles of a SUA
High Vulnerability	(5):	Greater than 280 miles of a SUA

Rules: Installations typically have only one SUA located within 70 to 280 miles. However, several installations do have two or more SUAs located within 70 to 280 miles. In this instance, the region around an installation takes on the SUA classification of the lowest vulnerability. For instance, if an installation has an SUA located within 70 miles and another SUA located within 210 miles, the region would be classified as very low vulnerability.

Indicator: **Terminal Airspace (AS3)**
Variables: Terminal Airspace
Scale: Installation
Year: 2005
Data Source:

Digital Aeronautical Flight Information File (DAFIF), National Imagery and Mapping Agency. (2005). *DAFIF Edition 6*. Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm

Logic: This indicator provides a measurement of the quantity of terminal airspace within 20 miles of a military installation. Terminal airspace is airspace in which approach-control service or airport traffic control service regulates all traffic. In addition to the burden of coordinating traffic routes with one or more traffic controller, terminal airspaces are increasingly experiencing congestion problems due to increased traffic demands induced, for example, by the deregulation of the air transport industry. Congestion problems may arise from arrival/departure overloads, frequency of en route aircraft, or simply inadequate coordination.

Having available airspace is typically a necessity for military shipments, mobilization, and training. Inadequate access places the installation in a vulnerable state, affecting mobilization or, possibly, the type and intensity of training that could take place. Therefore, terminal airspace is considered an important encroachment indicator.

Although travel through any terminal airspace requires approval, not all terminal airspaces will impose restrictions on an installations desired traffic route. Depending on the time and altitude of military aircraft as well as the time and altitude of airport operations, the two may rarely conflict. Thus, it is important to use local knowledge when interpreting the impact of terminal airspace.

Replicable: This indicator could be replicated annually based on information updated in the DAFIF System (DAFIF 2005).

Directions: Download the Airspace Boundary file from the DAFIF System at https://164.214.2.62/products/digitalaero/index.cfm (DAFIF 2005). This file includes boundary files for airspace designations. Import the terminal airspace boundary files into a GIS program. In the same GIS workspace, create 20-mile buffers around each installation. Intersect the terminal airspace boundaries with the installation buffers. Calculate the percentage of terminal airspace located within 20 miles of each installation. Use this percentage to form vulnerability-rating classifications.

Indicator Measure: This indicator provides insight into an installation's airspace accessibility. It is assumed that an installation's proximity to terminal airspace may restrict military shipments, mobilization, and training. Classifications were defined based on statistical analysis of the standard deviation (23.06) around the national average (15.34 percent). 135 of the 402 installations analyzed had no terminal airspace within 20 miles of the installation.

Very Low Vulnerability	(1):	0 percent Terminal Airspace within 20 miles of the installation boundary
Low Vulnerability	(2):	> 0 - <=15.34 percent Terminal Airspace within 20 miles of the installation boundary
Moderate Vulnerability	(3):	>15.34 - <=38.4 percent Terminal Airspace within 20 miles of the installation boundary
Vulnerable	(4):	>38.4 - <=61.46 percent Terminal Airspace within 20 miles of the installation boundary
High Vulnerability	(5):	>61.46 percent Terminal Airspace within 20 miles of the installation boundary

Rules: Since this data is collected by installation, there is no calculation to determine installation risk ratings.

Indicator: **Proximity to Military Training Routes, Fighter Range (AS4)**
Variables: Military Training Routes (MTR) Primary and Alternate Entry and Exit points
Scale: Installation
Year: 2005
Data Sources:

U.S. Air Force. (2005). *Air Force Link. Factsheets: Aircraft*. Washington, DC, available through URL: http://www.af.mil/factsheets/

U.S. Air Force. (2005). Air Force Link. Factsheets: Low-Altitude Flying Training. Washington, DC, available through URL: http://www.af.mil/factsheets/factsheet.asp?fsID=183

Digital Aeronautical Flight Information File (DAFIF), National Imagery and Mapping Agency. (2005). *DAFIF Edition 6*. Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm

Logic: National security depends largely on the deterrent effect of our airborne military forces. To be proficient, the military services must train in a wide range of airborne tactics. One phase of this training involves "low level" combat tactics. The required maneuvers and high speeds are such that they may occasionally make the avoid aspect of flight more difficult without increased vigilance in areas containing such operations. In an effort to ensure the greatest practical level of safety for all flight operations, the Military Training Route (MTR) was conceived.

The MTR program is a joint venture by the Federal Aviation Administration and the Department of Defense. MTRs are mutually developed for use by the military for the purpose of conducting low-altitude, high-speed training. Generally, MTRs are established below 10,000 ft (mean sea level) for operations at speeds in excess of 250 knots (Air Force 2005). However, route segments may be defined at higher altitudes for purposes of route continuity. For example, route segments may be defined for descent, climb-out, and mountainous terrain.

This indicator provides a measurement of MTR airspace available to fighter aircraft. Availability is measured by the aircrafts un-refueling range as defined by the U.S. Air Force (Air Force 2005). Having available airspace is typically a necessity for military training. Inadequate access is a strong indicator of limitations on military development and missions. This would then place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

It is important to note that although this indicator describes availability of fighter aircraft MTRs, not all installations make use of training airspace. Ideally, installations are prepared for transformations to any mission. However, it may not be realistic. It is important to use local knowledge of an installation's current and future mission requirements when interpreting this indicator.

Replicable: This indicator could be replicated annually based on information updated in the DAFIF System (DAFIF 2005).

Directions: Download the *MTR: Routes, Polylines, Entry/Exit Points, and Points* file from the DAFIF System at https://164.214.2.62/products/digitalaero/index.cfm (DAFIF 2005). Import all points designated as "A" Alternate Entry Point, "B" Alternate Exit Point, "C" Alternate Entry/Exit Point, "S" Primary Entry Point, and "X" Primary Exit Point for all kinds of flying routes ("VR" Visual Route, "IR" Instrument Route, and "SR" Slow Route) into a GIS program to create a Proximity to Military Training Routes, Fighter Range indicator layer. Create buffers at 35, 70, 105, and 140 mile intervals around all points to form vulnerability-rating classifications.

Indicator Measure: This indicator provides insight into an installation's fighter aircraft MTR access. Classifications were defined based on fighter aircraft capabilities as recommended by Air Force Headquarters (Air Force 2005).

Very Low Vulnerability	(1):	Within a designated MTR or Within 35 miles of a MTR
Low Vulnerability	(2):	Greater than 35 miles but Less than 70 miles of a MTR

Moderate Vulnerability	(3):	Greater than 70 miles but Less than 105 miles of a MTR
Vulnerable	(4):	Greater than 105 miles but Less than 140 miles of a MTR
High Vulnerability	(5):	Greater than 140 miles of a MTR

Rules: Installations typically have only one MTR located within 35 to 140 miles. However, several installations do have two or more MTRs located within 35 to 140 miles. In this instance, the region around an installation takes on the MTR classification of the lowest vulnerability. For instance, if an installation has an MTR located within 35 miles and another MTR located within 105 miles, the region would be classified as very low vulnerability.

Indicator: **Proximity to Military Training Routes, Bomber Range (AS5)**
Variables: Military Training Routes (MTR) Primary and Alternate Entry and Exit points
Scale: Installation
Year: 2005
Data Sources:

U.S. Air Force. (2005). *Air Force Link. Factsheets: Aircraft*. Washington, DC, available through URL: http://www.af.mil/factsheets/

U.S. Air Force. (2005). *Air Force Link. Factsheets: Low-Altitude Flying Training*. Washington, DC, available through URL: http://www.af.mil/factsheets/factsheet.asp?fsID=183

Digital Aeronautical Flight Information File (DAFIF), National Imagery and Mapping Agency. (2005). *DAFIF Edition 6*. Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm

Logic: National security depends largely on the deterrent effect of our airborne military forces. To be proficient, the military services must train in a wide range of airborne tactics. One phase of this training involves "low level" combat tactics. The required maneuvers and high speeds are such that they may occasionally make the avoid aspect of flight more difficult without increased vigilance in areas containing such operations. In an effort to ensure the greatest practical level of safety for all flight operations, the Military Training Route (MTR) was conceived.

The MTR program is a joint venture by the Federal Aviation Administration and the Department of Defense. MTRs are mutually developed for use by the military for the purpose of conducting low-altitude, high-speed training. Generally, MTRs are established below 10,000 ft (mean sea level) for operations at speeds in excess of 250 knots (Air Force 2005). However, route segments may be defined at higher altitudes for purposes of route continuity. For example, route segments may be defined for descent, climb-out, and mountainous terrain.

This indicator provides a measurement of MTR airspace available to bomber aircraft. Availability is measured by the aircrafts un-refueling range as defined by the U.S. Air Force (Air Force 2005). Having available airspace is typically a necessity for military training. Inadequate access is a strong indicator of greater demands and limitations on military development and missions. This would then place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

It is important to note that although this indicator describes availability of bomber aircraft MTRs, not all installations make use of training airspace. Ideally, installations are prepared for transformations to any mission. However, it may not be realistic. It is important to use local knowledge of installation's current and future mission requirements when interpreting this indicator.

Replicable: This indicator could be replicated annually based on information updated in the DAFIF System (DAFIF 2005).

Directions: Download the *MTR: Routes, Polylines, entry/Exit Points, and Points* file from the DAFIF System at https://164.214.2.62/products/digitalaero/index.cfm (DAFIF 2005). Import all "A" Alternate Entry Point, "B" Alternate Exit Point, "C" Alternate Entry/Exit Point, "S" Primary Entry Point, and "X" Primary Exit Point for all kinds of flying routes ("VR" Visual Route, "IR" Instrument Route, and "SR" Slow Route) into a GIS program to create a Proximity to Military Training Routes, Bomber Range indicator layer. Create buffers at 70, 140, 210, and 280 mile intervals around all points to form vulnerability-rating classifications.

Indicator Measure: This indicator provides insight into an installation's bomber aircraft MTR access. Classifications were defined based on bomber aircraft capabilities as recommended by Air Force Headquarters (Air Force 2005).

Very Low Vulnerability	(1):	Within a designated MTR or Within 70 miles of a MTR
Low Vulnerability	(2):	Greater than 70 miles but Less than 140 miles of a MTR
Moderate Vulnerability	(3):	Greater than 140 miles but Less than 210 miles of a MTR
Vulnerable	(4):	Greater than 210 miles but Less than 280 miles of a MTR
High Vulnerability	(5):	Greater than 280 miles of a MTR

Rules: Installations typically have only one MTR located within 70 to 280 miles. However, several installations do have two or more MTRs located within 70 to 280 miles. In this instance, the region around an installation takes on the MTR classification of the lowest vulnerability. For instance, if an installation has an MTR located within 70 miles and another MTR located within 210 miles, the region would be classified as very low vulnerability.

Sustainability Issue: Energy

Indicator: **Electrical Grid Congestion (EN1)**
Variables: Number of Transmission Loading Relief (TLR) Procedures and Regional Self-Assessments
Scale: NERC Regional Reliability Councils and Sub-Regions
Year: 2004
Data Sources:

North American Electric Reliability Council (NERC) (2004). Long-Term Reliability Assessment: The Reliability of Bulk Electric Systems in North America. Princeton, New Jersey, North American Electric Reliability Council: 88.

NERC TLR Trend Logs (2004) http://www.nerc.com/~filez/Logs/index.html

Logic: Portions of the transmission systems are reaching their limits as customer demand increases and the systems are subjected to new loading patterns resulting from increased power transfers caused by market conditions and weather patterns. Operating procedures, market-based congestion management procedures, and transmission loading relief procedures (TLRs) are used to control the flow on the system within operating reliability limits.

Some well-known transmission constraints are recurring and new constraints are appearing as electricity flow patterns change with installation generation capacity. The transmission system is being subjected to flows in magnitudes and directions that were not contemplated when it was designed or for which there is minimal operating experience. These new flow patterns result in an increasing number of facilities being identified as limits to transfers, and market-based congestion management procedures and TLR procedures are required in areas not previously subject to overloads to maintain the transmission facilities within operating limits.

In some areas, market operators employ locational marginal pricing (LMP) to effect a generation redispatch through economic incentives. In other areas of the Eastern Interconnection, reliability coordinators invoke NERC TLRs to maintain reliability by managing transactions within transmission operating reliability constraints. In effect, TLRs cause generation redispatch by restricting or curtailing scheduled transfers. As such, the number of TLRs is an indication of the grid reaching its capacity in a certain region. Since several other methods in addition to TLRs are used to control grid traffic and some regions do not report, NERC regional self-assessments also provide insight into the grid capacity and operation in the given regions and sub-regions.

The current operating paradigm for almost all defense installations is to obtain their electrical power from the grid. Therefore, grid congestion is an indicator of potential shortfalls in power availability and price volatility in a given region.

Replicable: This indicator could be replicated every year based on information updated in annual NERC reliability assessments. TLR data is continuously reported and updated.

Directions: The TLR data for the last 2 years is averaged to provide a preliminary assessment. This assessment is further tempered and adjusted based on the regional self-assessments in the annual long-term report. Data is from trend analysis of TLR logs on the NERC web-site (http://www.nerc.com/~filez/Logs/index.html). There is no TLR data for the Western Electricity Coordinating Council, Alaska, or Hawaii. Simply import the final data into a GIS program with NERC boundary files to create an Electrical Grid Congestion indicator layer.

Indicator Measure: Electrical Grid Congestion ranges were defined as follows based on natural breaks and implications in the data. Where TLR data was not available or incomplete, regional self-assessment data was used to generate or amplify the rating.

Very Low Vulnerability	(1):	<=50 TLRs
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>50-<=500 TLRs
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>500 TLRs

Rules: Every installation is located primarily in one reliability region, although several installations may cross regional boundaries. An area around an installation takes on the classification of the region in which the installation is primarily located.

Table A1. Regional data.

Reliability Region/Sub Region	TLRs	Encroachment Vulnerability Classification
ECAR	82.5	Moderate (Michigan & WV)
ERCOT	Market	Moderate (Dallas, Houston, West Texas)
FRCC	0	Low
MAAC	188	Moderate
MAIN	47.5	Moderate (Wisconsin and delayed upgrades)
MAPP	1000	High (Twin Cities area and interties)
NPCC/New England	0	Low
NPCC/New York	0	Moderate (NYC and Long Island)

Reliability Region/Sub Region	TLRs	Encroachment Vulnerability Classification
SERC/Entergy	65	Moderate
SERC/TVA	51	Moderate
SERC/SoCo	1	Low
SERC/VACAR	4	Low
SPP	193	Moderate
WECC/AZMNSV		Moderate
WECC/CA		Moderate
WECC/NWPP		Low
WECC/RMPA		Low

Indicator: **Electrical Grid Reserve Capacity in 2010 (EN2)**
Variables: Capacity Margins (% of Capacity Resources) Summer 2010
Scale: NERC Regional Reliability Councils
Year: 2010
Data Source:

North American Electric Reliability Council (NERC) (2005). Long-Term Reliability Assessment: The Reliability of Bulk Electric Systems in North America. Princeton, New Jersey, North American Electric Reliability Council: 88.

Logic: The Electrical Grid Reserve Capacity indicator shows the percentage of capacity margin for the NERC regions for the summer of 2010. This indicator is important because it shows how well the region is planning to meet electrical demand growth in the future. Reduced capacity margins indicate the possibility of future electric shortages in a region in times of high electrical demand.

Replicable: This indicator could be replicated every year based on the annual updates in NERC reliability assessments.

Directions: There are no calculations for this indicator. Data is from tables in the periodic reliability report. There is no data for Alaska or Hawaii, only the continental United States Simply import the final data into a GIS program with NERC boundary files to create an Electrical Grid Reserve Capacity indicator layer.

Indicator Measure: Electrical Grid Reserve Capacity ranges were defined as follows based on natural breaks in the data.

Very Low Vulnerability	(1):	>20-<=30 percent margin
Low Vulnerability	(2):	>17.5-<=20 percent margin
Moderate Vulnerability	(3):	>15-<=17.5 percent margin
Vulnerable	(4):	>12.5-<=15 percent margin
High Vulnerability	(5):	<=12.5 percent margin

Rules: Every installation is located primarily in one reliability region, although several installations may cross regional boundaries. The area around an installation takes on the rating of the NERC region where the installation is primarily located (area basis).

Table A2. NERC regional data.

Reliability Region	Reserve Margin (%)	Rating
ECAR	12.6	Vulnerability
ERCOT	11.9	High Vulnerability
FRCC	16.3	Moderate Vulnerability
MAAC	13.0	Vulnerable
MAIN	12.9	Vulnerable
MRO	12.8	Vulnerable
NPCC	11.9	High Vulnerability
SERC	7.8	High Vulnerability
SPP	13.0	Vulnerable
WECC	20.7	Very Low Vulnerability

Indicator: **Wind Resources (EN3)**
Variables: Wind Power Density
Scale: 1/4 degree of latitude by 1/3 degree of longitude Grid Cells
Year: 1986
Data Source:

Pacific Northwest Laboratory (2003). *Wind Energy Resource Atlas of the United States*. U.S. Department of Energy, Washington, DC. Available online at: http://rredc.nrel.gov/wind/

Logic: The Wind Resource indicator provides wind power class classifications ranging from 1 to 6, with 6 being the windiest. The assigned wind power class is representative of the range of wind power densities likely to occur at exposed sites within the grid cell. This indicator is important because it shows how well equipped the region is to provide renewable energy sources to meet future energy requirements once fossil fuel becomes unavailable or too expensive.

The wind resource assessment was based on surface wind data, coastal marine area data, and upper-air data, where applicable. In data-sparse areas, three qualitative indicators of wind speed or power were used when applicable: topographic/meteorological indicators (e.g., gorges, mountain summits, sheltered valleys); wind deformed vegetation; and eolian landforms (e.g., playas, sand dunes). The data was evaluated at a regional level to produce 12 regional wind resource assessments; the regional assessments were then incorporated into the national wind resource assessment.

The conterminous United States was divided into grid cells 1/4 degree of latitude by 1/3 degree of longitude. Each grid cell was assigned a wind power class ranging from 1 to 6. The wind power density limits for each wind power class is shown in the table below.

Wind Power Class*	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density (W/m^2)	Speed(b) m/s (mph)	Wind Power Density (W/m^2)	Speed(b) m/s (mph)
	0	0	0	
1				
	100	4.4 (9.8)	200	5.6 (12.5)
2				
	150	5.1 (11.5)	300	6.4 (14.3)
3				
	200	5.6 (12.5)	400	7.0 (15.7)
4				
	250	6.0 (13.4)	500	7.5 (16.8)
5				
	300	6.4 (14.3)	600	8.0 (17.9)
6				
	400	7.0 (15.7)	800	8.8 (19.7)
7				
	1000	9.4 (21.1)	2000	11.9 (26.6)

Where possible, existing ground measurement stations are used to validate the model. The degree of certainty with which the wind power class can be specified depends on three factors: the abundance and quality of wind data; the complexity of the terrain; and the geographical variability of the resource. Hilltops, ridge crests, mountain summits, large clearings, and other locations free of local obstruction to the wind are expected to be well exposed to the wind. In contrast, locations in narrow valleys and canyons, downwind of hills or obstructions, or in forested or urban areas are likely to have poor wind exposure. A certainty rating was assigned to each grid cell based on these three factors, and is included in the *Wind Energy Resource Atlas of the United States* available online at: http://rredc.nrel.gov/wind/

Furthermore, it is also recognized that there are several additional alternative sources of energy such as solar and biomass. For regions that lack wind resources, these additional resources may be prevalent and ample to meet future energy requirements. Given these recognitions, local knowledge of the region and its additional resources needs to be taken in consideration.

Replicable: The Pacific Northwest Laboratory typically updates the data annually. However, it is dependent on changes in the data. It is recommended to contact the Laboratory to inquire about the latest available data.

Directions: There are no calculations for this indicator. Data is downloaded directly from the Pacific Northwest Laboratory website located at: http://rredc.nrel.gov/wind/. Simply import the data into a GIS program to create the

Wind Resource indicator layer. Note, there is no data for Alaska or Hawaii—only the continental United States.

Indicator Measure: Areas designated class 4 or greater are suitable for most utility-scale wind turbine applications, whereas class 3 areas are marginal for utility-scale applications but may be suitable for rural applications. Class 2 and 1 areas are generally not suitable, although a few locations (e.g., exposed hilltops) with adequate wind resource for wind turbine applications may exist in some class 1 areas (Pacific Northwest Laboratory 2003). Therefore, it is important to use local knowledge to interpret wind power classifications. Wind Resource ranges were defined as follows based on Pacific Northwest Laboratory literature.

Very Low Vulnerability	(1):	Wind Power Class of 6
Low Vulnerability	(2):	Wind Power Class of 5
Moderate Vulnerability	(3):	Wind Power Class of 4
Vulnerable	(4):	Wind Power Class of 3
High Vulnerability	(5):	Wind Power Class of 1 or 2

Rules: Every installation is located primarily in one grid cell, although several installations may cross cell boundaries. The area around an installation takes on the rating of the grid cell where the installation is primarily located (area basis).

Indicator: **Solar Resources (EN4)**
Variables: Solar Resources for Flat Plate Collectors
Scale: 40 km by 40 km Grid Cells
Year: 1985-1992
Data Source:

National Renewable Energy Laboratory (NREL) (2003). *Climatologically Solar Radiation Model.* U.S. Department of Energy, Washington, DC. Available online at: http://rredc.nrel.gov/solar/

Logic: The Solar Resource indicator is based on the monthly average daily total solar resource information on grid cells of approximately 40 km by 40 km in size. The insolation values represent the resource available to a flat plate collector, such as a photovoltaic panel, oriented due south at an angle from horizontal equal to the latitude of the collector location. This is typical practice for PV system installation, although other orientations are also used (NREL 2003). This indicator is important because it shows how well equipped the region is to provide renewable energy sources to meet increasing demand in the future. The availability of renewable energy in a region is an indicator of future sustainability once transition away from fossil fuels is required due to resource limitations and cost.

Indicator data was developed from the Climatological Solar Radiation (CSR) Model. The CSR model was developed by the NREL for the U.S. Department of Energy. This model uses information on cloud cover, atmospheric water vapor and trace gases, and the amount of aerosols in the atmosphere, to calculate the monthly average daily total insolation (sun and sky) falling on a horizontal surface. The cloud cover data used as input to the CSR model are an 8-year histogram (1985 – 1992) of monthly average cloud fraction provided for grid cells of approximately 40 km x 40 km in size. Thus, the spatial resolution of the CSR model output is defined by this database. The data are obtained from the National Climatic Data Center in Asheville, North Carolina, and were developed from the U.S. Air Force Real Time Nephanalysis (RTNEPH) program. Atmospheric water vapor, trace gases, and aerosols are derived from a variety of sources, as summarized in the references.

Where possible, existing ground measurement stations are used to validate the model. Nevertheless, there is uncertainty associated with the meteorological input to the model, since some of the input parameters are not available at a 40 km resolution. As a result, it is believed that the modeled values are accurate to approximately 10 percent of a true measured value within the grid cell. Due to terrain effects and other microclimate influences, the local cloud cover can vary significantly even within a single grid cell. Furthermore, the uncertainty of the modeled estimates increases with distance from reliable measurement sources and with the complexity of the terrain.

It is also recognized that there are several additional alternative sources of energy such as wind and biomass. For regions that lack solar resources, these additional resources may be prevalent and available to meet future energy requirements. Therefore, local knowledge of the region and its additional resources needs to be taken in consideration.

Replicable: NREL typically updates the data annually. However, it is dependent on changes in the data. It is recommended to contact the Laboratory to inquire about the latest available data.

Directions: There are no calculations for this indicator. Data is downloaded directly from the NREL website located at http://rredc.nrel.gov/solar/. Simply import the data into a GIS program to create the Solar Resource indicator layer. Note, there is no data for Alaska or Hawaii, only the continental United States It is assumed that Hawaii is very low vulnerability and Alaska is high vulnerability.

Indicator Measure: Solar Resource ranges were defined by NREL (NREL 2003).

Very Low Vulnerability (1): >=7 insolation value

Low Vulnerability	(2):	>=6-<7 insolation value
Moderate Vulnerability	(3):	>=5-<6 insolation value
Vulnerable	(4):	>=4-<5 insolation value
High Vulnerability	(5):	<4 insolation value

Rules: Every installation is located primarily in one grid cell, although several installations may cross cell boundaries. The area around an installation takes on the rating of the grid cell where the installation is primarily located (area basis).

Indicator: **Biomass Resources (EN5)**
Variables: Total Annual Biomass Available (in dry tons) at $30/dry ton
Scale: State
Year: 1999
Data Sources:

Walsh, Mary (2000). *Bioenergy Feedstock Development Program*. Oak Ridge National Laboratory, U.S Department of Energy Washington, DC. Available online at: http://bioenergy.ornl.gov/resourcedata/index.html

The White House, Office of the Press Secretary (1999). *Executive Order 13134, Developing and Promoting Biobased Products and Bioenergy*. Washington, DC. Available online at http://ceq.eh.doe.gov/nepa/regs/eos/eo13134.html

Logic: Current biobased product and bioenergy technology has the potential to make renewable farm and forestry resources major sources of affordable electricity, fuel, chemicals, pharmaceuticals, and other materials. These technologies can create new markets for farm and forest waste products, new economic opportunities for underused land, and new value-added business opportunities. They also have the potential to reduce our Nation's dependence on foreign oil, improve air quality, water quality, and flood control, decrease erosion, and help minimize net production of greenhouse gases. Executive Order 13134 of 12 August 1999 set the goal to develop a comprehensive national strategy, including research, development, and private sector incentives, to stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in large national and international markets (USA 1999). This indicator is important in assuring an affordable supply of energy for today and the future to a military installation. Thus, available biomass resources serves as an energy sustainability indicator.

Since Executive Order 13134, interest in using biomass feedstocks to produce power, liquid fuels, and chemicals in the United States is increasing. Central to determining the potential for these industries to develop is an understanding of the location, quantities, and prices of biomass resources. This indicator contains estimates of biomass quantities potentially available in five categories: mill wastes, urban wastes, forest residues, agricultural residues, and energy crops, and at an anticipated delivered price of $30 per dry ton. A presentation that explains how this information was used to support the goal of increasing biobased products and bioenergy three times by 2010 expressed in Executive Order 13134 is available at:

http://bioenergy.ornl.gov/resourcedata/index.html

Furthermore, it is also recognized that there are several additional alternative sources of energy such as solar and wind. For regions that lack biomass resources at an affordable rate, these additional resources may be highly prevalent and ample to meet increasing demand growth in the future. Given these recognitions, local knowledge of the region and its additional resources need to be taken in consideration.

Replicable: The Oak Ridge National Laboratory typically updates the data every 2 to 4 years. However, it is dependent on changes in the data. It is recommended to contact the Laboratory to inquire about the latest available data.

Directions: Download total dry tons delivered at or below $30 per dry ton directly from the Oak Ridge National Laboratory website located at:

http://bioenergy.ornl.gov/resourcedata/index.html

Simply import the data into a GIS program to create the Biomass Resource indicator layer. Note, there is no data for Alaska or Hawaii—only the continental United States.

Indicator Measure: Biomass resources are available at a delivered price ranging from $20 to over $50 per dry ton. Research conducted by the Oak Ridge National Laboratory reveals $30 per dry ton or less is considered an affordable delivery price (Oak Ridge National Laboratory 2000). Therefore, total dry tons delivered at or below $30 per dry ton were used to classify biomass resource availability.

The quantity of biomass resources delivered per state was divided by its respective state area (square miles) resulting in available biomass resources by state per square mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area states. In other words, it protects against a small-area state from a more vulnerable classification because it naturally has less resources compared to a large-area state. Biomass Resources per square mile were statistically classified based on the mean (50.6) and standard deviation (39.6) values. Using this logic, the following classifications were defined.

Very Low Vulnerability	(1):	>60 tons per square mile
Low Vulnerability	(2):	>50-<=60 tons per square mile
Moderate Vulnerability	(3):	>40-<=50 tons per square mile

Vulnerable	(4):	>30-<=40 tons per square mile
High Vulnerability	(5):	<=30 tons per square mile

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. A region takes on the rating of the state the nearby installation is primarily located within.

Indicator: Electrical Price Structure (Deregulation) (EN6)
Variables: Electric Utility Deregulation Status
Scale: State
Year: 2003
Data Source:

Energy Information Administration, U.S. Department of Energy. (2003). *Status of State Electric Industry Restructuring Activity*. Office of Electricity. Washington, DC. http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html

Logic: The price structure for electricity demand and delivery indicates whether the commodity has been deregulated and is thus more susceptible to market distortion such as price instability and availability fluctuations (EIA 2003). Deregulation of electrical markets in the United States is still very much a "work in progress," and the market has not normalized. This indicator will affect the availability and price of electricity to a military installation, and is thus highly sought after as an energy sustainability indicator. Also, utilities in states that have been deregulated have not made the needed investments into the grid because return on investment is ill defined and thus these are more susceptible to outages as seen in the August 2003 blackout. Virtually all areas affected by the blackout were in deregulated markets.

Replicable: This indicator could be replicated every year based on events that occur from states that are in the process of going to electric industry restructuring. February 2003 was the last update made by the EIA.

Directions: The EIA website for electric utility deregulation can be found at URL: http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html, which contains a map showing the states that: (1) have active deregulation, (2) have deregulation activity delayed/suspended, and (3) have no deregulation activity (EIA 2003). Details on the deregulation status of each state can be found by clicking on the desired state on the map located on the EIA website listed above. Download this data. Import it into a GIS program and join it with state boundary files to create an Electrical Price Structure indicator layer.

Indicator Measure: Electrical Price Structure classifications were defined as follows based on the definitions of the EIA (EIA 2003).

Very Low Vulnerability	(1):	No Regulation
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Delayed/suspended
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	Active

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. The area surrounding an installation takes on the classification of the state the installation is primarily located within.

Indicator: **Net Metering (EN7)**
Variables: Net Metering Actions
Scale: State
Year: 2003
Data Source:

Database of State Incentives for Renewable Energy (DSIRE). (2004). Green Power Network. Interstate Renewable Energy Council, U.S. Department of Energy. North Carolina State University Solar Center. (Summary of State Net Metering Programs; Map of Net Metering Programs).

http://www.dsireusa.org/

http://www.eere.energy.gov/greenpower/pdfs/metering_0603.pdf

http://www.eere.energy.gov/greenpower/resources/maps/netmetering_map.shtml)

Logic: The availability of net metering indicates whether a state allows non-energy producers, such as consumers, to sell excess electrical energy produced onsite back to the grid at the local rate. The implications of this indicator are whether or not the state is progressive in its approach to integrated resource planning and management. A progressive approach ensures electricity availability and security in the future, while other approaches may not. The use of distributed generation adds to the robustness of the grid and its overall reliability (DSIRE 2004).

Replicable: This indicator could be replicated every year based on updated actions by states that do not currently have net metering regulations.

Directions: Determine if each state participates in net metering using the Green Power Network website:

http://www.eere.energy.gov/greenpower/pdfs/metering_0603.pdf

Determine if enactments for net metering regulations are either (a) complete, (b) underway, or (c) not considered for action. If enactments are complete, specify the year in which the state net metering rules are implemented (DSIRE 2004). Download the data into a GIS program and join it to state boundary files to create a Net Metering indicator layer.

Indicator Measure: Net Metering classifications were defined as follows based on information provided by the DSIRE (DSIRE 2004).

Very Low Vulnerability	(1):	"Complete" (State-Wide Net Metering)
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	"Underway" (Only Selected Utilities)
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	"No Action" (No Net Metering)

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. The region around an installation takes on the classification of the state the installation is primarily located within.

Sustainability Issue: Urban Development

Indicator: **Regional Population Density (UD1)**
Variables: Population, Land Area (square mile)
Scale: County
Year: 2004
Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2004). *County Population Estimates and Estimated Components of Change, April 1, 2000 to July 1, 2004.* Population Estimates Program. Washington, DC.
http://eire.census.gov/popest/estimates_dataset.php

Bureau of the Census, U.S. Department of Commerce. (2000). *Summary File 1: GCT-PH1-R Population, Housing Units, Area, and Density*. American FactFinder. Washington, DC.
http://factfinder.census.gov

Craig, John. (1984). "Averaging Population Density." *Demography, 21*(3), pp.405-412.
http://www.jstor.org/

Logic: This indicator provides a measure of the population density of all counties in the United States. A high population density in the region surrounding an installation is a strong indicator of potential encroachment issues. This can affect the type and intensity of training that can take place on an installation.

Population density is a commonly quoted statistic. Almost no general descriptive summary of the population of an area is complete without a density listing, table, or map. As each such density statistic is an average, it is worth considering what kind of average is being used (Craig 1984). Additionally, it is important to note that this data is on the county level, not community or installation. Hence, it may be skewed by local "hotspots." In other words, if a county has one community with relatively high regional population density, the entire county data is skewed by that density and may be classified as high regional population density regardless of the characteristics of the remaining majority of the county. Because of these concerns, it is important to use local knowledge in interpreting the regional population density classifications.

Replicable: This indicator could be replicated every year based on Census population estimates, or every decade based on actual, verifiable counts.

Directions: Download county population from the Bureau of the Census (2004) website, *County Population Estimates and Estimated Components of Change, April 1, 2000 to July 1, 2004* at URL: http://eire.census.gov/popest/estimates_dataset.php.

Download land area from Summary File 1: GCT-PH1-R *Population, Housing Units, Area, and Density* of the 2000 U.S. Census at http://factfinder.census.gov (Bureau of the Census 2000). Divide the total population for each county in the United States by the land area (not total area, which includes water bodies) in that county to reach a population density figure.

Regional Population Density = total population / land area

Import the resulting math into a GIS program and join it with county boundary files to create a GIS Regional Population Density indicator layer.

Indicator Measure: The average population density for the entire United States is 79.6 people per square mile according to the 2000 U.S. Census. The mean density for U.S. counties is 267 people per square mile. The results were then subjected to a normal statistical distribution (19%/62%/19%) to determine vulnerability classifications.

Very Low Vulnerability	(1):	<6 people per square mile
Low Vulnerability	(2):	>=6 -<12 people per square mile
Moderate Vulnerability	(3):	>=12 -<247 people per square mile
Vulnerable	(4):	>=247-<2,000 people per square mile
High Vulnerability	(5):	>=2,000 people per square mile

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the region around the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Region Around Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Increasing Regional Growth Rate (UD2)**
Variables: Total Population 1995, 2000, and 2004
Scale: County
Year: 2004

Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2004). *Intercensal State and County Characteristics Population Estimates with 1990-Base Race Groups*. Population Division. Washington, DC.

http://eire.census.gov/popest/estimates_dataset.php

Bureau of the Census, U.S. Department of Commerce. (2004). *County Population Estimates and Estimated Components of Change, April 1, 2000 to July 1, 2004.* Population Estimates Program. Washington, DC.

http://eire.census.gov/popest/estimates_dataset.php

Logic: An increasing regional growth rate is a strong indicator of increased population pressures in the future, leading to greater demands for services, access, resources, and land in competition with the military installation. This can affect the type and intensity of training that can take place on the installation.

Additionally, it is important to note this data is on the county level, not community or installation. Hence, it may be skewed by local "hotspots." In other words, if a county has one community with relatively high regional growth rates, the entire county is classified as high regional growth regardless of the characteristics of the remaining majority of the county. Because of this concern, it is important to use local knowledge in interpreting the increasing regional growth rate classifications.

Replicable: This indicator could be replicated every year based on Census population estimates, or every decade based on actual, verifiable counts.

Directions: Download population for all U.S. counties for 1995 and 2000 from the *Intercensal State and County Characteristics Population Estimates with 1990-Base Race Groups* database maintained by the U.S. Census Bureau (Bureau of the Census 2004). Sum total population per county. Download populations for all U.S. counties for 2004 from the *County Population Estimates and Estimated Components of Change, April 1, 2000 to July 1, 2004* database maintained by the U.S. Census Bureau (Bureau of the Census 2004). Compare the population growth rate from 1995 to 2000 with the growth rate from 2000 to 2004. The increasing regional growth rate calculation used is as follows.

Increasing Regional Growth Rate = (Population Growth Rate from 2000 to 2004) – (Population Growth Rate from 1995 to 2000)

Population Growth Rate from 2000 to 2004 = [(Population 2004 – Population 2000)/ Population 2000] *100

Population Growth Rate from 1995 to 2000 = [(Population 2000 – Population 1995)/ Population 1995] *100

Import the resulting math into a GIS program and join it with county boundary files to create a GIS Increasing Regional Growth Rate indicator layer.

Indicator Measure: Increasing Regional Growth Rate is a measure of how fast a county is growing in the past 5 years compared with data from the previous 5 years. The population growth rate from 2000 to 2004 is compared with the growth rate from 1995 to 2000. This data is available from the U.S. Census at

http://eire.census.gov/popest/estimates_dataset.php

(Bureau of the Census 2004). The data illustrates a county average increasing growth rate of 3.13 percent. Range classifications were based on natural breaks.

Very Low Vulnerability	(1):	<= -10 percent change in population growth rate
Low Vulnerability	(2):	>-10 - <=0 percent change in population growth rate
Moderate Vulnerability	(3):	>0 - <=5 percent change in population growth rate
Vulnerable	(4):	>5 - <=10 percent change in population growth rate
High Vulnerability	(5):	>10 percent change in population growth rate

In random instances, the U.S. Census Bureau does not report population estimates for select counties. These instances are rare but do occur. Additionally, county boundaries are subject to change. Again, occurrence is rare but does occur. Drastic changes in population could reflect a division or merge of 1 or more counties.

Rules: Installations are often in two or more counties. Therefore, installation classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. Those values for each county of the installation are then totaled to arrive at a value for the region around an installation. This value is subjected to the same ranking metric that determined the classifications for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Regional Population Growth (UD3)**
Variables: Total Population 1995 and 2004
Scale: County
Year: 2004

Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2004). *Intercensal State and County Characteristics Population Estimates with 1990-Base Race Groups*. Population Division. Washington, DC.

http://eire.census.gov/popest/estimates_dataset.php

Bureau of the Census, U.S. Department of Commerce. (2004). *County Population Estimates and Estimated Components of Change, April 1, 2000 to July 1, 2004.* Population Estimates Program. Washington, DC.

http://eire.census.gov/popest/estimates_dataset.php

Logic: This indicator measures the population growth over the last decade of every county in the United States. Population growth is one of the leading causes of environmental degradation, because more people use more resources including water, energy, and waste disposal, and other problems. This indicator assumes that fast growing human populations are less sustainable.

The degree of regional population growth is a strong indicator of the demand for services, access, resources, and land in competition with the military installation. This can affect the type and intensity of training that can take place on the installation. This indicator was calculated based on population data from the U.S. Census Bureau.

Additionally, it is important to note this data is on the county level, not community or installation. Hence, it may be skewed by local "hotspots." In other words, if a county has one community with relatively high regional population growth, the entire county is classified as high regional population growth regardless of the characteristics of the remaining majority of the county. Because of this concern, it is important to use local knowledge in interpreting the regional population growth classifications.

Replicable: This indicator could be replicated every year based on Census population estimates, or every decade based on actual, verifiable counts.

Directions: Download population for all U.S. counties for 1995 from the *Intercensal State and County Characteristics Population Estimates with 1990-Base Race Groups* database maintained by the U.S. Census Bureau (Bureau of the Census 2004). Sum total population per county. Download populations for all U.S. counties for 2004 from the *County Population Estimates and Estimated Components of Change, April 1, 2000 to July 1, 2004* database maintained by the U.S. Census Bureau (Bureau of the Census 2004). Given the total population for each county in the United States for 1995 and 2004, the population growth rate from 1995 to 2004 was calculated as follows.

Regional Growth Rate = [(Population 2004 - Population 1995)/Population 1995]*100

Import the resulting math into a GIS program and join it with county boundary files to create a GIS Regional Growth Rate indicator layer.

Indicator Measure: Regional Growth Rate is a measure of how fast a county has grown during the previous decade. The population growth rate is measured from 1995 to 2004. This data is available from the Bureau of the Census (2004) at URL:

http://eire.census.gov/popest/estimates_dataset.php

The data illustrates a county average growth rate of 8.5 percent. The results were statistically classified based on the mean (8.5) and standard deviation (56.3) values.

Very Low Vulnerability	(1):	<=0 percent Population Growth
Low Vulnerability	(2):	>0 -<=8.5 percent Population Growth
Moderate Vulnerability	(3):	>8.5 -<=22.5 percent Population Growth
Vulnerable	(4):	>22.5 -<=36.5 percent Population Growth
High Vulnerability	(5):	>36.5 percent Population Growth

In random instances, the U.S. Census Bureau does not report population estimates for select counties. These instances are rare but do occur. Additionally, county boundaries are subject to change. Again, occurrence is rare but does occur. Drastic changes in population could reflect a division or merge of 1 or more counties.

Rules: Installations are often in two or more counties. Therefore, installation classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. Those values for each county of the installation are then totaled to arrive at a value for the region around an installation. This value is subjected to the same ranking that determined the ratings for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Regional Land Urbanization (UD4)**
Variable: Urbanized Land Area, Total Land Area
Scale: Installation (30 Meter Cells)
Year: 1992

Data Source:

U.S. Geological Survey Bureau (USGS), U.S. Department of the Interior. (1992). *Land Cover Characterization Program*. Reston, VA. (National Land Cover/MRLC). http://landcover.usgs.gov

Logic: This indicator provides a measure (in percent) of land urbanization within a 20-mile boundary surrounding the installation. The indicator value is found by dividing the amount of urbanized land by the total land area surrounding a given installation.

The degree of regional development is a strong indicator of potential encroachment problems that can affect the type and intensity of training that can take place on the installation.

Replicable: This indicator calculation was performed with GIS using the National Land Cover Characterization data available from the USGS online at http://landcover.usgs.gov (USGS 1992). This website provides more about the data and the USGS's program for land characterization. Overall, the data set describes land use for the entire United States, for a 1992 timeframe, by 60 land use and vegetation types (USGS 1992). Currently only 1992 data is available, but the USGS is in the process of making 2000 Land Cover data available on the USGS website. It is recommended that this indicator be updated as new data is available.

Directions: Download land coverages for each state from the USGS Internet site through URL:

http://landcover.usgs.gov

or more directly from:

http://edcww.cr.usgs.gov/pub/data/landcover/states

in a geotiff format (USGS 1992). Convert these tiff image files to raster data.

Once the data is in a grid/raster format, the only information needed for the regional land urbanization analysis for risk assessment is developed land; all other land covers are irrelevant for this task. Thus to simplify processing, reduce storage requirements, and minimize display and processing times, reclassify the dataset to display urban or non-urban land. Classify cells originally labeled as attribute 21, 22, or 23 as urban (reclassify values to 1) and all other land covers (any other attribute value) as non-urban (reclassify values to 0).

Next, using the ArcGIS buffer wizard, create 20-mile buffers around each military installation. Finally, tabulate the percentage of urban and non-urban land areas within each 20-mile buffer. With the data simplified to two classifications (1 = urban and 0 = non-urban) and a polygon file with the appropriate buffers for each installation, the ratio of urbanized land surrounding each installation was determined as follows.

Urbanization Ratio = value-1 area/(value-1 area + value-0 area).

Indicator Measure: Regional Land Urbanization classifications are defined by the percent of land urbanization within a 20-mile boundary surrounding the installation. This value is found by dividing urbanized land by the total land area. The classifications were defined by natural breaks in the data as follows.

Very Low Vulnerability	(1):	<=29 percent Urbanized
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>29 -<=35 percent Urbanized
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>35 percent Urbanized

Rules: Since this data is collected by installation, there is no calculation to determine installation risk ratings.

Indicator: State Smart Growth Plans (UD5)
Variables: Presence of State Smart Growth Plan
Scale: State
Year: 2002
Data Source:

American Planning Association (APA). (2002). *Planning for Smart Growth: 2002 State of the States*. Smart Growth Network. Chicago, IL, available through URL: http://www.planning.org/growingsmart/states2002.htm

Logic: This indicator shows the status of State Smart Growth Initiatives across the United States. Smart growth is the planning, design, development, and revitalization of cities, towns, suburbs, and rural areas to create and promote social equity, a sense of place and community, as well as to preserve natural and cultural resources. Smart growth enhances ecological integrity over both the short- and long-term, and improves quality of life for all by expanding—in a fiscally responsible manner—the range of transportation, employment, and housing choices available to a region (APA 2002).

The presence of a state smart growth plan is important because smart growth legislation can reduce sprawl and decrease the growth of urbanized land surrounding a military installation. The potential encroachment caused by sprawl and urban development can affect the type and intensity of training that can take place on the installation.

However, this indicator does not indicate whether or not the initiatives were successful. Typically, state smart growth initiatives have positive results, yet there is never a guarantee. Additionally, APA monitors smart growth initiatives at a state level. Local communities may have established local smart growth initiatives, yet here they are rated as high vulnerability because of the state's status. Therefore, it is critical to use local knowledge in interpreting smart growth initiatives classifications.

Replicable: This indicator could be replicated regularly as long as the APA continues to monitor Smart Growth (which is likely considering that one of the main tenants of the APA currently is to get smart growth passed in every state). It is recommended that this indicator be updated annually. 2002 was the last update made by the APA.

Directions: APA constructed a map to chart the progress of smart growth reform. That map is available through URL:

http://www.planning.org/growingsmart/states2002.htm

and was synthesized to create the map and scale used for this indicator (APA 2002). Download the map data, import it into a GIS program, and join it with state boundary files to create a GIS State Smart Growth Plans indicator layer.

Indicator Measure: Substantial Reforms means that smart growth legislation has been passed in the state. Moderate reforms or pursuing additional reforms means that some form of land use laws resembling smart growth have been passed or legislation has been proposed. No reforms mean that no legislation has been passed or proposed (APA 2002).

Very Low Vulnerability	(1):	Substantial Reforms
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Moderate Reforms or Pursuing
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	No Reforms

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. The region around an installation takes on the rating of the state in which the installation is primarily located.

Indicator: **Joint Land Use Study (JLUS) (UD6)**
Variables: JLUS Program Participation
Scale: Installation
Year: 1985-2003
Data Sources:

Joint Land Use Study Assistance Grant, Title 10 U.S. C. Section 2391 (1985).

Office of Economic Adjustment (OEA), U.S. Department of Defense. (2003). Joint Land Use Study Program. Washington, DC, available through URLs:

http://www.nga.org/cda/files/1002LANDUSESUMMARY.pdf

http://www.ngms.state.ms.us/cfmo/joint_land.html

Logic: Military operations can be loud and present safety concerns for nearby civilian communities. For example, low flying, high performance, military aircraft, create both noise and accident potential during landings, take-off, and training exercises. Likewise, ground-training exercises (e.g., artillery firing ranges, maneuver areas, and aerial bombing ranges) generate impact noise that can adversely affect the surrounding community if the civilian population chooses to locate too close. Conversely, civilian activities located adjacent to active military bases can impair the operational effectiveness, training, and readiness of the installations' mission (OEA 2003). In other words, urban encroachment near a military base, if allowed to go unregulated, can compromise the utility and effectiveness of the installation and its mission. Thus, in the mid-1970s, the Department of Defense (DoD) established the Air Installation Compatible Use Zone (AICUZ) and the Environmental Noise Management Program (ENMP) in response to existing and potential threats of incompatible land development compromising the defense missions at military installation (OEA 2003). The programs include noise propagation studies of military activities to delineate on- and off-base areas most likely to be affected by unacceptable noise levels. The programs also identify aircraft landing and take-off accident potential zones that often extend off a base into the neighboring community (OEA 2003).

Since then, Congress authorized the DoD to make community planning assistance grants ("Joint Land Use Study Assistance Grant," 1985) to state and local governments to help better understand and incorporate the AICUZ/ENMP technical data into local planning programs (OEA 2003). This is done in the form of a Joint Land Use Study (JLUS). The OEA manages the JLUS program. A JLUS is a cooperative land use planning effort between affected local government and the military installation. The recommendations present a rationale and justification, and provide a policy framework to support adoption and implementation of compatible development measures designed to prevent urban encroachment; safeguard the military mission; and protect the public health, safety, and welfare (OEA 2003).

The presence of a JLUS indicates an effort between the local community and the military installation to work together. Thus, any form of a JLUS is viewed as a positive. Whether the installation has completed a JLUS, begun a JLUS, or is simply receiving technical assistance, the installation is classified as "very low vulnerability." If no effort is shown toward completing a JLUS, the installation is classified as "high vulnerability." However, this puts some limitations on the data. First, the classifications do not indicate whether or not the JLUS was successful. The local community and military installation may never have agreed on a future course of action and the result was less compatibility than before the JLUS. Typically all JLUS have positive results, yet there is never a guarantee. Second, and more critical, installations not near urban development have no need to perform a JLUS, yet they are rated as "high vulnerability" because they have not completed or pursued a JLUS. Thus, it is critical to read this data along with an understanding of the installation's proximity to Metropolitan Statistical Areas and other Urban Development sustainability issues. Any user of this data must have local knowledge to interpret the JLUS classifications.

Replicable: This indicator could be replicated every year based on material printed by the DoD, OEA concerning the JLUS program. The same material is often published on the DoD, OEA website. (2003 was the last update made by the OEA.) Current data may be found through URL:

http://www.ngms.state.ms.us/cfmo/joint_land.html

Directions: OEA JLUS constructs a map to chart the progress of JLUSs. That map is available from the OEA JLUS program and updated periodically (OEA 2003). The data from the map was synthesized to create the map and scale used for this indicator. Download the map data, import it into a GIS program, and join it with the installation boundary files to create a GIS JLUS indicator layer.

Indicator Measure: The JLUS program identifies military installations where JLUS have been "completed," "underway," and where "technical assistance" has been given. Any installation with one of these characterizations was classified as very low vulnerability. All other installations were classified as high vulnerability. It is assumed that if a JLUS has been completed, is underway, or is expected to occur on a military installation, then the installation is concerned about land use compatibility and therefore received a "higher" rating. However, there are concerns in this logic with the success of the JLUS and the relative need for such a study to be made (refer to the section labeled "Logic" of this report). The following risk classifications were defined for JLUS.

Very Low Vulnerability	(1):	JLUS Completed, Underway, or Technical Assistance
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Not Applicable
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	JLUS Not Completed, Underway, or no Technical Assistance

Overall, there are 33 installations that have completed a JLUS, 34 with a JLUS underway, and four installations receiving technical assistance.

Rules: Since this data is collected by installation, there is no calculation to determine installation classification.

Indicator: **Proximity to Metropolitan Statistical Areas (MSA) (UD7)**
Variables: MSA, Mile Buffers
Scale: Installation
Year: 2000
Data Source:

Bureau of the Census, U.S. Department of Commerce. (2000). *About Metropolitan and Micropolitan Statistical Areas*. Office of Management and Budget. Washington, DC, available through URL:

http://www.census.gov/population/www/estimates/aboutmetro.html

Logic: This indicator shows the proximity of Military installations to Metropolitan Statistical Areas (MSA), which indicates the potential for encroachment on military facilities. MSAs are a geographic entity designated by the Federal Office of Management and Budget for use by Federal statistical agencies (Bureau of the Census 2000). An MSA consists of one or more counties, except in New England, where MSAs are defined in terms of county subdivisions (primarily cities and towns) (Bureau of the Census 2000). Encroachment is a strong indicator of pressures on the future use and vulnerability of military installations. Encroachment places the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation due to greater demands and limitations on military developments.

Replicable: This indicator could be replicated every year based on Census population estimates or every decade based on actual, verifiable counts. It is recommended that the data be replicated only once a decade due to the inaccuracy of census estimates. The GIS compatible layer containing MSAs (Bureau of the Census 2000). is available through URL:

http://www.census.gov

Directions: Download the GIS layer containing MSAs from the U.S. Census Bureau (Bureau of the Census 2000). Import the data into a GIS program to create a Proximity to MSA indicator layer. Create buffers at 20-miles from the edge of each MSA to show a level of risk.

Indicator Measure: Proximity to MSA is defined as the distance from the nearest MSA to an installation. All areas within an MSA were classified as highly vulnerable, while all areas not within an MSA, but within 20 miles of an MSA were classified as moderately vulnerable. All areas outside of the 20-mile buffer were considered not vulnerable. Proximity to MSA classifications were defined as follows.

Very Low Vulnerability	(1):	Areas greater than 20 miles away from any MSA
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Areas not within an MSA, but within 20 miles of one or more MSAs
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	Within a Census designated MSA

Rules: This indicator measures an installations' proximity to an MSA. If only part of an installation is located within an MSA, then that region surrounding the installation takes on the highly vulnerable classification. The same follows if an installation straddles the 20 mile buffer—half of the installation within 20 miles the other half greater than 20 miles, the region takes on the "moderate" vulnerability classification.

Sustainability Issue: Threatened and Endangered Species (TES)

Indicator: **Number of TES per State (TE1)**
Variables: Number of TES per square mile
Scale: State
Year: 2004
Data Sources:

Bak, J.M., S. Sekscienski, and B. Woodson. (2002). *FY 2000 Survey of Threatened and Endangered Species on Army Lands*. U.S. Army Environmental Center. Aberdeen Proving Ground, MD. (21010-5401. SFIM-AEC-EQ-TR-20018. U.S. Navy HQ NAVFAC. U.S. Air Force AFCEE), available through URL:

http://clients.emainc.com/navfac/

Sikes Act, 16 USC 670a-670o, 74 Stat. 1052 (1960), available through URL:

http://laws.fws.gov/lawsdigest/sikes.html

U.S. Department of Defense, and the U.S. Fish and Wildlife Service, U.S. Department of the Interior. (2002). *Integrated Natural Resources Management Plans*. Washington, DC, available through URL:

http://endangered.fws.gov/DoD/inrmp.pdf

U.S. Fish and Wildlife Service, U.S. Department of the Interior. (2004). *Threatened and Endangered Species System*. The Endangered Species Program. Washington, DC. (Species Information) , available through URL:

http://endangered.fws.gov

Logic: This indicator gives an indication of the comparative number of TES in each state. The presence of TES is highly sought after as a sustainability indicator due to the possible limitations they may put on certain land use actions, military or otherwise, in time or in space. In addition, other Federal requirements (e.g., Sikes Act) may require consideration and protection of state listed or other identified species identical or comparable to that required by the Endangered Species Act ("Sikes Act," 1960). Overall, the presence of TES on a military installation may result in legal and other requirements regarding the conservation and management of those species (DoD et al. 2002).

Replicable: This information could be replicated daily based on updates from the U.S. Fish and Wildlife Service, Endangered Species Program (2004). It can be anticipated that the individual state lists will increase over time and that the removal of species from state lists will be uncommon and infrequent. However, changes in numbers can be anticipated to be relatively small and replication every day, or even year, should not be universally necessary.

Directions: Download the number of TES in each state from the U.S. Fish and Wildlife Service, Endangered Species Program (2004). Import the resulting data into a GIS program and join it with state boundary files to create a Number of TES per State indicator layer.

Indicator Measure: Download the U.S. Fish and Wildlife Service's state listed TES data from their Species Information website and then divide by its respective state area (square miles) resulting in Number of TES per State per Square Mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area states. In other words, it protects against a large-area state from a more vulnerable classification because it naturally has more occurrences compared to a small-area state. The number TES per state per square mile were statistically classified by determining the mean (0.003298 species per square mile) and standard deviation (0.009745). Using this logic, the following classifications were defined.

Very Low Vulnerability	(1):	<=0.0005 species per square mile
Low Vulnerability	(2):	>0.0005-<=0.0017 species per square mile
Moderate Vulnerability	(3):	>0.0017-<=0.0028 species per square mile
Vulnerable	(4):	>0.0028-<=0.0038 species per square mile
High Vulnerability	(5):	>0.0038 species per square mile

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. A region around an installation takes on the classification of the state in which the installation is primarily located.

Indicator: **Species at Risk (TE2)**
Variable: **Number** of Species
Scale: Watershed
Year: 1997
Data Sources:

USEPA. (1997). *The Index of Watershed Indicators, EPA-841-R-97-010.* Office of Water. Washington, DC, available through URL:
http://www.epa.gov/wateratlas/geo/maplist.html

Hurd, B., N. Leary, R. Jones, and J. Smith. (1999). "Relative Regional Vulnerability of Water Resources to Climate Change." *Journal of the American Water Resources Association, 35*(6), pp.1399-1409, available through URL:
http://www.awra.org

Sikes Act, 16 USC 670a-670o, 74 Stat. 1052 (1960) , available through URL:
http://laws.fws.gov/lawsdigest/sikes.html

16 USC 670a-670o, 74 Stat. 1052, available through URL:
http://laws.fws.gov/lawsdigest/sikes.html

Logic: This indicator measures the number of threatened and endangered aquatic and wetland species known to be in a watershed based on Federal Threatened and Endangered species (TES) counts as given by the U.S. EPA in 1997 (USEPA 1997). This indicator characterizes the degree of relative stress that a watershed may be currently experiencing from a variety of sources, including habitat loss, pollution, predation, and disease by counting the number of at-risk, water-dependant species within a watershed (B. Hurd et al. 1999).

According to the Sikes Act, the DoD and Department of Interior (DoI) must cooperate with local state agencies for the planning, management, and maintenance of fish and wildlife populations and their associated habitat on military installations ("Sikes Act," 1960). Watersheds with a high number of TES will significantly increase the possibility of regulatory restrictions on the installation's mission. This would then place the military installation in a vulnerable state, possibly affecting the type and intensity of training that would take place on the installation. Reduction and or change in military training activities may result if state and Federal agencies question military training impacts on TES and associated habitat. Restrictions, reductions, and change of training could result, including the permanent removal of land parcels from training. (Supplementary applicable laws and regulations can be found at http://www.epa.gov/win/law.html.)

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. Watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6-digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin. There are many states that have defined down to 16-digit HUCs (USEPA 1997).

Replicable: Efforts are being made to replicate this analysis so it can be updated when new EPA data is available using the methodologies generated by the original study. This data is found in the EPA's Index of Water Quality Indicators at http://www.epa.gov/wateratlas/geo/maplist.html (USEPA 1997). The EPA intends to replicate the effort and produce new data, although the timeline is unclear at this point due to lack of funding.

Directions: Download "species at risk" from the EPA *Index of Watershed Indicators* at http://www.epa.gov/wateratlas/geo/maplist.html (USEPA 1997). Import the data into a GIS program and join it with watershed boundary files to create a GIS Species at Risk indicator layer.

Indicator Measure: Number of aquatic and wetland species identified were defined as either threatened or endangered, at-risk, or water-dependant, as estimated by EPA IWI (USEPA 1997). The species at risk ratings were grouped into the following classifications based on definitions assigned by the EPA (USEPA 1997) as well as expert opinion. A complete explanation of the EPA ranges is available at http://www.epa.gov/wateratlas/geo/maplist.html.

Very Low Vulnerability	(1):	0 species at risk per square mile
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	1 species at risk per square mile
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	2 or more species at risk per square mile

Rules: Every installation is located primarily in one watershed, although several installations do cross watershed boundaries. The area around an installation takes on the rating of the watershed where the installation is primarily located (area basis).

Indicator: **Federally Listed TES by Ecoregion (TE3)**
Variables: Year-round presence/resident, Seasonal, Migratory, Contiguous, and Accidental per square mile
Scale: Ecoregion
Year: 2004
Data Sources:

Sikes Act, 16 USC 670a-670o, 74 Stat. 1052 (1960) , available through URL: http://laws.fws.gov/lawsdigest/sikes.html

U.S. Department of Defense, and the U.S. Fish and Wildlife Service, U.S. Department of the Interior. (2002). *Integrated Natural Resources Management Plans*. Washington, DC, available through URL: http://endangered.fws.gov/DoD/inrmp.pdf

NatureServe Central Databases (2004). *TNC Ecoregion Threatened and Endangered Species*. Arlington, VA.

Logic: The species included in this analysis consist of all species with Federal status under the U.S. Endangered Species Act (USESA) for which NatureServe has associated Element Occurrence (EO) data. This indicator is important as a TES indicator because the presence of TES on or near a military installation may result in legal and other requirements regarding the conservation and management of those species (DoD et al. 2002). The presence of TES may limit certain land use actions, military or otherwise, in time or in space. In addition, other Federal requirements (e.g., Sikes Act) may require consideration and protection of state listed or other identified species identical or comparable to that required by the Endangered Species Act ("Sikes Act," 1960). Reporting TES by ecoregions as opposed to States have certain advantages in naming species by habitat. In other words, classifying by state may result in the entire state classified as high TES vulnerability regardless of the characteristics of the majority of the state.

Replicable: Although this information could be replicated every year from the NatureServe Central Database there would be relatively little reason to do so. TES presence, once identified, would not be expected to change unless the species was extirpated, or its status changed. If the species were extirpated, other political and social concerns and considerations would raise themselves.

Directions: Data was ordered from the NatureServe Central Database (NatureServe 2004). Since data comes with a fee, it is recommended that the data be reproduced no more often than annually. The data will arrive in a spreadsheet format. Import the data into a GIS program and join with ecoregion boundary files to create a TES by Ecoregion indicator layer.

Indicator Measure: NatureServe collects species occurrence data from local Natural Heritage Programs across the United States. It is important to note that the following data is missing in the NatureServe Central Databases and the dataset used for this analysis.

Most Washington animal data - with the exception of some select species, animal data in Washington is tracked by an agency outside the Washington Natural Heritage Program and the methodology of that animal location data is not currently compatible with Heritage EO Methodology.

Alaska animal data – NatureServe is unable to provide Alaska animal data until they complete their next data exchange with their Heritage program in the coming year.

Massachusetts data – NatureServe has an incomplete EO dataset for Massachusetts that is also a couple of years old. While these records were included in the crosstab tallies, the numbers for Ecoregions that intersect with Massachusetts may be low.

Arizona data – NatureServe does not currently store the coordinates for Arizona species location data in their Central Database. The crosstab tallies for Ecoregions that intersect with Arizona do not include counts of species locations within the state of Arizona.

NatureServe grouped the location of sited TES species by ecogregion. The number of TES per ecoregion was then divided by its respective ecoregion area (square miles) resulting in Federally Listed TES by Ecoregion per Square Mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area ecoregions. In other words, it protects against a large-area ecoregion from a more vulnerable classification because it naturally has more occurrences compared to a small-area ecoregion. Federally Listed TES by Ecoregion per square mile were statistically classified around natural breaks in the mean (0.0018) and standard deviation (0.0086) values.

Very Low Vulnerability	(1):	<=0.00016 species per square mile
Low Vulnerability	(2):	>0.00016-<=0.00031 species per square mile
Moderate Vulnerability	(3):	>0.00031-<=0.00086 species per square mile
Vulnerable	(4):	>0.00086-<=0.0015 species per square mile
High Vulnerability	(5):	>0.0015 species per square mile

Rules: Every installation is located primarily in one ecoregion, although several installations do cross ecoregion boundaries. The area around an installation takes on the rating of the ecoregion where the installation is primarily located (area basis).

Indicator: **Species of Concern (TE4)**
Variables: Species with a Global Conservation Status Rank of G1/T1 – G2/T2 and having no Federal Status per square mile
Scale: Ecoregion
Year: 2004
Data Sources:

Sikes Act, 16 USC 670a-670o, 74 Stat. 1052 (1960) , available through URL:
http://laws.fws.gov/lawsdigest/sikes.html

U.S. Department of Defense, and the U.S. Fish and Wildlife Service, U.S. Department of the Interior. (2002). *Integrated Natural Resources Management Plans*. Washington, DC, available through URL:
http://endangered.fws.gov/DoD/inrmp.pdf

NatureServe Central Databases (2004). *TNC Ecoregion Species of Concern*. Arlington, VA.

Logic: The species included in this analysis consist of all species with a Global Conservation Status Rank of G1/T1 – G2/T2 and having no Federal status. In other words, the data only includes location records in the counts for which that status does NOT apply and those records do NOT have Federal protection. For example, if a species only has Federal status within 50 miles of a coastline, then only records for that species that are further then 50 miles from the coast would be included. This indicator is important as a TES indicator because the presence of TES on or near a military installation may result in legal and other requirements regarding the conservation and management of those species (DoD et al. 2002). The presence of TES may limit certain land use actions, military or otherwise, in time or in space.

In addition, other Federal requirements (e.g., Sikes Act) may require consideration and protection of state listed or other identified species identical or comparable to that required by the Endangered Species Act ("Sikes Act," 1960). Reporting TES by ecoregions as opposed to States have certain advantages in naming species by habitat. In other words, classifying by state may result in the entire state classified as high TES vulnerability regardless of the characteristics of the majority of the state.

Replicable: Although this information could be replicated every year from the NatureServe Central Database there would be relatively little reason to do so. TES presence, once identified, would not be expected to change unless the species was extirpated, or its status changed. If the species were extirpated, other political and social concerns and considerations would raise themselves.

Directions: Data was ordered from the NatureServe Central Database (NatureServe 2004). Since data comes with a fee, it is recommended that the data be reproduced no more often than annually. The data will arrive in a spreadsheet format. Import the data into a GIS program and join with ecoregion boundary files to create a Species of Concern indicator layer.

Indicator Measure: NatureServe collects species occurrence data from local Natural Heritage Programs across the United States. It is important to note that the following data is missing in the NatureServe Central Databases and the dataset used for this analysis.

Most Washington animal data - with the exception of some select species, animal data in Washington is tracked by an agency outside the Washington Natural Heritage Program and the methodology of that animal location data is not currently compatible with Heritage EO Methodology.

Alaska animal data – NatureServe is unable to provide Alaska animal data until they complete their next data exchange with their Heritage program in the coming year.

Massachusetts data – NatureServe has an incomplete EO dataset for Massachusetts that is also a couple of years old. While these records were included in the crosstab tallies, the numbers for Ecoregions that intersect with Massachusetts may be low.

Arizona data – NatureServe does not currently store the coordinates for Arizona species location data in their Central Database. The crosstab tallies for Ecoregions that intersect with Arizona do not include counts of species locations within the state of Arizona.

NatureServe grouped the location of species of concern by ecogregion. The number of species of concern per ecoregion was then divided by its respective ecoregion area (square miles) resulting in Species of Concern by Ecoregion per Square Mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area ecoregions. In other words, it protects against a large-area ecoregion from a more vulnerable classification because it naturally has more occurrences compared to a small-area ecoregion. Species of Concern by Ecoregion per square mile were statistically classified around natural breaks in the mean (0.0023) and standard deviation (0.0042) values.

Very Low Vulnerability	(1):	<=0.0006 species per square mile
Low Vulnerability	(2):	>0.0006-<=0.00195 species per square mile
Moderate Vulnerability	(3):	>0.00195-<=0.0033 species per square mile
Vulnerable	(4):	>0.0033-<=0.00466 species per square mile
High Vulnerability	(5):	>0.00466 species per square mile

Rules: Every installation is located primarily in one ecoregion, although several installations do cross ecoregion boundaries. The area around an installation takes on the rating of the ecoregion where the installation is primarily located (area basis).

Sustainability Issue: Locational

Indicator: **Federally Declared Floods (LO1)**
Variable: Number of Federally declared floods per Square Mile
Scale: County
Year: 12/24/1964 through 6/15/2004, totaled
Data Sources:

Federal Emergency Management Agency, U.S. Department of Homeland Security. (2004). *Federally Declared Disasters by Calendar Year*. FEMA GIS and Data Solutions Branch. Washington, DC, available through URL:

http://www.fema.gov/library/drcys.shtm

International Federation of Red Cross and Red Crescent Societies (IRRCRCS). (2002). *World Disasters Report: Focus on Reducing Risk 2002*, available through URL:

http://www.ifrc.org/publicat/wdr2002/

Logic: Every year flood disasters cause damage amounting to billions of dollars world-wide. Floods inflict the greatest loss in money than any other Federally declared disaster in the United States. Floods are a threat to both built structures and human health and safety. Thus, the military must be sensitive to potential threats from the natural and built environment. The mission of the installation can be severely impacted by a flood if proper provisions are not in place.

This indicator measures the number of Federally Declared Floods occurring between 1964 and 2004. Federally Declared Floods are those floods declared by communities to the Federal government. Often times on declaration, the Federal government offers some form of relief to the community (IFRCRCS 2002). Thus whether or not a flood is declared depends largely on the resources of the community and the aggressiveness of community leaders. Many floods of significant consequences are not declared while some of relatively little consequences are declared. In other words, declaration may have little to do with severity. Nonetheless, Federally Declared Floods offer the best indication of a community's flood risk reduction efforts. It is simply vital to use local knowledge in interpreting the Federally Declared Floods classifications.

Replicable: This indicator can be updated annually based on Federally Declared Disasters by Calendar Year data, as collected in the National Emergency Management Information System (NEMIS) maintained by the Federal Emergency Management Agency (FEMA 2004).

Directions: FEMA database, “declarations by type,” is sorted by disaster type. Eliminate all disasters except flooding. Download and compile the data for all U.S. counties. Import the data into a GIS program and join it with county boundary files to create a Federally Declared Floods indicator layer.

Indicator Measure: The number of Federally declared floods for each county was summed to obtain a 38-year total for floods (FEMA 2004). This sum was then divided by its respective county area (square miles) resulting in Federally declared floods per square mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area counties. In other words, it protects against a large-area county from a more vulnerable classification because it naturally has more occurrences compared to a small-area county. Statistical analysis resulted in a mean of 0.0058 floods per square mile and a standard deviation of 0.0259. The following classifications were defined using the mean and standard deviation values.

Very Low Vulnerability	(1):	<0.0059 floods per square mile
Low Vulnerability	(2):	>=0.0059-<0.0189 floods per square mile
Moderate Vulnerability	(3):	>=0.0189-<0.0317 floods per square mile
Vulnerable	(4):	>=0.0317-<0.046 floods per square mile
High Vulnerability	(5):	>=0.046 floods per square mile

Rules: Installations are often in two or more counties. Therefore, regional classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county, and that percentage is multiplied by that county’s value. The values for each county the installation lies in are then totaled to arrive at a value for the region. This value is then subject to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator:	**Seismicity (LO2)**
Variables:	Spectral acceleration for 0.2 second period with 2 percent probability of exceedance in 50 years
Scale:	National
Year:	2002

Data Sources:

Frankel, Arthur, Charles Mueller, Theodore Barnhard, David Perkins, E.V. Leyendecker, Nancy Dickman, Stanley Hanson, and Margaret Hopper. (2002). *Seismic-Hazard Maps for the Conterminous United States: Document for 2002 Update of National Seismic Hazard Map, U.S. Geological Survey Open-File Report 02-420* U.S. Geological Survey Bureau, U.S. Department of the Interior. Reston, VA. (Map F - Horizontal spectral response acceleration for 0.2 second period [5% of critical damping] with 2% probability of exceedance in 50 years) , available through URL:

http://earthquake.usgs.gov/hazmaps/

Sweeney, Steven. (2002). Structural Engineer, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory. In Adam Sagert (Ed.). Champaign, IL.

Logic: Earthquakes are a threat to both built structures and human health and safety. Thus, the military must be sensitive to potential threats from the natural environment. The mission of the installation can be severely impacted by an earthquake.

Replicable: This indicator can be replicated as often as the USGS updates their Seismic Risk data. The trend seems to be that these maps are updated every 5 or 6 years.

Directions: Download the horizontal spectral response acceleration for 0.2 second period (5% of critical damping) with 2% probability of exceedance in 50 years. Import the data into a GIS program to create a Seismicity Risk area indicator layer. GIS data (A. Frankel et al. 2002) concerning seismicity is available through URL:

http://earthquake.usgs.gov/hazmaps/

Indicator Measure: The values found on the map are the horizontal spectral response acceleration for 0.2 second period (5% of critical damping) with 2% probability of exceedance in 50 years. USGS documentation (A. Frankel et al. 2002) separates the data into various seismic classifications, which were then translated into a vulnerability scale with the assistance of seismic expert and structural engineer, Steven Sweeney, at ERDC-CERL (2002).

Very Low Vulnerability	(1):	<=7%g (gravity)
Low Vulnerability	(2):	>7-<=8%g (gravity)
Moderate Vulnerability	(3):	>8-<=16%g (gravity)
Vulnerable	(4):	>16-<=24%g (gravity)
High Vulnerability	(5):	>24%g (gravity)

Rules: This indicator measures seismicity for a certain location. The region around an installation takes on the rating of the highest seismicity classification area that the installation touches. For instance, if an installation is partly in a moderate vulnerability classified area, and partly in a high vulnerability classified area, then the region around the installation has a high vulnerability classification.

Indicator: **Weather Related Damage (LO3)**
Variable: **Damage** in dollars due to weather (crop and property) per square mile
Scale: State
Year: 1995-2004 data, totaled
Data Source:

National Oceanographic and Atmospheric Administration (NOAA): National Weather Service, U.S. Department of Commerce. (2005). *Summary of Natural Hazard Statistics in the United States*. Office of Climate, Water, and Weather Services. Silver Spring, MD, available through URL

http://www.nws.noaa.gov/om/hazstats.shtml

Logic: The United States suffered nearly $200 billion in economic losses due to extreme weather in the 1990s, including $14 billion in damage in 1999 (NOAA 2005). The insurance industry is worried about the soaring costs of severe weather damage and is already refusing to cover various weather events in certain regions. The DoD lost an installation with Hurricane Andrew's destruction of Homestead AFB in Florida in August 1992. By examining historical weather related damage trends, one can see the vulnerability of the military mission to extreme weather. Thus, the military must be sensitive to potential threats from the natural environment. Weather conditions are a threat to built structures, human health and safety, and the mission of the installation. This indicator provides a measurement of the cost of the loss of crops and damage due to natural disasters for the past 7 years.

Replicable: This indicator could be updated annually as new data is posted to the National Weather Service website (NOAA 2005).

Directions: From the NOAA website, select a year from the "State Summaries" pull-down menu (NOAA 2005). This opens an Adobe acrobat document for that year containing fatalities, injuries, property damage, and crop damage for each state and U.S. territory. Download and compile the data into a spreadsheet for 1995 through 2004 for all U.S. counties. Import the totals into a GIS program and join it with county boundary files to create a Weather Related Damage indicator layer.

Indicator Measure: The damage in dollars due to weather for each state and territory was summed to obtain a 7-year total for weather related crop and property damage (NOAA 2005). This sum was then divided by its respective state area (square miles) resulting in weather damage in dollars per square mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area states. In other words, it protects against a large-area state from a more vulnerable classification because it naturally has more occurrences compared to a small-area state. Statistical analysis resulted in a median of $25,730 per square mile and a standard deviation of 33,506. Using these statistics, the following classification were determined.

Very Low Vulnerability	(1):	<$8,977
Low Vulnerability	(2):	>=$8,977-<$25,730 per square mile
Moderate Vulnerability	(3):	>=$25,730-<$42,483 per square mile
Vulnerable	(4):	>=$42,483-<$59,236 per square mile
High Vulnerability	(5):	>=$59,236 per square mile

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. The region around an installation takes on the classification of the state in which the installation is primarily located.

Indicator: **Federally Declared Disasters (LO4)**
Variables: Number of Federally declared natural disasters in the categories of tsunami, coastal storm, drought, earthquake, flood, freezing, hurricane, typhoon, dam/levee break, mud/landslide, severe ice storm, fire, snow, tornado, volcano, and severe storm per square mile
Scale: County
Year: 12/24/1964 through 6/15/2004, totaled
Data Sources:

Federal Emergency Management Agency (FEMA), U.S. Department of Homeland Security. (2004). *Federally Declared Disasters by Calendar Year*. FEMA GIS and Data Solutions Branch. Washington, DC, available through URL http://www.fema.gov/library/drcys.shtm

International Federation of Red Cross and Red Crescent Societies (IRRCRCS). (2002). *World Disasters Report: Focus on Reducing Risk 2002*, available through URL http://www.ifrc.org/publicat/wdr2002/

Logic: In the 1990s, some 2 billion people were affected by disasters world-wide (IFRCRCS 2002). No one is immune from disasters. Everyone is vulnerable, but some are more vulnerable than others. By examining historical disaster trends, one can see that it is not only weather related damage causing disasters. Flawed development patterns (e.g., rapid unplanned urbanization, deforestation, installation of non-flood-proof dykes, no early warning systems, etc.) are also exposing more people to disasters (IFRCRCS 2002). For example, earthquake fatalities are not necessarily the result of an earthquake but rather ineffective building codes. Tornados sweeping away homes may not be a sign of strong winds as much as poorly sited housing. There is no doubt disasters are a threat to both built structures and human health and safety. Thus, the military must be sensitive to potential threats from the natural and built environment. The mission of the installation can be severely impacted by disasters if proper provisions are not in place.

This indicator measures the number of Federally Declared Disasters occurring between 1964 and 2004. Federally declared disasters are those disasters declared by communities to the Federal government. Often times on declaration, the Federal government offers some form of relief to the community (IFRCRCS 2002). Thus whether or not a disaster is declared depends largely on the resources of the community and the aggressiveness of community leaders. Many disasters of significant consequences are not declared while some of relatively little consequences are declared. In other words, declaration may have little to do with severity. Nonetheless, Federally declared disasters offer the best indication of a community's disaster vulnerability reduction efforts. It is simply vital to use local knowledge in interpreting the Federally Declared Disasters classifications.

Replicable: This indicator can be updated annually based on Federally Declared Disasters by Calendar Year data, as collected in the National Emergency Management Information System (NEMIS) maintained by FEMA (FEMA 2004).

Directions: The database, "declarations by type," is sorted by disaster type (FEMA 2004). Eliminate those disasters that are not in the categories of tsunami, coastal storm, drought, earthquake, flood freezing, hurricane, typhoon, dam/levee break, mud/landslide, severe ice storm, fire, snow, tornado, volcano, or severe storm. Download and compile the data by U.S. counties. Import the data into a GIS program and join it with county boundary files to create a Federally Declared Disasters indicator layer.

Indicator Measure: The number of Federally declared natural disasters in the categories of tsunami, coastal storm, drought, earthquake, flood, freezing, hurricane, typhoon, dam/levee break, mud/landslide, severe ice storm, fire, snow, tornado, volcano, and severe storm for each county was summed to obtain a 38-year total for natural disasters (FEMA 2004). This sum was then divided by its respective county area (square miles) resulting in Federally declared disasters per square mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area counties. In other words, it protects against a large-area county from a more vulnerable classification because it naturally has more occurrences compared to a small-area county. Statistical analysis resulted in a mean of 0.0239 disasters per square mile and a standard deviation of 0.1136. Using these statistics along with natural breaks in the data, the following classifications were determined.

Very Low Vulnerability	(1):	<0.0245 disasters per square mile
Low Vulnerability	(2):	>=0.0245-<0.0183 disasters per square mile
Moderate Vulnerability	(3):	>=0.0183-<0.1375 disasters per square mile
Vulnerable	(4):	>=0.1375-<0.1945 disasters per square mile
High Vulnerability	(5):	>=0.1945 disasters per square mile

Rules: Installations are often in two or more counties. Therefore, regional classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county, and that percentage is multiplied by that county's value. Those values for each county around the installation are then totaled to arrive at a regional value. This value is then subject to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Tornado Occurrences (LO5)**
Variable: Tornado County-Segments per Square Mile
Scale: County
Year: 1992 - 2002
Data Source:

National Oceanic and Atmospheric Administration (NOAA). (2004). *Tornados*. U.S. Department of Commerce, Washington, DC, available through URL http://www.noaa.org/tornadoes.html

Logic: Tornadoes are one of nature's most violent storms. In an average year, about 1,000 tornadoes are reported across the United States, resulting in 80 deaths and over 1,500 injuries. A tornado is a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph or more. Damage paths can be in excess of 1 mile wide and 50 miles long (NOAA 2004). Thus, the military must be sensitive to potential threats from tornadoes. Tornadoes, just as any other severe weather conditions, are a threat to built structures, human health and safety, and the mission of the installation.

This indicator measures the number and strength of tornadoes segments that passed through a county in a given year. It is not a measure of the number of total tornadoes by strength. If a tornado stays in one county, then a "tornado" is the same as a "segment." However, if a tornado that passes through two counties, it is then counted twice. If a tornado passes through three counties, it is then counted three times, and so forth. Tornadoes come in all shapes, sizes, and strengths and can occur anywhere in the United States at any time of the year. Yet, there are several geographic and climatic characteristics that may increase the probability of experiencing a tornado. For instance, in the southern states, peak tornado season is March through May, while peak months in the northern states are during the summer (NOAA 2004).

Tracking the occurrence and strength of tornadoes provides an indication of the likelihood of similar tornado damage re-occurring in the area. Yet there is an inherent inaccuracy in attempting to summarize expectations about what will happen in the future—weather forecasting. When predicting tornadoes, forecasters look for the development of temperature and wind flow patterns in the atmosphere that can cause enough moisture, instability, lift, and wind shear for tornadic thunderstorms. Those are the four needed ingredients. But it is not as easy as it sounds. "How much is enough" of those is not a hard fast number, but varies significantly from situation to situation—and is sometimes unknown. A large variety of weather patterns can lead to tornadoes; and often, similar patterns may produce no severe weather at all. To further complicate it, the various computer models can have major biases and flaws when the forecaster tries to interpret them on the scale of thunderstorms. In other words, what may have caused several tornadoes one year may not result in any tornadoes the next year, or vice versa (NOAA 2004). The best anyone can do is to make an educated guess where the most favorable combination of ingredients tends to occur and classify the vulnerability.

Lastly, it is important to note this data is on the county level. Tornadoes typically only hit a relatively small portion of land, especially compared at the county level. Yet, to name that specific piece of land more than several hours in advance is impossible. Thus, it is often an area much greater than county borders that are highly vulnerable to tornado occurrences. In other words, if a neighboring county to the study county has a high occurrence of tornadoes; it may be wise to regard the study county as a higher potential county. Because of the inaccuracy of forecasting and large high-potential areas, it is important to use local knowledge in interpreting the tornado classifications.

Replicable: This indicator is updated annually by the NOAA Storm Prediction Center (NOAA 2004), and is available through URL

http://www.spc.noaa.gov/software/svrplot2/

Directions: Query tornado occurrences for 1992-2002 from the NOAA Storm Prediction Center's SeverePlot system is available online through URL:

http://www.spc.noaa.gov/software/svrplot2/

Download the file in a tabular format and import it into a GIS program. The file should contain an "ID" for each tornado occurrence and a latitude/longitude for the beginning of the event and latitude/longitude for the end. Single touchdowns have the same beginning and ending latitude/longitude. Use the GIS software to form a polyline shapefile from the beginning to the end of the tornado's path. Finally, intersect the tornado paths with county boundary files to note which counties the path crossed through, and use the GIS count function to get a number of tornadoes per county.

Indicator Measure: The number of tornado segments for each county was summed to obtain the total number of tornado segments occurring within a county from 1992 to 2002 (NOAA 2004). This sum was then divided by its respective county area (square miles) resulting in tornado segments per square mile. This distributes the data by area. Distributing the data by area allows for an equal comparison between large and small-area counties. In other words, it protects against a large-area county from a more vulnerable classification because it naturally has more occurrences compared to a small-area county. Statistical analysis resulted in a mean of 0.0072 tornadoes per square mile and a standard deviation of 0.0112. Using these statistics along with natural breaks in the data, the following classifications were determined.

Very Low Vulnerability	(1):	<0.0027 tornadoes per square mile
Low Vulnerability	(2):	>=0.0027-<0.0083 tornadoes per square mile
Moderate Vulnerability	(3):	>=0.0083-<0.0139 tornadoes per square mile
Vulnerable	(4):	>=0.0139-<0.0195 tornadoes per square mile
High Vulnerability	(5):	>=0.0195 tornadoes per square mile

Rules: Installations are often in two or more counties. Therefore, regional classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county, and that percentage is multiplied by that county's value. The values for each county around the installation are then totaled to arrive at a regional value. This value is then subject to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Region around an Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Sustainability Issue: Water

Indicator: **Level of Development (WA1)**
Variables: Water withdrawal, Stream flow levels
Scale: Watershed
Year: 1990
Data Sources:

USEPA. (1997). *The Index of Watershed Indicators, EPA-841-R-97-010.* Office of Water. Washington, DC, available through URL
http://www.epa.gov/wateratlas/geo/maplist.html

Hurd, B., N. Leary, R. Jones, and J. Smith. (1999). "Relative Regional Vulnerability of Water Resources to Climate Change." *Journal of the American Water Resources Association, 35*(6), pp.1399-1409, available through URL
http://www.awra.org

Logic: This indicator measures the ratio of current water withdrawal to mean annual unregulated streamflow. Watersheds with low water availability and high demand are vulnerable, i.e., in areas of development intensive use of off-stream water generally occurs resulting in decreased water availability (B. Hurd et al. 1999). With a reduction in streamflow, either via seasonal or dramatic climatic change, an increase in both in-stream and off-stream uses will occur, especially in areas of high development and high irrigation (B. Hurd et al. 1999). This indicator has an impact on the military mission if and when an installation is in an area with vulnerable watersheds. Water availability could be compromised resulting in a negative impact on soldiers, training, carrying capacity, and threatened and endangered species.

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. Watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6-digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin. There are many states that have defined down to 16-digit HUC.

Replicable: The EPA Watershed Atlas is no longer available. Current watershed information is being made available from the EPA through the Watershed Information Network (http://www.epa.gov/win/). Efforts are being made to replicate this analysis with updated data.

Directions: Download "level of development" from the EPA *Index of Watershed Indicators* at http://www.epa.gov/wateratlas/geo/maplist.html (USEPA 1997). Import the data into a GIS program and join it with watershed boundary files to create a GIS Level of Development indicator layer.

Indicator Measure: Ranges were defined as the ratio of total annual surface and groundwater withdrawals in 1990 (Q_W) to unregulated mean annual streamflow (Q_S).

$$\text{Level of Development} = (Q_W / Q_S)$$

The level of development ratings were grouped into the following classifications based on definitions created by the EPA Watershed Atlas (USEPA 1997).

Very Low Vulnerability	(1):	Low Level of Development (< 20 percent)
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Average Level of Development (20 to 85 percent)
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	High Level of Development (>85 percent)

Rules: Every installation is located primarily in one watershed, although several installations do cross watershed boundaries. The area around an installation takes on the rating of the watershed where the installation is primarily located (area basis).

Indicator: **Groundwater Depletion (WA2)**
Variables: Groundwater Outflow, Groundwater Withdrawals (annual)
Scale: Watershed
Year: 1990
Data Sources:

USEPA. (1997). *The Index of Watershed Indicators, EPA-841-R-97-010.* Office of Water. Washington, DC, available through URL:
http://www.epa.gov/wateratlas/geo/maplist.html

Hurd, B., N. Leary, R. Jones, and J. Smith. (1999). "Relative Regional Vulnerability of Water Resources to Climate Change." *Journal of the American Water Resources Association, 35*(6), pp.1399-1409, available through URL:
http://www.awra.org

Logic: This indicator shows the level of groundwater withdrawal within watersheds of the continental U.S. Groundwater depletion characterizes the extent to which rates of groundwater withdrawals exceed long-run average recharge rates, resulting in overdraft and a condition referred to as "groundwater mining" (B. Hurd et al. 1999). Average groundwater withdrawals in excess of natural baseflows indicate an unsustainable rate of groundwater use. Excessive groundwater withdrawals suggest that increased groundwater use may not be a viable adaptation to changes in surface water supply or increases in water demand (B. Hurd et al. 1999).

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. Watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6-digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin. There are many states that have defined down to 16-digit HUC.

Replicable: The EPA Watershed Atlas is no longer available. Current watershed information is being made available from the EPA through the Watershed Information Network (http://www.epa.gov/win/). Efforts are being made to replicate this analysis with updated data.

Directions: Download "groundwater outflow" and "annual groundwater withdrawals" from the EPA *Index of Watershed Indicators* (USEPA 1997) through URL:

http://www.epa.gov/wateratlas/geo/maplist.html

Import the data into a GIS program and join it with watershed boundary files to create a GIS Ground Water Depletion indicator layer.

Indicator Measure: Ranges were defined as the ratio of average groundwater withdrawals (Q_{GW}) in 1990 to annual average baseflow (Q_{Base}), reflecting the extent that groundwater use rates may exceed recharge.

$$\text{Ground Water Depletion} = (Q_{GW} / Q_{Base})$$

The groundwater depletion ratings were grouped into the following classifications based on definitions created by the EPA Watershed Atlas (USEPA 1997).

Very Low Vulnerability	(1):	Low Ground Water Depletion (<8 percent)
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Average Ground Water Depletion (8 to 25 percent)
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	High Ground Water Depletion (>25percent)

Rules: Every installation is located primarily in one watershed, although several installations do cross watershed boundaries. The area around an installation takes on the rating of the watershed where the installation is primarily located (area basis).

Indicator: **Flood Risk (WA3)**
Variable: Population
Scale: Watershed
Year: 1990
Data Source:

USEPA. (1997). *The Index of Watershed Indicators, EPA-841-R-97-010.* Office of Water. Washington, DC, available through URL:
http://www.epa.gov/wateratlas/geo/maplist.html

Hurd, B., N. Leary, R. Jones, and J. Smith. (1999). "Relative Regional Vulnerability of Water Resources to Climate Change." *Journal of the American Water Resources Association, 35*(6), pp.1399-1409, available through URL:
http://www.awra.org

Logic: This indicator is based on the current population living within a 500-Year flood plain. The flood risk indicator characterizes the extent to which lives and property are at risk of flood damages. The 500-Year Floodplain was selected over the more commonly used 100-Year standard because most, if not all, zoning standards and building practices have been based on the 100-Year standard (B. Hurd et al. 1999). This means that those living within the 100-Year Flood plain have generally taken the necessary precautions to mitigate flood risks. There is more concern and risk for populations and property that lie just beyond the margin of the 100-Year Floodplain, where people have not had regulations that have required modifications to properties to mitigate flood risks generally (B. Hurd et al. 1999). This takes into consideration the pressures on the future of negative impacts on water quality and availability. Training mission and carrying capacity would be negatively impacted as a result of a 500-Year flood. This would then place the military installation in a vulnerable state, possibly affecting the type and intensity of training that would take place on the installation. Applicable laws and regulations can be found through URL:

http://www.epa.gov/win/law.html

Replicable: The EPA Watershed Atlas is no longer available. Current watershed information is being made available from the EPA through the Watershed Information Network (http://www.epa.gov/win/). Efforts are being made to replicate this analysis with an analysis of an installation's proximity to the 100 and 500-Year Floodplain once that data is released in its entirety by FEMA.

Directions: Download "flood risk" from the EPA *Index of Watershed Indicators* through URL: http://www.epa.gov/wateratlas/geo/maplist.html (USEPA 1997). Import the data into a GIS program and join it with watershed boundary files to create a GIS Flood Risk indicator layer.

Indicator Measure: Ranges were classified as an estimated number of people within the 500-year 1990 defined floodplain. The flood vulnerability was grouped into the following classifications based on definitions created by the EPA Watershed Atlas (USEPA 1997).

Very Low Vulnerability	(1):	Low Flood Vulnerability (<20,000 people)
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Average Flood Vulnerability (20,000-200,000 people)
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	High Flood Vulnerability (<200,000 people)

Rules: Every installation is located primarily in one watershed, although several installations do cross watershed boundaries. The area around an installation takes on the rating of the watershed where the installation is primarily located (area basis).

Indicator: **Low Flow Sensitivity (WA4)**
Variables: Streamflow in cubic feet squared per second
Scale: Watershed
Year: 2002-2004
Data Sources:

USEPA. (1997). *The Index of Watershed Indicators, EPA-841-R-97-010.* Office of Water. Washington, DC, available through URL:

http://www.epa.gov/wateratlas/geo/maplist.html

Hurd, B., N. Leary, R. Jones, and J. Smith. (1999). "Relative Regional Vulnerability of Water Resources to Climate Change." *Journal of the American Water Resources Association, 35*(6), pp.1399-1409, available through URL:

http://www.awra.org

U.S. Geological Survey (USGS). (2004). National Water Information System (NWIS): Surface-Water Data for the Nation, Daily Streamflow for the Nation. Washington, DC, available through URL:

http://nwis.waterdata.usgs.gov/usa/nwis/discharge

Logic: Streamflows are critical to many riparian areas, and falling below safe threshold levels can threaten individual species or potentially endanger entire aquatic ecosystems. Riparian ecosystems where seasonal periods of extreme low flow occur are the most vulnerable to climatic and hydrologic changes. This further diminishes streamflows during the low flow seasons, since there is less capacity for enduring additional stresses (B. Hurd et al. 1999).

Impacts to the military mission would include diminished or stressed threatened and endangered species (TES) habitat and population, which in turn could negatively impact the ability for certain training and other missions. Diminished carrying capacity across training may result due to the increased erosion, as a result. Finally, the availability of water would significantly decrease resulting in resource vulnerability.

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. Watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6-digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin. There are many states that have defined down to 16-digit HUC.

Replicable: USGS surface-water data includes more than 850,000 stations recording time-series data that describe stream levels, streamflow (discharge), reservoir and lake levels, surface-water quality, and rainfall. The data is collected by automatic recorders and manual measurements by field personnel and relayed through telephones or satellites to offices where it is stored and processed. The data relayed through the Geostationary Operational Environmental Satellite (GOES) system are processed automatically in near real time, and in many cases, real-time data are available online within minutes. Annually, the USGS finalizes and publishes the daily data in a series of water-data reports. Daily streamflow data and peak data are updated annually following publication of the reports.

Due to extensive downloading and numerous calculations of streamflow data to create the Low Flow Sensitivity indicator, it is recommended that this indictor be updated annually or every other year.

Directions: Download average annual streamflow by hydrologic region for 2002 through 2004 from USGS NWIS at:

http://nwis.waterdata.usgs.gov/usa/nwis/discharge

Save files as tab-separated data. Import and join all files into a spreadsheet program. Average streamflows for each data station for 2002 through 2004. Group all data stations by HUC. Average streamflows for 2002 through 2004 by HUC. Since not all basin and sub-basin HUC have data stations, compute averages for the largest HUC units first then for smaller HUC units as data allows. Import the HUC streamflow averages from 2002-2004 into a GIS program and join them with watershed (HUC) boundary files to create a GIS Low Flow Sensitivity indicator layer.

Note, downloading average annual streamflow measurements for over 850,000 stations over 2 years results in millions of data points. Due to query limitation of the NWIS webserver, it is recommended to contact USGS Surface-Water Data Department for assistance in these queries.

Indicator Measure: This indicator measures the unregulated mean streamflow in cubic feet squared per second. Streamflow is defined as the mean value of discharge that occurs in a natural channel. This measurement is mostly independent of levels and changes in surface runoff. The low flow sensitivity indicator averages streamflows over a 2-year period. Ratings of low flow sensitivity were grouped into the following classifications based on definitions created by the EPA (USEPA 1997). A complete explanation of the EPA ranges, available through URL:

http://www.epa.gov/win/

Very Low Vulnerability	(1):	>=0.236 cubic feet squared per second
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>= 0.065 cubic feet squared per second and <0.236 cubic feet squared per second
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	< 0.065 cubic feet squared per second

Rules: Every installation is located primarily in one watershed, although several installations do cross watershed boundaries. The area around an installation takes on the rating of the watershed where the installation is primarily located (area basis).

Indicator: **Water Quality Index (WA5)**
Variables Waters meeting designated uses, Source water condition for drinking water systems, Fish & wildlife consumption advisories, Indicators of source water condition, Contaminated sediments, Ambient water quality – toxics, Water quality – conventional, Wetlands loss, Aquatic and wetlands species at risk, Loads over limits – toxics, over limits – conventional, Urban runoff potential, Agriculture runoff potential, Population change, Hydrologic modification caused by dams, Estuarine pollution susceptibility, Deposition
Scale: Watershed
Year: 1999
Data Source:

USEPA. (1999). *EPA Overall Watershed Characterization: September 1999 IWI Release*. Office of Water. Washington, DC, available through URL:

http://www.epa.gov/iwi/1999sept/catalog.html

Logic: The Index of Watershed Indicators (IWI) characterizes the condition and vulnerability of aquatic systems in each of the 2,262 watersheds in the 50 states and Puerto Rico (USEPA 1999). This involves an assessment of condition, vulnerability, and data sufficiency. All variables taken into consideration are strong indicators of pressures in the future on water quality and vulnerability, leading to greater demands and risks to water supplies (USEPA 1999). This would then place the military installation in a vulnerable state, possibly affecting the type and intensity of training that would take place on the installation. (Supplementary applicable laws and regulations can be found at http://www.epa.gov/win/law.html.)

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. Watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6-digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin. There are many states that have defined down to 16-digit HUC.

Replicable: Efforts are being made to replicate this analysis so it can be updated when new data is available using similar methodologies of the original study. The EPA intends to replicate the effort and produce new data, although the timeline is unclear at this point due to lack of funding. Replicability depends heavily on current and future monitoring programs.

Directions: Download "water quality" from the EPA Overall Watershed Characterization: September 1999 IWI Release (USEPA 1999),available through URL:

http://www.epa.gov/iwi/1999sept/catalog.html

Import the data into a GIS program and join it with watershed boundary files to create a GIS Water Quality indicator layer.

Indicator Measure: This map combines 17 disparate data layers as listed above; layers were weighted and then combined by the EPA (1999). The approach taken by the EPA can be found through URL:

http://oaspub.epa.gov/eims/direntrpt.report?p_deid=9996&p_chk=9186

Indicators of the condition of the watershed were scored and assigned to one of three categories: better water quality, water quality with less serious problems, and water quality with more serious problems (USEPA 1999). It is important to note that the strength of monitoring programs varies across the country and is reflected in the map. Areas with strong monitoring programs may show more problems than those with weaker programs. The water quality IWI ratings were defined as follows by the EPA (USEPA 1999).

Very Low Vulnerability	(1):	Better Water Quality
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Less Serious Water Quality Problems
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	More Serious Water Quality Problems

Rules: Every installation is located primarily in one watershed, although several installations do cross watershed boundaries. The area around an installation takes on the rating of the watershed where the installation is primarily located (area basis).

Sustainability Issue: Economic

Indicator: **DoD Local Employment (EC1)**
Variables: Military Employment, Total Employment
Scale: County
Year: 2003
Data Sources:

Bureau of Economic Analysis (BEA), U.S. Department of Commerce. (2005). *Regional Economic Information System*. Washington, DC. (Detailed county annual tables of income and employment by SIC industry: CA25—Total Full-Time and Part-Time Employment by Industry), available through URL:

http://www.bea.gov/bea/regional/reis/

National Governors Association Center for Best Practices. (2003). *State Strategies to Address Encroachment at Military Installations*. Natural Resources Policy Studies. Washington, DC, available through URL:

http://www.nga.org/cda/files/032403MILITARY.PDF

Logic: DoD local employment provides a measurement of the economic impact of military installations on the local economy. Military installations are often critical to local economies, accounting for thousands of jobs and for generating billions of dollars in economic activity and tax revenue (NGA Center for Best Practices 2003).

Military installations provide many benefits to their local region in terms of economic impact. Installations in areas with a strong independent economy or significant resource constraints may be economically less important to the area. This indicator is a measure of the economic investment of military employment within each county's economy. The assessment is based on the percentage of military employment within a county's total employment. It is assumed that the higher the percentage of military employment within an economy, the more likely the DoD will be looked on as a friend and field fewer complaints pertaining to stationing and mission decisions.

Replicable: Since 1969 REIS updates its datasets annually. Updated employment figures are downloadable from http://www.bea.gov/bea/regional/reis/ (BEA 2005).

Directions: Download the most recent military and total employment figures by county (BEA 2005). Import the data into a GIS program and join it with county boundary files to create a GIS DoD Local Employment indicator layer.

Indicator Measure: The DoD local employment indicator provides a measure of the percent of military employment at a county level. The indicator is calculated by dividing the total military employment within a county by its total employment then multiplying the result by 100. This yields a percentage of military employment per county.

DoD Local Employment = [(total military employment)/(total employment)]*100

This data has evident natural breaks that have been used to classify the data into vulnerability ranges. Very Low Vulnerability is the lowest level of military involvement, Moderate Vulnerability is the middle classification, and High Vulnerability indicates the highest level of military involvement, usually a major installation. Statistical analysis of the data reveals a county average of 1.15 percent of total local employment with a standard deviation value of 3.06.

Very Low Vulnerability	(1):	0-0.54 percent of total local employment
Low Vulnerability	(2):	0.55-1.07 percent of total local employment
Moderate Vulnerability	(3):	1.08-2.62 percent of total local employment
Vulnerable	(4):	2.63-4.17 percent of total local employment
High Vulnerability	(5):	>4.17 percent of total local employment

Rules: Installations are often in two or more counties. Therefore, regional classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage by that county's value. The values for each county surrounding the installation are then totaled to arrive at a value for the region. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Region Around an Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Job Availability/Unemployment (EC2)**
Variables: Unemployment Rate
Scale: County
Year: 2004
Data Sources:

Bureau of Labor Statistics (BLS), U.S. Department of Labor. (2003). *Employment Situation Explanatory Note*. Washington, DC, available through URL: http://www.bls.gov/news.release/empsit.tn.htm

Bureau of Labor Statistics (BLS), U.S. Department of Labor. (2005). Local Area Unemployment Statistics. Washington, DC, available through URL: http://www.bls.gov/lau/home.htm

Department of the Army, U.S.. (2002). *FY03 Army Well-Being Action Plan*. Deputy Chief of Staff for Personnel. Washington, DC, available through URL: http://www.odcsper.army.mil/Directorates/wb/FY03_WBAP_Vol_1.pdf

Logic: The most common measure of job availability is the unemployment rate. Theoretically, the unemployment rate characterizes the job-market in a particular area. However, the system for gathering employment data is not perfect. Unemployment surveys miss self-employed and discouraged job seekers. Other workers hold temporary jobs when they want permanent jobs, working part-time when they want to work full time, or holding jobs below their skill and education levels. Some workers counted as unemployed may be halfheartedly job-hunting to keep unemployment benefits (BLS 2003). Regretfully, there is not some quality of job measure available—comparing minimum and living wage and part-time and full-time employment.

Unemployment rates do, however, characterize the quality of life. The Army has recognized in its *Well-Being Action Plan* that “Soldier and family satisfaction help to retain Soldiers” (USDA 2002). Part of being “satisfied” is having the financial stability and employment needed to meet that. The military is beginning to move aggressively into addressing family member employment. Initial efforts are focused on establishing public partnerships with private corporations to provide training and career continuity to military spouses. A Spouse Telework Employment Program (STEP) is nearing completion and the Department of Defense is working with the Department of Labor to explore opportunities in the public sector. In the interim, the military’s Spouse Employment Program is developing capabilities in the following areas: job search assistance, private sector job bank, and career counseling. Mid and long-term objectives focus on capturing lessons learned from the initial partnerships and expanding the program to more corporations (USDA 2002).

Characteristics of the labor market reveal a lot about the economy and quality of life of a community. Although the job market may seem not to affect service members, it will affect their family members and the overall economic growth of the area. Like most economic news, a low unemployment rate is a mixed blessing. It is good news for workers and their families in terms of prosperity. But it means that employers must scramble to fill their openings, and prospective employers may be a bit wary about locating in areas where workers are hard to find and they have to offer higher wages to compete with other employers. Thus, economists have determined an ideal unemployment rate range of 4 to 5.6 percent (BLS 2003). Some level of unemployment is normal. Yet, too low or too high unemployment rates leads to problems.

Replicable: The U.S. Department of Labor, Bureau of Labor Statistics, provides unemployment statistics for the latest year available for download through URL:

http://www.bls.gov/lau/home.htm

Directions: Download unemployment rate county data from the U.S. Department of Labor, Bureau of Labor Statistics, Local Area Unemployment Statistic website available online at http://www.bls.gov/lau/home.htm (BLS 2005). Import the data into a GIS program and join it with county boundary files to create a GIS Job Availability/Unemployment indicator layer.

Indicator Measure: The rationale for the legend is based on unemployment levels around the ideal or "natural" unemployment rate (4-5.6 percent). Scholars disagree about what the exact natural rate of unemployment is and how it should be derived. From data and papers accessible through the Bureau of Labor Statistics, most scholars commonly agree on 5.5 percent natural unemployment (BLS 2003). From this, levels of unemployment that are acceptable were designated Very Low Vulnerability, and outside of this range natural breaks occurred to designate Moderate and High Vulnerability classifications.

Very Low Vulnerability	(1):	>=4 and <5.7 percent
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>=2.4 and <4 or >=5.7 and <9.1 percent
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>=0 and <2.4 or >9.1 and <=25 percent

Rules: In the case where an installation is in two or more counties, regional classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage by that county's classification value. The values for each county of the installation are then totaled to arrive at a value for the region around the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation Region = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Housing Affordability (EC3)**
Variables: Net Rents, Net Income
Scale: County
Year: 1999

Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2000). *Summary File 3: Table H69, Gross Rent as a Percentage of Household Income*. American FactFinder. Washington, DC, available through URL:

http://factfinder.census.gov

Department of Housing and Urban Development, U.S.. (2003). *Buying a Home: Find out How Much Mortgage Can You Afford*. Washington, DC

http://www.hud.gov/buying/index.cfm

Department of the Army, U.S.. (2002). *FY03 Army Well-Being Action Plan*. Deputy Chief of Staff for Personnel. Washington, DC

http://www.hud.gov/buying/index.cfm

National Association of REALTORS. (2003). *Housing Affordability*. Chicago, IL

http://www.hud.gov/buying/index.cfm

Logic: Housing affordability is "the ratio of median family income to the income needed to purchase the median priced home based on current interest rates and underwriting standards, expressed as an index" (National Association of REALTORS 2003). The National Association of Realtors compiles such an index at the national level annually. The proportion of income spent on housing can be used as a broad measure of the ease (or difficulty) that people experience in meeting their housing commitments. However to the extent that higher housing payments may reflect discretionary savings among home purchasers, care should be exercised in the use of such a measure. In the rental sector, households may choose to pay a higher rent to live close to employment and so reduce travel time and cost. Nevertheless, a comparison of the proportion of income spent on housing for different types of households and levels of income provides insight into those groups most likely to be under financial pressure through housing costs.

Housing affordability is also a characteristic of the overall cost of living. Referenced from the U.S. Department of Housing and Urban Development (HUD 2003), people typically allocate 30 percent of their income to housing. This is the largest amount allocated to any one good or service. In other words, it is a large portion of a households' spending. If housing costs are high, it detracts from an individual's ability to afford other goods and services. People living where housing costs are high are more likely to not be able to afford a standard of living as high as those living where housing costs are lower. If standard of living is lower, quality of life is lower—cannot afford the social and cultural aspects of personal enrichment (USDA 2002). More specifically to the military are DoD housing allowances. With many military employees forced to choose off-base housing, local cost of living is an important indicator in determining the DoD housing allowance.

Housing costs are determined based on gross rent within a community due to their high flexibility to change with rapidly changing market conditions.

Replicable: The U.S. Census provides housing statistics every decade reported in Summary File 3 available for download at http://www.census.gov (Bureau of the Census 2000). Housing statistics are also replicated every 5 years in a Decennial Supplementary Survey. It is recommended that the data is replicated only once a decade due to the non-comprehensiveness of the supplementary surveys.

Directions: Download table *H69 Gross Rent as Percentage of Household Income: 1999* from the U.S. Census 2000 Summary File 3 at the county level available online at http://factfinder.census.gov/ (Bureau of the Census 2000). Import the data into a GIS program and join with county boundary files to create a GIS Housing Affordability indicator layer.

Indicator Measure: Gross rent as a percentage of household income in 1999 is a computed ratio of monthly gross rent to monthly household income (total household income in 1999 divided by 12). The ratio is computed separately for each unit and is rounded to the nearest tenth. Units for which no rent is paid and units occupied by households that reported no income or a net loss in 1999 comprise the category "Not computed." The sample is assumed to be relatively normal; the classifications were configured around HUD's recommended 30 percent allocation. The national average is 29.86 percent.

Very Low Vulnerability	(1):	<30.00 percent
Low Vulnerability	(2):	>=30.01-<33.15 percent
Moderate Vulnerability	(3):	>=33.15-<36.28 percent
Vulnerable	(4):	>=36.28-<39.4 percent
High Vulnerability	(5):	>=39.4 percent

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Poverty (EC4)**
Variables: Population Under 18 Years Below Poverty, Population 18–65 Years Below Poverty, Population Above 65 Years Below Poverty, Total Population
Scale: County
Year: 2000
Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2000). *Glossary*. American FactFinder. Washington, DC. (Poverty), available through URL:
http://www.hud.gov/buying/index.cfm

Kids Count, Annie E. Casey Foundation. (2000). *The High Cost of Being Poor: Another Perspective on Helping Low-Income Families Get By and Get Ahead*. Kids Count Online Database. Baltimore, MD. (Census Data Online)
http://www.hud.gov/buying/index.cfm

Logic: This indicator measures the economic sustainability in a particular county based on the economic indicator of income. The amount of disposable income a household or individual has to provide the basic needs determine the extent to which economic development is either self-undermining or self-renewing. Many military installations depend on the economic resources of the surrounding community. Thus, it is important that current economic practices occurring around military installations focus on providing positive options and choices of future generations. Economic development thrives when there is sufficient income and stagnates without sufficient income.

Poverty rates measure the sufficiency of income to provide basic needs. Poverty rates are most easily accessible through the U.S. Census Bureau. The U.S. Census Bureau defines poverty by following the Office of Management and Budget's (OMB's) Directive 14. The Census Bureau uses a set of money income thresholds that vary by family size and composition to detect who is poor. If the total income for a family or unrelated individual falls below the relevant poverty threshold, then the family or unrelated individual is classified as being "below the poverty level" (Bureau of the Census 2000). The Kids Count project compiles these census figures into a comprehensive database addressing poverty for each U.S. County. By using these statistics, this study identifies areas with relatively high proportion of individuals without a sufficient disposable income to provide the basic needs and services (Kids Count 2000).

Lastly, it is important to note this data is on the county level, not community. Hence, it may be skewed by local "hotspots." In other words, if a county has one community ranking high in poverty, the entire county is classified as high poverty regardless of the characteristics of the remaining majority of the county. Because of this concern, it is important to use local knowledge in interpreting the poverty classifications.

Replicable: The Kids Count database is maintained by the Annie E. Casey Foundation. The database includes a comprehensive source of population poverty status at the state and county level obtained from the U.S. Census Bureau (Kids Count 2000). This indicator could be replicated every year from the U.S. Census Bureau small income and poverty estimates program based on population estimates, or every decade based on actual, verifiable counts. It is recommended that the data be replicated only once a decade due to the inaccuracy of census estimates. Poverty statistics may be obtained directly from the U.S. Census Bureau at http://factfinder.census.gov, or a "cleaned" version downloaded from the Kids Counts at http://www.aecf.org/kidscount/data.htm.

Directions: Download Population Under 18 Years Below Poverty, Population 18-65 Years Below Poverty, Population Above 65 Years Below Poverty, and Total Population for all U.S. counties from the Kids Count 2003 Database (Kids Count 2000). Import the data into a GIS program and join it with county boundary files to create a GIS Poverty indicator layer.

Indicator Measure: The poverty indicator provides a measure of the percent of the total population below the poverty level at a county level. The indicator is calculated by summing population under 18 years below poverty, population 18–65 years below poverty, and population above 65 years below poverty within a county and then dividing the total by the county's total population and finally multiplying the result by 100. This yields a percentage of poverty within a county.

Poverty = [(Population Under 18 Years Below Poverty+Population 18-65 Years Below Poverty+Population Above 65 Years Below Poverty)/Total Population]*100

The data is assumed to be relatively normal and thus classification is statistically based on the standard deviation (6.33) and national mean (13.65 percent). The classes are as follows.

Very Low Vulnerability	(1):	<=12.08 percent
Low Vulnerability	(2):	>12.08-<=13.65 percent
Moderate Vulnerability	(3):	>13.65-<=16.83 percent
Vulnerable	(4):	>16.83-<=18.40 percent
High Vulnerability	(5):	>18.40 percent

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Residential Construction Value (EC5)**
Variables: Annual Average value per unit
Scale: County
Year: 2004
Data Source:

Bureau of the Census, U.S. Department of Commerce. (2005). *New Residential Construction, Building Permits by County or Place.* Manufacturing, Mining, and Construction Statistics. Washington, DC

http://www.hud.gov/buying/index.cfm

Logic: This indicator along with Housing Affordability provides an idea of the overall cost of living. If housing costs are high, it detracts from an individual's ability to afford other goods and services. People living where housing costs are high are more likely to not be able to afford a standard of living as high as those living where housing costs are lower. If the standard of living is lower, the quality of life is lower and residents are less likely to afford the social and cultural aspects of personal enrichment. More specifically to the military are DoD housing allowances. With increasing numbers of military employees living off-base, local housing cost is an important indicator in determining the DoD housing allowance.

Additionally, the cost of local housing may be an indicator of the economic and political influence of the regional population. A more forceful and influential regional population (accustomed to a higher standard of living) competing with the military installation for services, access, resources, and land can affect the type and intensity of training that can take place on the installation.

Lastly, it is important to note this data is on the county level, not community. Hence, it may be skewed by local "hotspots." In other words, if a county has one community with a high residential construction value, the entire county is classified as high vulnerability regardless of the characteristics of the remaining majority of the county. Because of these concerns, it is important to use local knowledge in interpreting the residential construction value classifications.

Replicable: The U.S. Census provides residential construction statistics by county on new privately-owned residential housing units authorized by building permits. Data items include number of buildings, units, and construction cost for monthly new privately-owned residential building permits. This data is updated monthly. County level data are totals provided for each county in which every permit office is requested to report monthly. Data is available for download through URL:

http://www.hud.gov/buying/index.cfm

It is recommended that this indicator be updated on an annual basis. The U.S. Census, Building Permits by County or Place webserver limits queries to one county or place at a time. Thus, it is more time effective to request annual county level residential building statistics directly from the U.S. Census for a minimal fee.

Directions: Request "Annual County Level Residential Building Permits" for 2004 in ASCII format from the U.S. Census through URL:

http://www.hud.gov/buying/index.cfm

(Note, this file will include construction value.) Import the data into a spreadsheet program and sum "value" and "units" columns for each county. Calculate the residential construction value as follows.

Residential Construction Value = (Total Value of Construction in 2004/Total Units for which permits were issued in 2004)

Import the resulting math into a GIS program and join it with county boundary files to create a Residential Construction Value indicator layer.

Indicator Measure: This indicator provides a measure of the value of residential construction at a county level. The data is assumed to be relatively normal and thus classification is statistically based on the standard deviation (50,089) and national mean ($124,220 per unit) excluding 294 of 3,141 counties not reporting residential construction values in 2004. The classes are as follows.

Very Low Vulnerability	(1):	< $74,131 per unit
Low Vulnerability	(2):	>=$74,131 - <$99,175 per unit
Moderate Vulnerability	(3):	>= $99,175 - <$149,264 per unit
Vulnerable	(4):	>=$149,264 - <$174,308 per unit
High Vulnerability	(5):	>=$174,308 per unit

In random instances, the County permit office does not report the value or number of issued permits to the U.S. Census. These instances are rare but do occur.

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

> Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Housing Permits Issue Rate (EC6)**
Variables: Annual Building Permits Issued in1995 and 2004
Scale: County
Year: 1995-2004
Data Source:

Bureau of the Census, U.S. Department of Commerce. (2005). *New Residential Construction, Building Permits by County or Place.* Manufacturing, Mining, and Construction Statistics. Washington, DC, available through URL: http://www.hud.gov/buying/index.cfm

Logic: This indicator along with Rental and Housing Availability provides an idea of the availability of housing in a particular county. With an increasing number of military employees living off-base, local housing availability is an important indicator in determining DoD stationing attractiveness and quality of life for military employees and their family. Housing construction rates can directly impact a number of housing availability and quality of life indicators. For example, it may determine housing costs, commute times, access to schools or cultural amenities, or if a family may live with a service member.

Additionally, increasing residential construction may be an indicator of expected regional growth. The degree of regional population growth is a strong indicator of the demand for services, access, resources, and land in competition with the military installation. This can affect the type and intensity of training that can take place on the installation. This indicator assumes that fast growing human populations are less sustainable.

However, it is also important to note a national trend of decreasing household size (Bureau of the Census 2005). Thus, an increasing housing construction rate may be reflective of the local population consuming more housing as opposed to increasing regional population. In this case, local commercial and industrial land use would remain stable. Regardless, increasing land consumption for housing, commercial, and/or industrial uses is one of the leading causes of environmental degradation.

Lastly, it is important to note this data is on the county level, not community. Hence, it may be skewed by local "hotspots." In other words, if a county has one community with a high building permit issue rate, the entire county is classified as high vulnerability regardless of the characteristics of the remaining majority of the county. Because of these concerns, it is important to use local knowledge in interpreting the building permit issue rate classifications.

Replicable: The U.S. Census provides building permit statistics by county on new privately-owned residential housing units authorized by building permits. Data items include number of buildings, units, and construction cost for monthly new privately-owned residential building permits. This data is updated monthly. County level data are totals provided for each county in which every permit office is requested to report monthly. Data is available for download through URL

http://www.hud.gov/buying/index.cfm

It is recommended that this indicator be updated on an annual basis. The U.S. Census, Building Permits by County or Place webserver limits queries to one county or place at a time. Thus, it is more time effective to request annual county level residential building permits directly from the U.S. Census for a minimal fee.

Directions: Request "Annual County Level Residential Building Permits" for 1995 and 2004 in ASCII format from the U.S. Census at:

http://www.census.gov/const/www/permitsindex.html

Import the data into a spreadsheet program and sum total units for each county in 1995 and 2004 separately. Calculate the housing permit issue rate from 1995 to 2004 as follows.

Housing Permit Issue Rate = [(Total Issued Permits in 2004 -Total Issued Permits in 1995)/Total Issued Permits in 1995]*100

Import the resulting math into a GIS program and join it with county boundary files to create a Housing Permit Issue Rate indicator layer.

Indicator Measure: This indicator provides a measure of residential construction growth rate at a county level. The data is assumed to be relatively normal and thus classification is statistically based on the standard deviation (407) and national mean (99.1 percent) excluding 263 of 3,141 counties not reporting permit data for 1995, 2004, or both years. The classes are as follows.

Very Low Vulnerability	(1):	<=0 percent
Low Vulnerability	(2):	>0 - <=100 percent
Moderate Vulnerability	(3):	>100 - <=200 percent
Vulnerable	(4):	>200 - <=300 percent
High Vulnerability	(5):	>300 percent

In random instances, the County permit office does not report the number of issued permits to the U.S. Census. These instances are rare but do occur

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Sustainability Issue: Quality of Life

Indicator: **Crime Rate (QL1)**
Variables: Murder, Rape, Robbery, Aggravated Assault, Burglary, Larceny, Auto Theft, and Arson Counts, Population
Scale: County
Year: 2002
Data Sources:

Bureau of Investigation, U.S. Department of Justice. (2005). *Uniform Crime Reporting Program Data: County-Level Detailed Arrest and Offense Data.* National Archive of Criminal Justice Data/Inter-university Consortium for Political and Social Research. Washington, DC/Ann Arbor, MI, available through URL:

http://www.hud.gov/buying/index.cfm

Wilson, James Q., and George Kelling. (1982). *Broken Windows: The Police and Neighborhood Safety*. The Atlantic Monthly. Boston, MA, available through URL:

http://www.hud.gov/buying/index.cfm

Logic: For years, practitioners and experts in the field of law enforcement assert the crime rate as an indicator of the overall quality of life and level of public services offered in a particular area. The U.S. Department of Justice supports the theory that higher incidences of crime tend to reflect economic stagnation, sprawl, and lack of community resources. If crime is prevalent in an area, people do not wish to live there, land is used inefficiently, and economic resources are spent fighting crime. The result is diverted resource away from other priorities such as protecting the environment. For these reasons, crime statistics are highly sought after as an indicator in the decisionmaking process for location of families and military development. The hosts of social and economic pressures that high crime incidences create result in large limitation on development potential of an area to military installations. These military installations are where soldiers and their families are housed. Thus, any installation must provide for their safe and secure future.

Supporting studies for these overall quality of life and level of public services assertions can be traced to a relatively simple theory referred to as “broken windows,” which was first discussed by James Q. Wilson and George Kelling in 1982 (J.Q. Wilson et al. 1982). Wilson and Kelling prove that on a community level, disorder and crime are inextricably linked. Their analogy is simple—linking social disorder to the condition of windows in a vacant building. If a single window is broken and goes un-repaired, it is a symbol that no one cares and thus is an acceptable act within the community. It is then only a matter of time before all of the windows are broken. The failure to repair the broken window is evidence of a social failure that results in disorder and inevitably leads to more serious disorder and crime and overall lack of stability. People move to new areas excluding themselves from others, and public services decline as more resources are put into crime defense. The overall environment declines—decreased quality of life (J.Q. Wilson et al. 1982). Therefore, high incidences of crime should indicate a non-ideal location for military personnel, their families, and military operations.

The *Uniform Crime Reporting Program Data: County-Level Detailed Arrest and Offense Data, 2002* reports counts of arrests and offenses for the Uniform Crime Reports (UCR) of the National Archive of Criminal Justice Data (NACJD) index (Part I) crimes: murder, rape, robbery, aggravated assault, burglary, larceny, auto theft, and arson (Bureau of Investigation 2005). The UCR County-level Arrest files also report arrests for additional (Part II) crimes such as forgery, fraud, vice offenses, and drug possession or sale. The Federal Bureau of Investigation (FBI) originally collected the data from reports submitted by agencies and states participating in the UCR Program. Detailed discussions of reporting procedures are found in the *Uniform Crime Reporting Handbook* (Washington, DC: U.S. Government Printing Office 1980), and in the codebooks for the Inter-university Consortium for Political and Social Research (ICPSR) data collections available through URL:

http://www.hud.gov/buying/index.cfm

The FBI maintains the data in the NACJD, which is hosted by the ICPSR (Bureau of Investigation 2005).

Only Part I data—murder, rape, robbery, aggravated assault, burglary, larceny, auto theft, and arson—were used for this indicator. This data was summed by the ICPSR index and is a comprehensive list relevant to military installation quality of life assessment.

In one sense this crime data is complete because it accurately describes the accountancy of each event. Yet, in another sense, it is incomplete because it may not easily be used to explore circumstance patterns. Missing from this data is the day-to-day social context of crime, which may be understood more completely by community residents than by statistics because of the resident's expertise concerning neighborhood problems and activity patterns. For community residents, there is a wealth of information that affects their perceptions of the safety of their community. These perceptions are formed not only by crime data, but graffiti, rowdiness, public drunkenness, abandoned autos, and other such factors may be as influential in coloring perceptions and appear as threatening as murder, rape, robbery, aggravated assault, burglary, larceny, auto theft, and arson.

Lastly, it is important to note this data is on the county level, not community. Hence, it may be skewed by local "hotspots." In other words, if a county has one community ranking high in crime, the entire county is classified as high crime regardless of the characteristics of the remaining majority of the county. Because of these two concerns, it is important to use local knowledge in interpreting the crime classifications.

Replicable: The FBI provides estimations of national reported crime activity and arrest statistics from law enforcement agencies periodically. These statistics are managed by the NACJD, and are updated through the ICPSR. The NACJD data are available from the ICPSR at http://www.icpsr.umich.edu (Bureau of Investigation 2005).

Directions: Download *Study No. 4009 Uniform Crime Reporting Program Data [United States]: County-Level Detailed Arrest and Offense Data, 2002* from the NACJD/ICPSR website http://www.icpsr.umich.edu/ (Bureau of Investigation 2005). Import *Dataset 4: Crimes Reported* data into a GIS program and join it with county boundary files to create a GIS Crime Rate indicator layer.

Indicator Measure: The Crime indicator provides a measure of murder, rape, robbery, aggravated assault, burglary, larceny, auto theft, and arson arrests at a county level. The indicator is calculated by dividing the total number of the above-mentioned arrests within a county by its population and then multiplying the result by 1,000. This yields a rate of crime per 1,000 residents per county.

Crime Rate = [(murder+rape+robbery+aggravated assault+burglary+larceny+auto theft+arson arrests)/population]*1,000

Crime data was statistically classified using the standard deviation around a relatively normal mean. The national average is 46 crimes per 1,000 persons, and the standard deviation is 31. Thus, the scale is as follows.

Very Low Vulnerability	(1):	<31 crimes per 1,000 persons
Low Vulnerability	(2):	>=31-<46 crimes per 1,000 persons
Moderate Vulnerability	(3):	>=46-<62 crimes per 1,000 persons
Vulnerable	(4):	>=62-<77 crimes per 1,000 persons
High Vulnerability	(5):	>=77 crimes per 1,000 persons

Rules: Installations are often in two or more counties. Therefore, regional rating around those installations is determined by a weighted average. The weighted average calculation determines the percentage of the installation in each county and multiplies that percentage by that county's value. The values for each county surrounding an installation are then totaled to arrive at a value for the region. This value is subjected to the same metric that determined the classification of the individual counties.

Example:

> Indicator Value for the Region around an Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Housing Availability (QL2)**
Variables: Homeowner Vacancy Rate
Scale: County
Year: 2000
Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2000). *Summary File 1: Homeowner Vacancy Rate*. American FactFinder. Washington, DC, available through URL: http://www.hud.gov/buying/index.cfm

Heumann, Leonard F. (2002). Professor of Urban at Regional Planning and Psychology, University of Illinois at Urbana-Champaign. PhD, University of Pennsylvania, 1973. Adam Hall (Ed.). Champaign, IL.

Logic: This indicator along with Rental Availability provides an idea of the housing availability in a particular county and its neighboring area. Referenced in consultation with housing expert and professor at the University of Illinois Leonard Heumann, the homeownership and rental vacancy rate is relatively tight and small movements in one direction or another can have large effects in the surrounding economy. It is important to examine owner and rental availability separately to grasp a realistic picture of available housing in a given area (L.F. Heumann 2002).

With many service members required to use off base housing, housing availability is an important indicator in determining DoD stationing attractiveness and quality of life for the military and their families. Housing availability can directly impact a number of quality of life indicators. For example, it may determine commute times, access to schools or cultural amenities, or if a family may live with a service member.

Replicable: The U.S. Census provides vacancy statistics every decade reported in Summary File 1 available for download at http://www.census.gov (Bureau of the Census 2000). Vacancy statistics are also replicated as estimates annually. It is recommended that the data be replicated only once a decade due to the inaccuracy of census estimates.

Directions: Download *Homeowner Vacancy Rate* from the U.S. Census 2000 Summary File 1 at the county level. Available online at http://factfinder.census.gov/ (Bureau of the Census 2000). Import the data into a GIS program and join it with state boundary files to create a GIS Housing Availability indicator layer.

Indicator Measure: Housing Availability illustrates homeowner vacancy rate per county. It should be noted that some areas of high owner occupied vacancy might possibly be seasonal housing not occupied at the time of the census.

The rationale for the legend is that too high or too low of an owner vacancy rate can be an indicator of difficulty of obtaining housing (too low) or serious problems in the housing market and surrounding economy (too high). These rough classifications were provided from Leonard Heumann, a professor at the University of Illinois with expertise in housing issues, through a personal interview in 2002 (L.F. Heumann 2002).

Very Low Vulnerability	(1):	>=2.1-<3.5 percent
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>=1.5-<2.1 or >=3.5-<6.1 percent
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>=0-<1.5 or >=6.1 percent

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Rental Availability (QL3)**
Variables: Rental Vacancy Rate
Year: 2000
Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2000). *Summary File 1: Rental Vacancy Rate*. American FactFinder. Washington, DC, available through URL: http://www.hud.gov/buying/index.cfm

Heumann, Leonard F. (2002). Professor of Urban at Regional Planning and Psychology, University of Illinois at Urbana-Champaign. PhD, University of Pennsylvania, 1973. Adam Hall (Ed.). Champaign, IL.

Logic: This indicator along with Homeowner Availability provides an idea of the rental availability in a particular county and its neighboring area. Referenced in consultation with housing expert and professor at the University of Illinois Leonard Heumann, the homeownership and rental vacancy rate is relatively tight and small movements in one direction or another can have large effects in the surrounding economy. It is important to examine owner and rental availability separately to grasp a realistic picture of available housing in a given area (L.F. Heumann 2002).

Many military members are required to choose off base housing. Rental availability is an important indicator in determining DoD stationing attractiveness and quality of life for military members and their families. Similar to housing availability, rental availability also directly impacts a number of quality of life indicators. For example, it may determine commute times, access to schools or cultural amenities, or if a family may live with a service member.

Replicable: The U.S. Census provides vacancy statistics every decade reported in Summary File 1 available for download at http://www.census.gov (Bureau of the Census 2000). Vacancy statistics are also replicated as estimates annually. It is recommended that the data be replicated only once a decade due to the inaccuracy of census estimates.

Directions: Download *Rental Vacancy Rate* from the U.S. Census 2000 Summary File 1 at the county level. Available online at http://factfinder.census.gov/ (Bureau of the Census 2000). Import the data into a GIS program and join it with county boundary files to create a GIS Rental Availability indicator layer.

Indicator Measure: Map rental vacancy rate per county. It should be noted that some areas of high rental occupied vacancy might possibly be seasonal housing not occupied at the time of the census.

The rationale for the legend is that too high or too low a rental vacancy rate can be an indicator of difficulty of obtaining housing (too low) or serious problems in the housing market and surrounding economy (too high). These rough classifications were provided from Leonard Heumann, a professor at the University of Illinois with expertise in housing issues, through a personal interview in 2002 (L.F. Heumann 2002).

Very Low Vulnerability	(1):	>=7-<11.4 percent
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>=4.4-<7 percent or >=11.4-<13.8 percent
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>=0-<4.4 percent or >=13.8-<=100 percent

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Healthcare Availability (QL4)**
Variables: Health Professional Shortage Area (ratio of primary medical care physicians per 1,000 population)
Scale: ZIP Code
Year: 2004
Data Sources:

DA. (2002). *FY03 Army Well-Being Action Plan*. Deputy Chief of Staff for Personnel. Washington, DC, available through URL:

http://www.odcsper.army.mil/Directorates/wb/FY03_WBAP_Vol_1.pdf

Health Resources and Services Administration, U.S. Department of Health and Human Services. (2005). *HRSA Geospatial Data Warehouse: ZIP Code Tabulation Areas* . Washington, DC, available through URL:

http://datawarehouse.hrsa.gov/pcsa.htm

Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services. (2003). *What We Do*. Washington, DC, available through URL:

http://www.hhs.gov/news/press/2002pres/profile.html

Ringel, Jeanne S., Susan D. Hosek, Ben A. Vollaard, and Sergej Mahnovski. (2002). *The Elasticity of Demand for Health Care: A Review of the Literature and Its Application to the Military Health System*. National Defense Research Institute/RAND Health. Washington, DC, available through URL:

http://www.rand.org/publications/MR/MR1355/MR1355.pdf

Logic: The U.S. Department of Health and Human Service (HHS) defines healthcare as an "essential human service" (HRSA 2005). Access to preventive healthcare and treatment for families and individuals can affect both their personnel and the region's quality of life. The Army's Well-Being Program acknowledges that low availability to healthcare can diminish quality of life as populations go without preventive care such as immunizations, often leading to disease (USDA 2002). Unfortunately, healthcare is not provided equally across the nation nor do all individuals use it similarly. DoD-paid healthcare differs in several important ways from the demand for healthcare services in general (J.S. Ringel et al. 2002). These differences derive from the unusual organization structure of the Military Health System (MHS). Three key differences exist. First, active duty personnel have less discretion in seeking care than their civilian counterparts and some military duties involve higher risk. Moreover, "to ensure that active duty personnel are healthy and fit for duty, they are provided more frequent preventive and routine care than would be typical for civilian the same age" (J.S. Ringel et al. 2002). Second, TRICARE, insurance provider to DoD, treats military treatment facilities (MTF) differently than civilian care. In other words, a recipient may receive more benefits if using a MTF instead of civilian care, thus allocation between the MTF and civilian providers is a factor. Third, military beneficiaries typically use substantially more healthcare service than comparable civilians do. Thus, increased demand for prescriptions and the like (J.S. Ringel et al. 2002).

Therefore, it is important to the well-being of military installations to identify areas where healthcare is underserved. Underservice is an indication of the current health status for military operations and the lives of military personnel and their families.

The HHS' indices of Health Professional Shortage Area (HPSA) and Medical Underservice (IMU) are currently the most comprehensive sources of secondary data to characterize the health and resource capacity of communities in the United States (HRSA 2005). Both indices are compiled by the HRSA, and are used to allocate resources for Federal and sometimes state programs including the assignment of National Health Service Corps Physicians or allowing International Medical Graduates with J-1 visas to practice in a community (HRSA 2005). An HPSA is a geographically defined area having an inadequate ratio of full-time primary care, mental health, and dental practitioners to total population. IMU designation weights HPSA calculations based on regional infant mortality rates, percentage of the population with incomes below the poverty level, and percentage of the population age 65 or older. The HHS' HPSA national dataset is more complete compared to the IMU national dataset. Thus, HPSA is the selected indicator. However, because differenced do exist between communities' healthcare needs, it is important to use local knowledge in interpreting healthcare availability. A complete definition of these measures and methods. Available through URL:

http://bhpr.hrsa.gov/shortage/muadatadict.htm

HPSA data is reported at the ZIP code level. Health analysis experts recognize that there are many potential geographic units to use in the monitoring of our health system, yet there is no agreement or evidence to suggest a preferred geography. The reason for mentioning the units is that significant disparities among neighbors and community groups exist. Health is not expressed by political boundary, gender, age, occupation, etc. In other words, there is no ideal standard for expressing the degree of need in a community or at what scale to address those needs. Therefore, it must be understood that the HPSA indicator is an aggregate measure of the availability ZIP codes have to healthcare. A particular ZIP code may have many designations, yet the map aggregates all designations within any given code. Therefore, with spatially large or populous ZIP codes, the data may be skewed by local "hot-spots." Again, user knowledge of an area should be applied to the use of healthcare measurements.

Replicable: HRSA updates HPSA designations quarterly and is accessible through the HHS website at URL:

http://datawarehouse.hrsa.gov/pcsa.htm

Directions: Download HPSA designations from the HHS website. After downloading the data, "clean" the data by aggregating (averaging) rankings for ZIP codes with more than one HPSA designation. Note that some ZIP codes have insufficient data. Import the cleaned data set into a GIS program and join it with ZIP code boundary files to form a Healthcare Availability indicator layer.

Indicator Measure: This indicator identifies areas (ZIP codes) where populations are medically underserved. To be designated as an HPSA, an area must exceed a population to full-time provider ratio of 3,000 to 3,500 or more people per primary care, mental health, and dental practitioners. The lower threshold ideally apples to areas with unusually high need for providers (HRSA 2005). The indicator was calculated as a ratio of primary medical care physicians per 1,000 population as follows.

Health Professional Shortage Area = (Number of full-time primary care, mental health, and dental practitioners/total population)*1,000

Using the HRSA's recommendations, the following classifications were defined.

Very Low Vulnerability	(1):	>2.01 physicians per 1,000 population
Low Vulnerability	(2):	<=2.01->0.53 physicians per 1,000 population
Moderate Vulnerability	(3):	<=0.53->0.33 physicians per 1,000 population
Vulnerable	(4):	<=0.33->0.28 physicians per 1,000 population
High Vulnerability	(5):	>=0.28 physicians per 1,000 population

Rules: Installations are often in two or more counties. Therefore, the region around an installation is classified by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are totaled to arrive at a value for the region around the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Indicator: **Educational Attainment (QL5)**
Variables: Persons 25 years of age and older, Percent high school graduate or higher
Scale: County
Year: 2000
Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2000). *Summary File 3: Geographic Comparison Table P-11, Language, School Enrollment, and Educational Attainment*. American FactFinder. Washington, DC. (Population 25 years and over: Percent High School Graduate or Higher), available through URL:

http://factfinder.census.gov

DA. (2002). *FY03 Army Well-Being Action Plan*. Deputy Chief of Staff for Personnel. Washington, DC, available through URL:, available through URL:

http://www.odcsper.army.mil/Directorates/wb/FY03_WBAP_Vol_1.pdf

National Center for Educational Statistics, U.S. Department of Education. (2003). *Condition of Education*. Washington, DC, available through URL:

http://nces.ed.gov/programs/coe/

Logic: Educational opportunities allow individuals to grow and enrich their life. The Army places high priority on the well-being—the "personal, physical, material, mental, and spiritual state of soldiers, civilians, and their families that contributes to their preparedness to perform the Army's mission" (USDA 2002). Each year the Army updates an *Army Well-Being Action Plan*. This plan is dedicated to providing resources to meet the well-being needs of the Army as well as the entire U.S. military. These needs include the personal needs and aspirations of military personnel and family members to which education is a significant factor. The *FY03 Army Well-Being Action Plan* focuses on education and academic excellence for its personnel and their families (USDA 2002). Thus, educational attainment is a highly sought after indicator for the sustainability of military installations.

The U.S. military provides all necessary education to its members. Currently, through the Education Transition Study Memorandum of Agreement, the military education focus in now shifting to nurturing relationships between civilian institutions and military institutions to ensure swift implementation of agreements for their personnel and their families (USDA 2002). The military recognizes that it is easier to provide for education when there are resources to build off from within the surrounding community (USDA 2002). Therefore, for this indicator, the quality of an educational environment is determined by the overall educational attainment of the surrounding community. It is assumed that the percentage of the population with a high school diploma or higher is an indicator of societal support for education (including the parental and community support). With strong support, it is then assumed the educational system will be strong and have a large amount of resources put into it.

In addition to having the framework for educational opportunities for military employees, a high percentage of the population with a high school diploma or higher creates a strong pool of qualified employees for military operations.

Replicable: The U.S. Census provides educational attainment statistics every decade reported in Summary File 3 available for download at http://www.census.gov (Bureau of the Census 2000). Every year the U.S. Census provides estimated educational attainment statistics available for download at http://factfinder.census.gov/ through the American Community Survey Summary Tables (PCT-034). However, due to the inaccuracy of U.S. Census estimates, it is recommended that the data be replicated only once a decade.

Directions: Download *Geographic Comparison Table P-11. Language, School Enrollment, and Educational Attainment: 2000* from the U.S. Census website http://factfinder.census.gov/ (Bureau of the Census 2000). Import *Population 25 years and over: Percent High School Graduate or Higher* into a GIS program and join it with county boundary files to create a GIS Educational Attainment indicator layer.

Indicator Measure: Educational Attainment measures the percent of the population 25 years or older with a high school degree or higher (as calculated by the U.S. Census), and is available online at http://factfinder.census.gov/ (Bureau of the Census 2000).

The sample is assumed to be relatively normal. Therefore, the national average of 69.5 percent was used to figure class breaks. The classifications for percent population with a high school diploma or higher are as follows.

Very Low Vulnerability	(1):	>89.4 percent
Low Vulnerability	(2):	<=89.4->82.7 percent
Moderate Vulnerability	(3):	<=82.7->76.1 percent
Vulnerable	(4):	<=76.1->69.4 percent
High Vulnerability	(5):	<=69.4 percent

Rules: Installations are often in two or more counties. Therefore, regional classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the region around the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc**.**

Indicator: **Commute Time (QL6)**
Variables: Commute Time
Scale: County
Year: 2000
Data Sources:

Bureau of the Census, U.S. Department of Commerce. (2000). *Summary File 3: Geographic Comparison Table P-12, Employment Status and Commuting to Work.* American FactFinder. Washington, DC. (Workers 16 years and over: Who did not work at home-Mean travel time to work (minutes), available through URL: http://factfinder.census.gov

DA. (2002). *FY03 Army Well-Being Action Plan.* Deputy Chief of Staff for Personnel. Washington, DC, available through URL: http://www.odcsper.army.mil/Directorates/wb/FY03_WBAP_Vol_1.pdf

Surface Transportation Policy Project. (2003). *Transportation and Economic Prosperity.* Washington, DC, available through URL: http://www.transact.org/library/factsheets/transportation%20and%20economic%20prosperity%20.doc

Logic: Commute time relates to congestion of the local road network surrounding a military installation. Road congestion is an indicator of potential problems using the highway near installations. This addresses traffic from the military operations standpoint. Commute time addresses traffic from the quality of life standpoint. Individuals demand the conveniences of easy access between home and work with minimal time "wasted." Commute time also indicates the lag time in an off-post service member's ability to respond to alerts and emergencies. The natural tendency of a city is to prosper, grow, and expand outward. By nature, transportation improvements often do not keep pace with rapid population growth. Thus, commute time is a strong indicator of local quality of life. It is a measure of the inefficiency of the transportation system, which makes for happy or unhappy users (Surface Transportation Policy Project 2003).

The Surface Transportation Policy Project is a non-for-profit organization that advocates transportation systems as a component of quality of life (Surface Transportation Policy Project 2003). They cite:

> The transportation system should provide for the efficient and reliable delivery and distribution of goods and services to all markets, serve employer needs for recruitment and retention of a high-quality workforce, and be redundant, resilient, reliable, and resistant to service and system disruptions. In addition, transportation investments should support local and regional economic objectives and recognize efficient activity centers as the drivers of economic prosperity and sustainable growth.
>
> — Surface Transportation Policy Project 2003

In terms of the military, installations and their environs are where the military personnel and their families live. Excessive commute times may negatively impact reenlistment rates (USDA 2002). Thus commute times are sought after as an indicator of the local quality of life.

Replicable: The U.S. Census provides commuter statistics every decade reported in Summary File 3 available for download at http://www.census.gov (Bureau of the Census 2000). Commuter statistics are also replicated annually based on Census of Population estimates. It is recommended that the data be replicated only once a decade due to the inaccuracy of the census estimates.

Directions: Download *GCT-P12 Employment Status and Commuting to Work: 2000* from the U.S. Census 2000 Summary File 3 at the county level available online at http://factfinder.census.gov/ (Bureau of the Census 2000). Import *Workers 16 years and over: Who did not work at home—Mean travel time to work (minutes)* data into a GIS program and join it with county boundary files to create a GIS Commute Time indicator layer.

Indicator Measure: The U.S. Census Bureau reports average commute-time in minutes for each county (Bureau of the Census 2000). The national average was reported at 23 minutes for 2000. Since the sample is assumed to be relatively normal, the classifications were statistically configured using the standard deviation (1.5) around the national average.

Very Low Vulnerability	(1):	<=23 minutes
Low Vulnerability	(2):	>23-<=24.5 minutes
Moderate Vulnerability	(3):	>24.5-<=26 minutes
Vulnerable	(4):	>26-<=27 minutes
High Vulnerability	(5):	>27 minutes

Rules: Installations are often in two or more counties. Therefore, installation classifications are determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county and multiplies that percentage for each county by that county's classification value. The values for each county are then totaled to arrive at a value for the installation. This value is subjected to the same metric that determined the classification for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc.

Sustainability Issue: Transportation

Indicator: **Airport Capacity (TR1)**
Variables: Total Enplanement, Mile Buffers
Scale: Airport
Year: 2003
Data Sources:

AirNav.Com. (2004). *"Airports"*. (Complete list of airport codes), available through URL: http://www.airnav.com/

Digital Aeronautical Flight Information File, National Imagery and Mapping Agency. (2005). *DAFIF Edition 7*. Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm

Terminal Area Forecast System, Federal Aviation Administration. (2005). *Air Mobility Command, Scott AFB*. Unclassified Corporate Database, available through URLs: http://www.apo.data.faa.gov/faatafall.HTM https://www.afd.scott.af.mil

U.S. General Accounting Office, Report to Congressional Committees. (1995). *C-17 Aircraft: Cost and Performance Issues*. National Security and International Affairs Division. Washington, DC, available through URL: http://www.fas.org/man/gao/gao9526.htm

Logic: This indicator provides a measurement of the amount of access available to the military at commercial airports. The DoD has identified a need to augment military airfields with access to commercial airports (USGAO 1995). Often it is unnecessary to duplicate the provisions of a nearby civilian airport on a military airfield. Thus, identification of commercial airport capacity is a highly sought after indicator in the decisionmaking process for military development. Air space pressures created from high use levels result in large limitation on development potential of an area to military installations' air space missions. Airport operations (takeoffs and landings) are often reported for regions verses specific airports. Annual enplanements (persons boarding an airplane including certified, commuter, air-taxi, foreign, and in-transit planes) are reported at the airport level. Therefore, for the purposes of this study, total enplanements were used to measure airport capacity.

Total enplanements, however, have some limitations. Because it is a measure of the number of people using the airspace and not the number of planes using the airspace, it is not an adequate representation of the airspace capacity. For instance, two identical airports may both enplane 400 persons per day, but one airport enplanes all 400 persons onto one plane while the other airport enplanes the 400 persons among three planes. The airport enplaning three planes theoretically should have a lower availability to support military air operations, yet within this system both airports are rated equally. Although, this is a critical limitation of the data, the limitations of using available aircraft operation data are greater. Aircraft operations are not reported nationally at the airport level. The lowest level available is at the state level (TAF 2005). Because of this, airport capacity ratings are heavily skewed by local “hotspots.” In other words, if a state has one community ranking low in airport capacity, the entire state is classified as low capacity regardless of the characteristics of the remaining majority of the state. Aircraft operations data additionally does not take into consideration that installations located near state boundaries use airports located in more than one state. Because of these two concerns, the amount of people using an airport (total enplanements) is the preferred method to measuring airport capacity as long as local knowledge of activity patterns is understood in interpreting the capacity classifications of commercial airports.

Total enplanement data is most readily and widely available from the Federal Aviation Administration’s (FAA) Terminal Area Forecast System (TAF). TAF is the official aviation activity forecast of the FAA. It contains historical aviation activity data and FAA’s forecasts for 474 airports receiving FAA contract tower and radar service. This database also includes projections for more than 3,000 other airports in the National Integrated Airport Plan. The forecasts, covering fiscal years 2000-2030, project activity of four major users of the U.S. air traffic system: air carriers, air taxi and commuters, general aviation, and the military (TAF 2005). The FAA uses these forecasts to meet its budget and planning needs. It may be useful to refer to these forecasts when interpreting local airport capacity ratings. Additionally, since the TAF does not track all U.S. commercial airports, it is recommended to have an understanding of which airports near the installation in question are not included in the TAF database.

Finally, this indicator may be used in conjunction with Airspace Demand indicators to provide a greater understanding of airspace availability in a particular region.

Replicable: This indicator could be replicated every year based on information updated in the TAF System (TAF 2005).

Directions: Download the GIS airport boundary files from the Digital Aeronautical Flight Information File (AVDAFIF>ARPT.ZIP) (DAFIF 2005), available through URL:

https://164.214.2.62/products/digitalaero/index.cfm

These boundary files include all active civil, military, joint (civil and military), and private airports for the world. Delete all non-U.S. airports for the purposes of this indicator—keeping only civil, joint, and private airports in the United States.

Download total annual enplanements for all commercial airports from the TAF System. Import the TAF commercial airport data into a GIS program and join it with the DAFIF airports boundary files by airport code to create an Airport Capacity indicator layer. Create "buffers" around these airports at 25 miles to form vulnerability-rating classifications.

Indicator Measure: This indicator provides insight into the ability of a commercial airport within 25 miles of an installation and receiving FAA contract tower and radar service to supplement military installation air operations. Not all U.S. commercial airports are tracked by total annual enplanements. Therefore, it is vital to have an understanding of which airports near to the installation in question are not included in the study. This information may be obtained from the DAFIF airport boundary files or AirNav.com at http://www.airnav.com/airports. AirNav.com provides the 3-letter codes for all airports (e.g., ORD for Chicago O'Hare International Airport) by airport type and/or geographic location (AirNav.Com 2004).

Airport Capacity classifications were defined by natural breaks in the data. The national average is 2,644,376 total annual enplanements and the standard deviation is 5,733.024. The logic remains that the more people using the airport; the less available it will be to the military.

Very Low Vulnerability	(1):	<2,262,633 Total Annual Enplanements
Low Vulnerability	(2):	>=2,262,633-<3005916 Total Annual Enplanements
Moderate Vulnerability	(3):	>=3,005,916-<5,979,049 Total Annual Enplanements
Vulnerable	(4):	>=5,979,049-<6,722,332 Total Annual Enplanements
High Vulnerability	(5):	>=6,722,332 Total Annual Enplanements

Rules: Installations typically have only one commercial airport located within a 25-mile radius. However, several installations do have two or more airports located within 25 miles. In this instance, the region around an installation takes on the airport classification of the lowest vulnerability. For instance, if two airports are located within 25 miles of an installation and one is classified as high vulnerability and the other as moderate vulnerability, the region would be classified as moderate vulnerability.

Indicator: **Proximity to Airports Suitable for C-5 Aircraft (TR2)**
Variables: Suitability for C-5 Aircraft, Mile Buffers
Scale: Airports
Year: 2001

Data Sources:

AirNav.Com. (2003). *"Airports"*. (Complete list of airport codes), available through URL: http://www.airnav.com/

Digital Aeronautical Flight Information File, National Imagery and Mapping Agency. (2005). *DAFIF Edition 6*. Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm

Terminal Area Forecast System, Federal Aviation Administration. (2001). *Air Mobility Command, Scott AFB*. Unclassified Corporate Database, available through URLs:
http://www.apo.data.faa.gov/faatafall.HTM
https://www.afd.scott.af.mil

U.S. General Accounting Office, Report to Congressional Committees. (1994). *Military Airlift: Comparison of C-5 and C-17 Airfield Availability*. National Security and International Affairs Division. Washington, DC, available through URL: http://www.globalsecurity.org/military/library/report/gao/152088.pdf

Logic: Not all aircraft types have the capability to land at every airfield due to runway strength, runway size, and runway type. Landing requirements will also vary, whether it is based on wartime or peacetime criteria. According to the July 1994 General Accounting Office (GAO) Report to Congressional Committees, *Military Airlift: Comparison of C-5 and C-17 Airfield Availability the C-5* aircraft can land on a paved runway 5,000 ft long by 90 ft wide during wartime, while normal performance is defined as landing on a paved runway 6,000 ft long by 147 ft wide (USGAO 1994).

Access to a C-5 capable runway is typically a necessity for military shipments, mobilization, and training. If access is inadequate (measured by geographical distance), then it is a strong indicator of pressures on the future use and vulnerability of air space, leading to greater demands and limitations on Military development and missions. This would then place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

The DoD has identified a need to augment military airfields with access to commercial airports (USGAO 1994). Often it is unnecessary to duplicate the provisions of a nearby civilian airport on a military airfield. Thus, identification of commercial airports suitable for C-5 aircraft is a highly sought after indicator. Specifically, this indicator provides suitability for C-5 aircraft at all commercial airports receiving Federal Aviation Administration (FAA) contract tower and radar service within a prescribed distance. Thus, not all U.S. commercial airports are tracked for C-5 suitability. It is recommended to have an understanding of which airports near the installation in question are not included in the study.

Replicable: This indicator could be replicated every year based on information updated in FAA's Terminal Area Forecast (TAF) System and Scott AFB's Airport Search Database (TAF 2001).

Directions: Download complete airport GIS boundary files from the Digital Aeronautical Flight Information File (DAFIF 2005) available through URL, available through URL:

https://164.214.2.62/products/digitalaero/index.cfm

These boundary files include all active civil, military, joint (civil and military), and private airports for the world. Delete all non-U.S. airports for the purposes of this indicator—keeping only civil, joint, and private airports in the United States.

Download C-5 suitability airport data from the TAF System at https://www.afd.scott.af.mil/ (TAF 2001). As previously mentioned, TAF does not track all U.S. commercial airports. Therefore, it is critical to use local knowledge when interpreting this indicator. Further local information may be obtained from the DAFIF airport boundary files or AirNav.com at http://www.airnav.com/airports. AirNav.com provides the 3-letter codes for all airports (e.g., ORD for Chicago O'Hare International Airport) by airport type and/or geographic location (AirNav.Com 2003). Airfield information is obtainable from the Air Mobility Command (Scott AFB) to determine whether each airfield is suitable for specific types of aircraft (i.e., C-141B, C-5, C-130, C-17, KC-10, KC-135, and C-9) (TAF 2005).

Import the TAF commercial airport data into a GIS program and join it with the DAFIF airports boundary files by airport code to create an Airport Suitability for C-5 Aircraft indicator layer. Create "buffers" around these airports at 5 and 25 miles to form vulnerability classifications.

Indicator Measure: Airport Suitability for C-5 Aircraft classifications were defined as follows.

Very Low Vulnerability	(1):	Within 5 miles of a C-5 Aircraft Suitable Airport
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Within 25 miles but greater than 5 miles of a C-5 Aircraft Suitable Airport
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	Greater than 25 miles of a C-5 Aircraft Suitable Airport

Rules: Installations typically have only one commercial airport located within a 25-mile radius. However, several installations do have two or more airports located within 25 miles. In this instance, an installation takes on the airport classification of the closest airport. For instance, if an installation were located within 5 miles of one airport and within 25 miles of another airport, the installation would be classified as very low vulnerability.

Indicator: **Proximity to Airports Suitable for C-141 Aircraft (TR3)**
Variables: Suitability for C-141 Aircraft, Mile Buffers
Scale: Airports
Year: 2001
Data Sources:

AirNav.Com. (2003). *"Airports".* (Complete list of airport codes), available through URL: http://www.airnav.com/

Digital Aeronautical Flight Information File, National Imagery and Mapping Agency. (2005). *DAFIF Edition 6.* Bethesda, MD, available through URL: https://164.214.2.62/products/digitalaero/index.cfm

Terminal Area Forecast System, Federal Aviation Administration. (2001). *Air Mobility Command, Scott AFB.* Unclassified Corporate Database, available through URL: http://www.apo.data.faa.gov/faatafall.HTM (https://www.afd.scott.af.mil)

U.S. General Accounting Office, Report to Congressional Committees. (1995). *C-17 Aircraft: Cost and Performance Issues.* National Security and International Affairs Division. Washington, DC, available through URL: http://www.fas.org/man/gao/gao9526.htm

Logic: Not all aircraft types have the capability to land at every airport due to runway strength, runway size, and runway type. Landing requirements will also vary, whether it is based on wartime or peacetime criteria. According to a January 1995 General Accounting Office (GAO) report entitled, *C-17 Aircraft: Cost and Performance Issues*, only the C-141 and C-130 aircraft have the capability of routinely performing airdrop missions (USGAO 1995).

Access to a C-141 capable runway is typically a necessity for military shipments, mobilization, and training. If access in inadequate (measured by geographical distance), then it is a strong indicator of pressures on the future use and vulnerability of air space, leading to greater demands and limitations on Military development and missions. This would then place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

The DoD has identified a need to augment military airfields with access to commercial airports (USGAO 1995). Often it is unnecessary to duplicate the provisions of a nearby civilian airport on a military airfield. Thus, identification of commercial airports suitable for C-141 aircraft is a highly sought after indicator. Specifically, this indicator provides suitability for C-141 aircraft at all commercial airports receiving

Federal Aviation Administration (FAA) contract tower and radar service within a prescribed distance. Thus, not all U.S. commercial airports are tracked for C-141 suitability. It is recommended to have an understanding of which airports near to the installation in question are not included in the study.

Replicable: This indicator could be replicated every year based on information updated in FAA's Terminal Area Forecast (TAF) System and Scott AFB's Airport Search Database (TAF 2001).

Directions: Download complete airport GIS boundary files from the Digital Aeronautical Flight Information File (DAFIF 2005), available through URL:

https://164.214.2.62/products/digitalaero/index.cfm

This boundary files identify all active civil, military, joint (civil and military), and private airports for the world. Delete all non-U.S. airports for the purposes of this indicator—keeping only civil, joint, and private airports in the United States.

Download C-141 suitability airport data from the TAF System at https://www.afd.scott.af.mil/ (TAF 2001). As previously mentioned, TAF does not track all U.S. commercial airports. Therefore, it is critical to use local knowledge when interpreting this indicator. Further local information may be obtained from the DAFIF airport boundary files or AirNav.com at http://www.airnav.com/airports. AirNav.com provides the 3-letter codes for all airports (e.g., ORD for Chicago O'Hare International Airport) by airport type and/or geographic location (AirNav.Com 2003). Airfield information is obtainable from the Air Mobility Command (Scott AFB) to determine whether each airfield is suitable for specific types of aircraft (i.e., C-141B, C-5, C-130, C-17, KC-10, KC-135, and C-9) (TAF 2005).

Import the TAF commercial airport data into a GIS program and join it with the DAFIF airport boundary files by airport code to create an Airport Suitability for C-141 Aircraft indicator layer. Create "buffers" around these airports at 5 and 25 miles to form vulnerability classifications.

Indicator Measure: Airport Suitability for C-141 aircraft classifications were defined as:

Very Low Vulnerability	(1):	Within 5 mi. of a C-141 Aircraft Suitable Airport
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Within 25 miles but greater than 5 miles of a C-141 Aircraft Suitable Airport
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	> 25 mi. of a C-141 Aircraft Suitable Airport

Rules: Installations typically have only one commercial airport located within a 25-mile radius. However, several installations do have two or more airports located within 25 miles. In this instance, an installation takes on the airport classification of the closest airport. For instance, if an installation were located within 5 miles of one airport and within 25 miles of another airport, the installation would be classified as very low vulnerability.

Indicator: **Railroad Capacity (TR4)**
Variables: Train Movements per Crossing per Day
Scale: County
Year: 2004
Data Source:

Federal Railroad Administration, U.S. Department of Transportation. (2004). *Highway-Rail Crossing Inventory by State*. Office of Safety Analysis. Washington, DC, available through URL:
http://safetydata.fra.dot.gov/OfficeofSafety/Downloads/Default.asp?page=downloadbf.asp

Logic: This indicator provides a measurement of the number of trains passing through the terminal per day. The number of daily trains crossing the terminal is an indicator of potential availability problems and congestion on the rail system. The rail system may be required by the military for material shipment and mobilization. This would then place the installation in a vulnerable state, affecting mobilization or, possibly, the type and intensity of training that could take place.

It is important to note this data is on the county level, not community or installation. Hence, it may be skewed by local "hotspots." In other words, if a county has one railroad with numerous train movements, regardless of the movement characteristics, the entire county is classified as low available capacity (high vulnerability) regardless of the characteristics of the remaining majority of the county. Additionally, there are a limited number of counties that do not have a train crossing due to either a lack of railways or a lack of highways intersecting the rails. These counties may inappropriately receive a low-vulnerability rating. Thus, it is critical to interpret data along with an understanding of local characteristics.

Replicable: This indicator could be replicated annually based on information updated in Federal Railroad Administration's *Highway-Rail Crossing Inventory by State* (FRA 2004).

Directions: Railroad capacity is defined as the number of trains per railroad crossing per day. A complete listing of railroad crossings at the state and county levels can be found using the *Highway-Rail Crossing Inventory by State* database (FRA

2004). Download county level trains per railroad per day and number of railroad crossings from the above-mentioned database. The calculation for determining the number of trains per crossing per day by county (or state) is as follows.

Number of Trains per Crossing per Day = Grand Total Number of Trains per Day / Number of Railroad Crossings

Table A3 lists some detailed example calculations for the state of Hawaii.

Table A3. List of Railroad Crossings in the State of Hawaii (USDoT. FRA 2003)

Railroad Crossing #	Railroad Line	Street	Number of Railroad Tracks	Annual Average Daily Traffic Through Crossing	No. Of Day Through Trains Per Day	No. Of Day Switch Trains Per Day	No. Of Night Through Trains Per Day	No. Of Night Switch Trains Per Day	Total No. Of Trains Per Day
311009v		Kapunakea	1	3,800	10	0	0	0	10
311010p		Fleming	1	1,700	10	0	0	0	10
311011w		Wahikuli	1	25	10	0	0	0	10
311012d		Kaniau	1	950	10	0	0	0	10
311013k		Civic Center	1	1,500	10	0	0	0	10
311014s		Puukolii	1	25	10	0	0	0	10
918996x	Hawaiian Railw	Ft Barrette Rd	1	2,000	0	0	0	0	0
918997e	Hawaiian Railw	Kalaeloa Blvd	1	17,000	0	0	0	0	0
Grand Total No. Of Trains Per Day					60	0	0	0	60

Based on the information from Table A8, the State of Hawaii has a total of 8 railroad crossings (6 active, 2 non-active) for a grand total of 60 trains per day.

Number of Trains per Crossing per Day = 60 / 6 = 10 trains per railroad crossing per day for the state of Hawaii.

Compute the "number of trains per crossing per day" for each county. Import the resulting math into a GIS program and join it to county boundary files to create a Railroad Capacity indicator layer.

Indicator Measure: Railroad Capacity classifications were defined as follows based on definitions provided by the Federal Railroad Administration (FRA 2004).

Very Low Vulnerability	(1):	<10 Trains per Crossing per Day
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>=10-<20 Trains per Crossing per Day
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>=20 Trains per Crossing per Day

Rules: Installations are often in two or more counties and regional classifications are then determined by a weighted average. The weighted average calculation determines what percentage of the installation is in each county, and that percentage is multiplied by that county's value. The values for each county around the installation are then totaled to arrive at a value for the region around an installation. This value will then be subjected to the same metric that determined the classifications for the individual counties.

Example:

Indicator Value for the Installation = (Percentage of Installation in County A* Indicator Value for County A) + (Percentage of Installation in County B* Indicator Value for County B)…etc**.**

Indicator: **Proximity to Interstate (TR5)**
Variables: Interstate Highways, Mile Buffers
Scale: Installation
Year: 2002
Data Source:

ESRI. *GIS Data and Maps Media Kit*. (2002) http://www.esri.com.

Logic: This indicator provides a measurement of the distance from the nearest interstate highway to an installation. The proximity of an interstate to an installation is an indicator of availability of transportation access. The interstate system is often required by the military for material shipment and mobilization. Lack of interstate access would place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation.

Replicable: This indicator could be replicated every year based on updated interstate highway maps as new construction occurs.

Directions: Download interstates boundary files from http://www.esri.com. Create "buffers" around these interstates at 20 and 50 miles to develop a Proximity to Interstate indicator layer.

Indicator Measure: Proximity to interstates is defined as the distance from the nearest interstate highway to an installation. All areas within 20 miles of an interstate were considered to be well served (very low vulnerability), while all areas more than 20 miles, but less than 50 miles from an interstate were considered to be moderately served (moderate vulnerability). All areas outside of these buffers are considered underserved (high vulnerability). Proximity to Interstate classifications are defined as follows.

Very Low Vulnerability	(1):	Within 20 miles of an interstate
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	Within 50 miles but greater than 20 miles from an interstate
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	Greater than 50 miles from an interstate

Rules: This indicator rates the region around an installation by evaluating its proximity to interstate highways. The region around an installation takes on the lowest vulnerability classification depending on its proximity to an interstate. For instance, if an installation straddles the 20 mile buffer—half of the installation within 20 miles the other half greater than 20 miles, the region resource takes on the "low vulnerability" classification.

Indicator: **Roadway Congestion (TR6)**
Variables: Roadway Congestion Index (RCI)
Scale: State
Year: 2003
Data Sources:

Chen, Ciao, Zhanfeng Jia, and Pravin Varaiya. (2001). *Causes and Cures of Highway Congestion*. University of California at Berkeley. Berkeley, CA, available through URL:

http://paleale.eecs.berkeley.edu/~varaiya/papers_ps.dir/csmpaperv3.pdf

Federal Highway Administration, U.S. Department of Transportation. (2005). *Highway Statistics 2003*. Office of Highway Policy Information. Washington, DC. (Table PS-1, Selected Measures for Identifying Peer States; Table VM-2, Functional System Travel Annual Vehicle-Miles; Table HM-60, Functional System Lane-Length Lane-Miles), available through URL:, available through URL:

http://www.fhwa.dot.gov/policy/ohim/hs03/ps1.htm

http://www.fhwa.dot.gov/policy/ohim/hs03/vm2.htm

http://www.fhwa.dot.gov/policy/ohim/hs03/hm60.htm

Pima Association of Governments. (2004). *Roadway Congestion*. Tucson, Arizona, available through URL:

http://www.pagnet.org/TPD/rsp/default.htm

Texas Transportation Institute (TIT). (2004). *2003 Urban Mobility Study*. Texas A&M University. College Station, Texas. (Methodology - Base UMS Calculations), available through URL:

http://mobility.tamu.edu/ums/report/methodology_appB.pdf

Texas Transportation Institute (TIT). (2003). *The Keys to Estimating Mobility*. Texas A&M University. College Station, Texas. (Chapter 5: Recommended Mobility Measures), available through URL:

http://mobility.tamu.edu/ums/estimating_mobility/chapter5.pdf

Logic: This indicator provides a measurement of the congestion of the local road network surrounding a military installation. Road congestion is an indicator of potential problems using highway system near the installation. This addresses traffic from the military operations standpoint. Congestion problems would place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation. For instance, commute times for work related travel for the local community surrounding and including the installation would be extended longer than normally expected as a result of congestion problems (TIT 2003). Heavy to severe congestion areas also impacts the quality of life for the local community (see Commute Times as a Quality of Life sustainability indicator). Highways and roads within the proximity of a large metropolitan statistical area (MSA) provide higher risks of congested travel and increasing potentials for vehicular accidents (C. Chen et al. 2001).

Additionally, it is important to note this data is on the state level, not community or installation. Hence, it may be skewed by local "hotspots." In other words, if a state has one roadway with relatively high congestion rates, the entire state may be classified as high roadway congestion regardless of the characteristics of the remaining majority of the state. Because of this concern, it is important to use local knowledge in interpreting the roadway congestion classifications. Since congestion is more associated with urban development and sprawl, the proximate to MSA indicator may be considered in conjunction with this indicator to give a better picture of the overall situation.

Replicable: This indicator could be replicated every year based on information updated annually in Federal Highway Administration's *Highway Statistics* (FHA 2005).

Directions: Road congestion is defined by the Roadway Congestion Index (RCI), which is defined as the ratio of traffic volume to road capacity, based on the *2003 Urban Mobility Study* published by the TIT (TIT 2004). The RCI, which varies from city to city, is a function of traffic volume (also defined as annual average daily traffic in vehicles/day), road segment length, and number of lanes in the road segment (TIT 2004). The U.S. Department of Transportation's Federal Highway Administration provides annual highway statistics containing urban and rural data by state on annual vehicle miles traveled (AVMT) and lane-miles (FHA 2005). The calculations for determining the RCI by state are as follows.

Daily Vehicle Miles Traveled (DVMT) = Annual Vehicle-Miles Traveled (AVMT) / 365

Freeway DVMT = Urban Freeway DVMT + Rural Freeway DVMT

Principal Arterial DVMT = Urban Principal Arterial DVMT + Rural Principal Arterial DVMT

Freeway DVMT per Lane-Mile = (Urban Freeway DVMT / Urban Freeway Lane-Miles) + (Rural Freeway DVMT / Rural Freeway Lane-Miles)

Principal Arterial DVMT per Lane-Mile = (Urban Principal Arterial DVMT / Urban Principal Arterial Lane-Miles) + (Rural Principal Arterial DVMT / Rural Principal Arterial Lane-Miles)

Roadway Congestion Index (RCI) = (((Freeway DVMT per Lane-Mile) * Freeway DVMT) + ((Principal Arterial DVMT per Lane-Mile) * Principal Arterial DVMT)) / ((14,000 * Freeway DVMT) + (5,500 * Principal Arterial DVMT))

Download Annual Freeway Vehicle-Miles Traveled, by State, Annual Rural Principal Arterial Vehicle-Miles Traveled, by State, Annual Urban Principal Arterial Vehicle-Miles Traveled, by State, and Lane-Miles Traveled by State data from the *Highway Statistics*. Calculate Roadway Congestion based on the equations above. Import the resulting math into a GIS program and join it with state boundary files to create a Roadway Congestion indicator layer. A detailed example calculation follows for the state of New York.

First, Calculate the total freeway DVMT for the state of New York.

Table A4. Annual Freeway Vehicle-Miles Traveled, by State (USDoT. FHA 2002).

	Interstate (Rural)	Interstate (Urban)	Other Freeways and Expressways
…			
New York	7,558	17,568	15,982
…			

Using Table B for the state of New York:

Rural Freeway AVMT = 7,558 million miles

Urban Freeway AVMT = 17,568 + 15,982 = 33,550 million miles

Therefore:

Rural Freeway DVMT = (7,558 * 1,000,000) / 365 = 20,706,849.32 miles

Urban Freeway DVMT = (33,550 * 1,000,000)/ 365 = 91,917,808.22 miles

Freeway DVMT = 20,706,849.32 + 91,917,808.22 = 112,624,657.54 miles

Second, calculate the principal arterial Daily Vehicle Miles Traveled (DVMT) for the state of New York.

Table A5. Annual Rural Principal Arterial Vehicle-Miles Traveled, by State (USDoT. FHA 2002)

	Principal Arterial (Rural)	Minor Arterial (Rural)	Major Collector (Rural)	Minor Collector (Rural)	Local (Rural)
…					
New York	5,120	6,232	5,279	8,903	4,361
…					

Using Table A5 for the state of New York:

Rural Principal Arterial AVMT = 5,120 + 6,232 + 5,279 + 8,903 + 4,361 = 29,895 million miles.

Therefore:

Rural Principal Arterial DVMT = (29,895 * 1,000,000) / 365 = 81,904,109.59 miles.

Table A6. Annual Urban Principal Arterial Vehicle-Miles Traveled, by State (USDoT. FHA 2002).

	Principal Arterial (Urban)	Minor Arterial (Urban)	Major Collector (Urban)	Minor Collector (Urban)
…				
New York	16,888	21,646	7,691	13,494
…				

Using Table A6 for the state of New York:

Urban Principal Arterial AVMT = 16,888 + 21,646 + 7,691 + 13,494 = 59,719 million miles.

Therefore:

Urban Principal Arterial DVMT = (59,719 * 1,000,000) / 365 = 163,613,698.63 miles

The total principal arterial DVMT can now be calculated as:

Principal Arterial DVMT = 81,904,109.59 + 163,613,698.63 = 245,517,808.22 miles

Third, calculate the freeway DVMT per lane-mile and principal arterial DVMT per lane-mile.

Table A7. Lane-Miles Traveled by State (USDoT. FHA 2002).

State	Urban (Freeway)	Urban (Principal Arterial)	Rural (Freeway)	Rural (Principal Arterial)
…				
New York	7,543	84,876	3,875	143,114
…				

Using Table A7 for the state of New York:

Urban Freeway Lane-Miles = 7,543 lane-miles

Rural Freeway Lane-Miles = 3,875 lane-miles

Urban Principal Arterial Lane-Miles = 84,876 lane-miles

Rural Principal Arterial Lane-Miles = 143,114 lane-miles

Therefore:

Freeway DVMT per Lane-Mile = (Urban Freeway DVMT / Urban Freeway Lane-Miles) + (Rural Freeway DVMT / Rural Freeway Lane-Miles)

Freeway DVMT per Lane-Mile = (91,917,808.22 / 7,543) + (20,706,849.32 / 3,875)

= 17,529.55 DVMT per Lane-Mile for the State of New York.

Principal Arterial DVMT per Lane-Mile = (Urban Principal Arterial DVMT / Urban Principal Arterial Lane-Miles) + (Rural Principal Arterial DVMT / Rural Principal Arterial Lane-Miles)

Principal Arterial DVMT per Lane-Mile = (163,613,698.63 / 84,876) + (81,904,109.59 / 143,114) = 2,499.98 DVMT per Lane-Mile for the State of New York.

Finally, calculate the RCI for the state of New York.

Roadway Congestion Index (RCI) =
(((Freeway DVMT per Lane-Mile) * (Freeway DVMT)) + ((Principal Arterial DVMT per Lane-Mile) * Principal Arterial DVMT)) / ((14,000 * Freeway DVMT) + (5,500 * Principal Arterial DVMT)))

Therefore:

RCI = (((17,529.55 * 112,624,657.54) + (2,499.98 * 245,517,808.22)) / ((14,000 * 112,624,657.54) + (5,500 * 245,517,808.22))) = 0.884 for the State of New York.

Indicator Measure: Roadway Congestion classifications were defined as follows based on information from Pima Association of Governments (Pima Association of Governments 2004).

Very Low Vulnerability	(1):	<0.57 RCI (Low Roadway Congestion)
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>=0.57-<2 RCI (Medium Roadway Congestion)
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>=2 RCI (High Roadway Congestion)

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. The region around an installation takes on the classification of the state in which the installation is primarily located.

Indicator: **Traffic Volume (TR7)**
Variables: Annual Average Daily Traffic per Lane (AADT)
Scale: State
Year: 2003
Data Sources:

Chen, Ciao, Zhanfeng Jia, and Pravin Varaiya. (2001). *Causes and Cures of Highway Congestion*. University of California at Berkeley. Berkeley, CA, available through URL:

http://paleale.eecs.berkeley.edu/~varaiya/papers_ps.dir/csmpaperv3.pdf

Federal Highway Administration, U.S. Department of Transportation. (2005). *Highway Statistics 2003*. Office of Highway Policy Information. Washington, DC. (Table HM-62, Average Daily Traffic per Lane on Principal Arterials; Appendix B, Methodology for 2003 Annual Report), available through URL:

http://www.fhwa.dot.gov/ohim/hs01/aspublished/hm62.htm;

http://mobility.tamu.edu/ums/study/methods/entire_methodology.pdf

Texas Transportation Institute (TTI). (2002). *Urban Mobility Study*. Texas A&M University. College Station, Texas. (Appendix A Exhibit A-17, 2000 Roadway Congestion Index), available through URL:

http://mobility.tamu.edu/ums/study/appendix_A/exhibit_A-17.pdf

Texas Transportation Institute (TTI). (2003). *The Keys to Estimating Mobility*. Texas A&M University. College Station, Texas. (Chapter 5: Recommended Mobility Measures), available through URL:

http://mobility.tamu.edu/ums/estimating_mobility/chapter5.pdf

Logic: This indicator provides a measurement of the congestion of the local road network in the region surrounding a military installation in terms of annual average daily traffic per lane. Traffic volume is an indicator of potential problems using the local roads near the installation. This addresses traffic from the military operations standpoint. Congestion problems would place the military installation in a vulnerable state, affecting the type and intensity of training that could take place on the installation. For instance, commute times for work related travel for the local community surrounding and including the installation would be extended longer than normally expected as a result of congestion problems (TTI 2003). Heavy to severe congestion areas also impacts the quality of life for the local community (see Commute Times as a Quality of Life sustainability indicator). Local roads within the proximity of a large metropolitan statistical area (MSA) provide higher risks of congested travel and increasing potentials for vehicular accidents (C. Chen et al. 2001).

Additionally, it is important to note this data is on the state level, not community or installation. Hence, it may be skewed by local "hotspots." In other words, if a state has one area with high local traffic volumes, it could skew the data for the entire state causing it to be classified as high traffic volumes regardless of the characteristics of the remaining majority of the state. Because of this concern, it is important to use local knowledge in interpreting the traffic volume classifications. This indicator should be taken in context and used in conjunction to proximity to MSA as a corroborating factor.

Replicable: This indicator could be replicated every year based on information updated annually in Federal Highway Administration's *Highway Statistics* (FHA 2005).

Directions: Road access is defined by annual average daily traffic (AADT), which is the number of vehicles passing through a particular road segment (FHA 2005). The Federal Highway Administration provides annual highway statistics containing urban and rural data by state on AADT. Download the *Highway Statistics* data into a GIS program and join it with state boundary files to create a Traffic Volume indicator layer.

Indicator Measure: Traffic Volume classifications were defined as follows based on definitions provided in the Texas Transportation Institute's *2002 Urban Mobility Study* (TTI 2002). From a statistical analysis of the 2003 data, the national average AADT is 5,060 vehicles.

Very Low Vulnerability	(1):	<=5500 AADT (Low Traffic Volume)
Low Vulnerability	(2):	Not Applicable
Moderate Vulnerability	(3):	>5500-<=7000 AADT (Medium Traffic Volume)
Vulnerable	(4):	Not Applicable
High Vulnerability	(5):	>7000 AADT (High Traffic Volume)

Rules: Every installation is located primarily in one state, although several installations do cross state boundaries. The region around an installation takes on the classification of the state in which the installation is primarily located.

Appendix B: Indicator Weighting Matrix by Mission/Function

Installation Mission Categories	Indicators						
	Air Quality Sustainability		Airspace Sustainability				
	Criteria Pollutant Non-Attainment	Noise Complaints	SUA, Fighter Range	SUA, Bomber Range	Terminal Airspace	MTR, Fighter Range	MTR, Bomber Range
Expeditionary Forces Facilities	3	3	3	3	3	3	3
These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.							
Training Facilities	2	3	2	2	2	2	2
These include non-expeditionary training installations, remote ranges, and reserve component training sites.							
Industrial Facilities	3	2	1	1	1	1	1
These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.							
Administrative Support Facilities	2	1	1	1	1	1	1
These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.							

Installation Mission Categories						
	Energy Sustainability					
	Electrical Grid Congestion	Electrical Reserve Margin	Renewable Energy--Wind	Renewable Energy--Solar	Renewable Energy--Biomass	Electrical Price Structure (Dereg)
Expeditionary Forces Facilities	2	2	2	2	2	2
These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.						
Training Facilities	1	1	1	1	1	1
These include non-expeditionary training installations, remote ranges, and reserve component training sites.						
Industrial Facilities	3	2	1	1	1	3
These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.						
Administrative Support Facilities	2	2	2	2	2	1
These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.						

Installation Mission Categories	Urban Development Sustainability						
	Regional Population Density	Incr. Regional Growth Rate	Regional Population Growth	Regional Land Urbanization	State Smart Growth Plans	Joint Land Use Study (JLUS)	Proximity to MSA
Expeditionary Forces Facilities These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.	3	3	3	3	3	3	3
Training Facilities These include non-expeditionary training installations, remote ranges, and reserve component training sites.	3	3	3	3	3	3	3
Industrial Facilities These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.	2	2	2	2	2	2	2
Administrative Support Facilities These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.	1	1	1	1	1	1	1

Installation Mission Categories	TES Sustainability				Locational Sustainability				
	Number of TES per State	Species at Risk	Federally Lised TES by Ecoregion	Species of Concern	Federally Declared Floods	Seismic Zones	Weather-Related damage	Federally Declared Disasters	Tornadoes
Expeditionary Forces Facilities These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.	3	3	3	3	2	1	2	2	2
Training Facilities These include non-expeditionary training installations, remote ranges, and reserve component training sites.	2	2	2	2	1	1	1	1	1
Industrial Facilities These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.	1	1	1	1	3	3	3	3	3
Administrative Support Facilities These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.	1	1	1	1	2	2	2	2	2

Installation Mission Categories	Water Sustainability				
	Level of Development	Ground Water Depletion	Flood Risk	Low Flow Sensitivity	Water Quality
Expeditionary Forces Facilities These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.	3	2	2	3	3
Training Facilities These include non-expeditionary training installations, remote ranges, and reserve component training sites.	1	1	1	2	2
Industrial Facilities These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.	1	2	2	1	2
Administrative Support Facilities These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.	2	1	2	1	1

Installation Mission Categories	Economic Sustainability					
	DoD Local Employment	Job Availability/Unemployment	Housing Affordability	Poverty	Avg Hsg Value of New Construction	Housing Permits Issued
Expeditionary Forces Facilities These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.	2	1	3	2	3	3
Training Facilities These include non-expeditionary training installations, remote ranges, and reserve component training sites.	1	1	1	1	1	3
Industrial Facilities These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.	2	2	1	1	1	2
Administrative Support Facilities These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.	2	2	3	2	3	1

Installation Mission Categories	Quality of Life Sustainability					
	Crime Rate	Housing Availability	Rental Availability	Healthcare Availability	Educational Attainment	Commute Times
Expeditionary Forces Facilities These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.	2	3	3	2	1	3
Training Facilities These include non-expeditionary training installations, remote ranges, and reserve component training sites.	1	1	1	1	1	1
Industrial Facilities These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.	1	1	1	1	2	1
Administrative Support Facilities These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.	2	3	3	2	2	2

Installation Mission Categories	Transportation Sustainability						
	Capacity of Comml Airports	Airport Suitability-C5	Airport Suitability-C141	Railroad Capacity	Proximity to Interstate	Roadway Congestion	Traffic Volume
Expeditionary Forces Facilities These include all installations (land, air, sea) that train and project forces. Includes airbases with active runways, maneuver installations, naval air facilities, and selected training installations.	3	3	3	2	2	2	2
Training Facilities These include non-expeditionary training installations, remote ranges, and reserve component training sites.	1	1	1	1	1	1	1
Industrial Facilities These include storage installations, arsenals, depots, industrial facilities, ammo plants, and ocean terminals.	2	1	1	1	2	2	2
Administrative Support Facilities These include command, control and administrative support installations, military treatment facilities, professional development installations, and RDT&E oriented locations.	2	1	1	1	2	2	2

Appendix C: Installation Region Vulnerability Scores by Service

Table C1. Installation region vulnerability scores, in rank order (Air Force).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Rome Laboratory	New York	Air Force	AFSOC	A	190
USAF Academy	Colorado	Air Force	USAFA	A	215
Keesler AFB	Mississippi	Air Force	AETC	A	223
Schriever AFB	Colorado	Air Force	AFSC	A	225
Portland IAP AGS	Oregon	Air Force	ANG AMC	I	227
Hill AFB	Utah	Air Force	AFMC	I	231
Niagara Falls IAP ARS	New York	Air Force	AFR AMC	I	233
Youngstown-Warren Reg APT ARS	Ohio	Air Force	AFR	I	238
Hurlburt Field	Florida	Air Force	AFSOC	A	241
Arnold AFB	Tennessee	Air Force	AFMC	I	243
Eglin AFB Main Base	Florida	Air Force	AFMC	I	247
Pittsburgh IAP ARS	Pennsylvania	Air Force	AFR AMC	I	247
Brooks City Base	Texas	Air Force	AFMC	A	251
Lackland AFB	Texas	Air Force	AETC	A	252
Hanscom AFB	Massachusetts	Air Force	AFMC	I	255
Edwards AFB	California	Air Force	AFMC	I	256
Randolph AFB	Texas	Air Force	AETC	A	256
Wright-Patterson AFB	Ohio	Air Force	AFMC	I	264
Los Angeles AFB	California	Air Force	AFSC	A	280
Fairchild AFB	Washington	Air Force	AMC	E	289
F.E. Warren AFB	Wyoming	Air Force	AFSC	E	306
Sheppard AFB	Texas	Air Force	AETC	E	309
Vance AFB	Oklahoma	Air Force	AETC	E	309
Mountain Home AFB	Idaho	Air Force	ACC	E	311
Minot AFB	North Dakota	Air Force	ACC	E	314
Malmstrom AFB	Montana	Air Force	AFSC	E	319
Ellsworth AFB	South Dakota	Air Force	ACC	E	322
Robins AFB	Georgia	Air Force	AFMC	E	323
Holloman AFB	New Mexico	Air Force	ACC	E	326
Altus AFB	Oklahoma	Air Force	AETC	E	327
Peterson AFB	Colorado	Air Force	AFSC	E	327
Grissom ARB	Indiana	Air Force	AFR	E	329
Whiteman AFB	Missouri	Air Force	ACC	E	329
Grand Forks AFB	North Dakota	Air Force	AMC	E	331
Maxwell AFB	Alabama	Air Force	AETC	E	332
Moody AFB	Georgia	Air Force	AFSOC ACC	E	332
Dyess AFB	Texas	Air Force	ACC	E	333
Shaw AFB	South Carolina	Air Force	ACC	E	334
McChord AFB	Washington	Air Force	AMC	E	335
Goodfellow AFB	Texas	Air Force	AETC	E	337
Barksdale AFB	Louisiana	Air Force	ACC	E	338
Columbus AFB	Mississippi	Air Force	AETC	E	340
Seymour Johnson AFB	North Carolina	Air Force	ACC	E	342
Tinker AFB	Oklahoma	Air Force	AFMC	E	344
Charleston AFB	South Carolina	Air Force	AMC	E	347
Davis-Monthan AFB	Arizona	Air Force	ACC	E	347
McEntire AGS	South Carolina	Air Force	ANG	E	348
Pope AFB	North Carolina	Air Force	AMC	E	348
Tucson IAP AGS	Arizona	Air Force	ANG AMC	E	351
General Mitchell IAP ARS	Wisconsin	Air Force	AFR AMC	E	355
Little Rock AFB	Arkansas	Air Force	AETC	E	357
Laughlin AFB	Texas	Air Force	AETC	E	358
Scott AFB	Illinois	Air Force	AMC	E	359
Westover ARB	Massachusetts	Air Force	AFR	E	359

McConnell AFB	Kansas	Air Force	AMC	E	361
Otis AGB	Massachusetts	Air Force	ANG	E	361
Kirtland AFB	New Mexico	Air Force	AFMC	E	362
Cannon AFB	New Mexico	Air Force	ACC	E	365
Springfield-Beckley MPT AGS	Ohio	Air Force	ANG	E	365
Luke AFB	Arizona	Air Force	AETC	E	366
Selfridge ANGB	Michigan	Air Force	ANG	E	367
Tyndall AFB	Florida	Air Force	AETC	E	370
Offutt AFB	Nebraska	Air Force	ACC	E	373
Nellis AFB	Nevada	Air Force	ACC	E	374
Patrick AFB	Florida	Air Force	AFSC	E	374
Homestead ARB	Florida	Air Force	AFR	E	376
Buckley AFB	Colorado	Air Force	AFSC	E	377
Dobbins ARB	Georgia	Air Force	AFR	E	377
Dover AFB	Delaware	Air Force	AMC	E	380
Stewart IAP AGS	New York	Air Force	AMC ANG	E	386
MacDill AFB	Florida	Air Force	AMC	E	393
McGuire AFB	New Jersey	Air Force	AMC	E	395
Andrews AFB	Maryland	Air Force	AMC AFSOC	E	396
Langley AFB	Virginia	Air Force	ACC	E	396
Beale AFB	California	Air Force	ACC	E	398
Willow Grove ARS	Pennsylvania	Air Force	AFR	E	401
March ARB	California	Air Force	AMC AFR	E	409
Vandenberg AFB	California	Air Force	AFSC	E	414
Bolling AFB	Washington DC	Air Force	AMC	E	416
Travis AFB	California	Air Force	AMC	E	452

Table C2. Installation region vulnerability scores, in rank order (Army).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Camp Guernsey	Wyoming	Army	NGB	T	169
Camp Grayling	Michigan	Army	NGB	T	180
Camp Grafton	North Dakota	Army	TRADOC	T	183
Fort Harrison	Montana	Army	NGB	T	190
Camp McCain	Mississippi	Army	NGB	T	194
Camp Ethan Allen	Vermont	Army	NGB	T	197
Pueblo Chemical Depot	Colorado	Army	AMC	I	197
Camp Ripley	Minnesota	Army	NGB	T	198
Umatilla Chemical Depot	Oregon	Army	AMC	I	198
Fort Chaffee	Arkansas	Army	NGB USARC	A	199
Camp Shelby	Mississippi	Army	NGB	T	200
Camp Dodge	Iowa	Army	NGB	T	201
Hawthorne Army Depot	Nevada	Army	AMC	I	204
Gowen Field and Orchard Range	Idaho	Army	NGB	T	205
Camp Crowder	Missouri	Army	NGB	T	206
Fort Gordon	Georgia	Army	TRADOC	A	206
Iowa AAP	Iowa	Army	AMC	I	206
Tooele Army Depot	Utah	Army	AMC	I	207
Camp Rilea	Oregon	Army	NGB	T	208
Fort McCoy	Wisconsin	Army	USARC	A	208
Kansas AAP	Kansas	Army	AMC	I	209
Fort Pickett	Virginia	Army	NGB	T	210
Boise Air Terminal AGS	Idaho	Army	NGB	A	211
Camp Beauregard	Louisiana	Army	NGB	T	212
Camp Edwards	Massachusetts	Army	NGB	T	212
Camp Williams	Utah	Army	NGB	T	213
Dugway Proving Ground	Utah	Army	ATEC	I	213
Camp Gruber	Oklahoma	Army	NGB	T	217
Fort Custer	Michigan	Army	NGB	T	217
Fort McPherson	Georgia	Army	FORSCOM USARC	A	217
Camp Robinson	Arkansas	Army	NGB	T	218
Fort Indiantown Gap	Pennsylvania	Army	NGB	A	219
Camp Perry	Ohio	Army	NGB	T	220
Deseret Chemical Depot	Utah	Army	AMC	I	220
Holston AAP	Tennessee	Army	AMC	I	220
Radford AAP	Virginia	Army	AMC	I	220

Fort AP Hill	Virginia	Army	MDW	T	221
McAlester AAP	Oklahoma	Army	AMC	I	221
Massachusetts Military Reservation	Massachusetts	Army		T	222
Newport Chemical Depot	Indiana	Army	AMC	I	222
Fort Huachuca	Arizona	Army	TRADOC	A	223
Pine Bluff Arsenal	Arkansas	Army	AMC	I	223
Carlisle Barracks	Pennsylvania	Army	TRADOC	A	224
Fort McClellan	Alabama	Army	TRADOC	A	224
Sierra Army Depot	California	Army	AMC	I	224
Camp Blanding	Florida	Army	NGB	T	226
Camp Fogarty	Rhode Island	Army	NGB	T	228
Camp Swift	Texas	Army	NGB	T	228
Lone Star AAP	Texas	Army	AMC	I	228
Fort Nathaniel Greene	Rhode Island	Army	USARC	T	229
Red River Army Depot	Texas	Army	AMC	I	229
Camp Navajo	Arizona	Army	NGB	T	230
Milan AAP	Tennessee	Army	AMC	I	231
Camp Atterbury	Indiana	Army	NGB	T	232
Fort Devens	Massachusetts	Army	USARC	A	233
Blue Grass Army Depot	Kentucky	Army	AMC	I	234
Camp Minden	Louisiana	Army	NGB	T	235
Mississippi AAP	Mississippi	Army	AMC	I	235
Watervliet Arsenal	New York	Army	AMC	I	235
Anniston Army Depot	Alabama	Army	AMC	I	236
White Sands Missile Range NM	New Mexico	Army	ATEC	I	237
Lake City AAP	Missouri	Army	AMC	I	238
Letterkenny Army Depot	Pennsylvania	Army	AMC	I	239
Scranton AAP	Pennsylvania	Army	AMC	I	240
Florence Mil Res	Arizona	Army	NGB	T	241
Fort Dix	New Jersey	Army	USARC	A	242
Fort Lee	Virginia	Army	TRADOC	A	243
Minneapolis-St Paul IAP ARS	Minnesota	Army	USARC AMC	I	243
Camp Roberts	California	Army	NGB	T	244
Fort Gillem	Georgia	Army	USARC ANG CIDC	A	244
Fort Ritchie	Maryland	Army	MDW	A	244
US Army Garrison Selfridge	Michigan	Army	AMC	A	244
Detrick Fort	Maryland	Army	MEDCOM	A	247
Soldier Systems Center (Natick	Massachusetts	Army	AMC	A	248
Twin Cities AAP	Minnesota	Army	AMC	I	248
Fort Sam Houston	Texas	Army	MEDCOM	A	249
Military Ocean Tml Sunny Point	North Carolina	Army	MTMC	I	249
Rock Island Arsenal	Illinois	Army	AMC	I	249
Camp Bullis	Texas	Army	MEDCOM	A	250
Redstone Arsenal	Alabama	Army	AMC	I	250
Fort Belvoir	Virginia	Army	MDW	A	251
Tobyhanna Army Depot	Pennsylvania	Army	AMC	I	251
Louisina AAP	Louisiana	Army	AMC	I	252
Corpus Christi Army Depot	Texas	Army	AMC	I	253
Camp Parks	California	Army	USARC	T	255
Fort Leavenworth	Kansas	Army	TRADOC	A	255
Kelly Support Center	Pennsylvania	Army	USARC	I	256
Lima Army Tank PLT	Ohio	Army	AMC	I	257
Yuma Proving Ground	Arizona	Army	ATEC	I	258
Fort Monmouth Main Post	New Jersey	Army	AMC	A	262
West Point Mil Reservation	New York	Army	USMA	A	264
Fort Hamilton	New York	Army	MDW	A	267
Aberdeen Proving Ground	Maryland	Army	AMC TRADOC	A	268
USA Adelphi Laboratory Center	Maryland	Army	AMC	A	271
Tripler Army Medical Center	Hawaii	Army	USARPAC	A	272
Fort Monroe	Virginia	Army	TRADOC	A	275
Pinyon Canyon	Colorado	Army	FORSCOM	E	275
Fort George G Meade	Maryland	Army	MDW	A	277
Fort Myer	Virginia	Army	MDW	A	278
Fort Lesley J McNair	Washington DC	Army	MDW	A	280
Picatinny Arsenal	New Jersey	Army	AMC	I	282
Walter Reed Army Medical Center	Washington DC	Army	MEDCOM	A	283
Fort Totten	New York	Army	MDW	A	284
Detroit Arsenal	Michigan	Army	AMC	I	286
Riverbank AAP	California	Army	AMC	I	286

Concord-CA-0696A	California	Army	MTMC	I	287
Fort Leonard Wood	Missouri	Army	TRADOC	E	294
Fort Riley	Kansas	Army	FORSCOM	E	295
Fort Wainwright	Alaska	Army	USARPAC	E	298
Yakima Training Center	Washington	Army	FORSCOM	E	299
Fort Carson	Colorado	Army	FORSCOM	E	302
Fort Story	Virginia	Army	TRADOC	A	312
Fort Greely	Alaska	Army	USARPAC	E	318
Fort Drum	New York	Army	FORSCOM	E	320
Fort Sill OK	Oklahoma	Army	TRADOC	E	324
Fort Stewart GA	Georgia	Army	FORSCOM	E	324
Fort Benning GA	Georgia	Army	TRADOC	E	326
Mickelsen Stanley R SFG MSR	North Dakota	Army	USASMDC	E	328
Fort Polk	Louisiana	Army	FORSCOM	E	337
Fort Bliss	New Mexico	Army	TRADOC	E	338
Fort Lewis	Washington	Army	FORSCOM	E	339
Fort Hood	Texas	Army	FORSCOM	E	342
Fort Rucker AL	Alabama	Army	TRADOC	E	343
Fort Jackson	South Carolina	Army	TRADOC	E	344
Fort Campbell	Tennessee	Army	FORSCOM	E	347
Hunter Army Airfield	Georgia	Army	FORSCOM	E	347
Fort Bragg	North Carolina	Army	FORSCOM	E	358
Fort Richardson	Alaska	Army	USARPAC	E	358
Fort Knox	Kentucky	Army	TRADOC	E	364
Fort Eustis	Virginia	Army	TRADOC	E	380
NTC and Fort Irwin CA	California	Army	FORSCOM	E	380
Hunter Liggett	California	Army	USARC	E	408
Pohakulua Training Area	Hawaii	Army	USARPAC	E	409
Schofield Barracks	Hawaii	Army	USARPAC	E	450
Fort Shafter	Hawaii	Army	USARPAC	E	454

Table C3. Installation region vulnerability scores, in rank order (Defense Logistics Agency).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Susquehanna DDD	Pennsylvania	DLA	OSD AT&L	I	235
Columbus DSCC	Ohio	DLA	AMC	I	253
Richmond DSC	Virginia	DLA	OSD AT&L	I	261
Tracy DDJC	California	DLA	OSD AT&L	I	283
Sharpe DDJC	California	DLA	OSD AT&L	I	284

Table C4. Installation region vulnerability scores, in rank order (Marine Corps).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Albany MCLB	Georgia	Marine Corps	MCLC	A	222
Kansas City MCRSC	Missouri	Marine Corps	MOBCOM	A	238
Twentynine Palms MAGTFTC	California	Marine Corps	TECOM	A	247
Beaufort MCAS	South Carolina	Marine Corps	TECOM	A	249
Blount Island Command	Florida	Marine Corps	MCLC	A	253
Barstow MCLB	California	Marine Corps	MCLC	A	254
Washington DC MARBKS	Washington DC	Marine Corps	MCCDC	A	280
Quantico MCB	Virginia	Marine Corps	MCCDC MCRC	A	281
San Diego MCRD	California	Marine Corps	TECOM	A	289
Camp Lejeune MCB	North Carolina	Marine Corps	TECOM	E	327
Cherry Point MCAS	North Carolina	Marine Corps	TECOM	E	337
New River MCAS	North Carolina	Marine Corps	TECOM	E	347
Parris Island MCRD	South Carolina	Marine Corps	TECOM	E	379

Bridgeport MCMWTC	California	Marine Corps	TECOM	E	390
Yuma MCAS	Arizona	Marine Corps	TECOM	E	394
Camp Pendleton MCB	California	Marine Corps	TECOM	E	432
Camp Pendleton MCAS	California	Marine Corps	TECOM	E	437
Miramar MCAS	California	Marine Corps	TECOM	E	450

Table C5. Installation region vulnerability scores, in rank order (Navy).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Cutler NRS	Maine	Navy	NAVFAC	A	208
Sugar Grove NRS	West Virginia	Navy	NCS	A	210
Puget Sound NSY	Washington	Navy	NAVSUP	I	215
Athens Navy Supply Corps School	Georgia	Navy	NETC	A	225
Crane NWSC	Indiana	Navy	NAVSEA NAVFAC	I	232
Gulfport CBC	Mississippi	Navy	NAVSUP	I	235
Charleston NWS	South Carolina	Navy	NAVSUP	I	238
Indian Island Naval Magazine	Washington	Navy	NAVSUP	I	238
Mechanicsburg NSPC Center	Pennsylvania	Navy	NAVSUP NAVSEA	I	245
Midsouth Millington NSA	Tennessee	Navy	NAVFAC	A	245
San Nicolas Island NR	California	Navy	NAVSEA	T	245
Dahlgren NSWC	Virginia	Navy	NAVSEA NAVFAC	A	247
Yorktown NWS	Virginia	Navy	NAVFAC NAVSUP	I	250
Cheatham Annex NSC	Virginia	Navy	NAVSUP	I	251
NSY Portsmouth	Maine	Navy	NAVSUP	I	256
NS Great Lakes	Illinois	Navy	NETC	A	262
Bethesda Naval Medical Center	Maryland	Navy	NMC	A	265
Portsmouth Naval Medical Center	Virginia	Navy	NMC	A	265
Jacksonville FISC	Florida	Navy	NAVSUP	I	267
Monterey NPS	California	Navy	NETC	A	270
San Clemente Island NR	California	Navy	NAVAIR	T	276
Carderock NSWC	Maryland	Navy	NAVSEA NAVFAC	I	277
Norfolk NSA	Virginia	Navy	NAVFAC	A	277
Naval Research Laboratory	Washington DC	Navy	NAVFAC	A	278
Washington NSA	Washington DC	Navy	NAVFAC	A	278
US Naval Observatory	Washington DC	Navy	USNO	A	279
Annapolis NS	Maryland	Navy	NETC	A	281
Norfolk NSY	Virginia	Navy	NAVSUP	I	282
US Naval Academy Annapolis	Maryland	Navy	USNA	A	283
Indian Head NSWC	Maryland	Navy	NAVSEA	I	286
San Diego Naval Medical Center	California	Navy	NMC	A	288
Earle NWS	New Jersey	Navy	NAVSUP	I	293
Meridian NAS	Mississippi	Navy	NAVAIR	E	294
Seal Beach NWS	California	Navy	NAVSUP	I	306
Fallon NAS	Nevada	Navy	NAVAIR	E	314
Kings Bay NSB	Georgia	Navy	NAVSEA	E	319
Everett NS	Washington	Navy	NAVSEA	E	322
Bangor NSB	Washington	Navy	NAVSEA	E	333
Whidbey Island NAS	Washington	Navy	NAVAIR	E	336
Whiting Field NAS	Florida	Navy	NAVAIR	E	337
Keyport NUWC	Washington	Navy	NAVSEA NAVSUP	E	340
Ingleside NS	Texas	Navy	NAVSEA	E	345
Pensacola NAS	Florida	Navy	NAVAIR	E	351
Corpus Christi NAS	Texas	Navy	NAVAIR	E	353
Brunswick NAS	Maine	Navy	NAVAIR	E	357
El Centro NAF	California	Navy	NAVAIR	E	358
New London NSB	Connecticut	Navy	NAVSEA	E	360
Fort Worth NAS JRB	Texas	Navy	NAVAIR NETC	E	361
Kingsville NAS	Texas	Navy	NAVAIR	E	361
Panama City CSS	Florida	Navy	NAVSEA	E	363
Atlanta NAS	Georgia	Navy	NAVAIR	E	375

Newport NAVSTA	Rhode Island	Navy	NAVSEA	E	375
Fentress NALF	Virginia	Navy	NAVAIR	E	382
NAS Lakehurst	New Jersey	Navy	NAVAIR	E	385
Willow Grove NAS and JRB	Pennsylvania	Navy	NAVAIR NETC	E	385
Jacksonville NAS	Florida	Navy	NAVAIR NAVSEA	E	388
Key West NAS	Florida	Navy	NAVAIR	E	389
New Orleans JRB	Louisiana	Navy	NAVAIR NAVSEA NETC	E	391
Patuxent River NAS	Maryland	Navy	NAVAIR	E	394
Oceana NAS	Virginia	Navy	NAVFAC NAVAIR	E	395
Little Creek Naval Amphibious Base	Virginia	Navy	NAVFAC NAVSEA	E	397
Bremerton	Washington	Navy	NAVSEA	E	405
China Lake NAWC	California	Navy	NAVAIR NAVSEA	E	405
Mayport NS	Florida	Navy	NAVSEA	E	412
Norfolk NB	Virginia	Navy	NAVSEA	E	420
Naval Air Station Lemoore	California	Navy	NAVAIR	E	434
Point Mugu NAS	California	Navy	NAVAIR NAVSEA	E	436
Coronado NB	California	Navy	NAVAIR NAVSEA	E	438
Pt Loma NB	California	Navy	NAVSEA	E	447
San Diego NB	California	Navy	NAVSUP NAVSEA	E	453

Appendix D: Installation Region Vulnerability Scores by Mission

Table D1. Installation region vulnerability scores, by mission (Air Force).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Brooks City Base	Texas	Air Force	AFMC	A	251
Hurlburt Field	Florida	Air Force	AFSOC	A	241
Keesler AFB	Mississippi	Air Force	AETC	A	223
Lackland AFB	Texas	Air Force	AETC	A	252
Los Angeles AFB	California	Air Force	AFSC	A	280
Randolph AFB	Texas	Air Force	AETC	A	256
Rome Laboratory	New York	Air Force	AFSOC	A	190
Schriever AFB	Colorado	Air Force	AFSC	A	225
USAF Academy	Colorado	Air Force	USAFA	A	215
Altus AFB	Oklahoma	Air Force	AETC	E	327
Andrews AFB	Maryland	Air Force	AMC AFSOC	E	396
Barksdale AFB	Louisiana	Air Force	ACC	E	338
Beale AFB	California	Air Force	ACC	E	398
Bolling AFB	Washington DC	Air Force	AMC	E	416
Buckley AFB	Colorado	Air Force	AFSC	E	377
Cannon AFB	New Mexico	Air Force	ACC	E	365
Charleston AFB	South Carolina	Air Force	AMC	E	347
Columbus AFB	Mississippi	Air Force	AETC	E	340
Davis-Monthan AFB	Arizona	Air Force	ACC	E	347
Dobbins ARB	Georgia	Air Force	AFR	E	377
Dover AFB	Delaware	Air Force	AMC	E	380
Dyess AFB	Texas	Air Force	ACC	E	333
Ellsworth AFB	South Dakota	Air Force	ACC	E	322
F.E. Warren AFB	Wyoming	Air Force	AFSC	E	306
Fairchild AFB	Washington	Air Force	AMC	E	289
General Mitchell IAP ARS	Wisconsin	Air Force	AFR AMC	E	355
Goodfellow AFB	Texas	Air Force	AETC	E	337
Grand Forks AFB	North Dakota	Air Force	AMC	E	331
Grissom ARB	Indiana	Air Force	AFR	E	329
Holloman AFB	New Mexico	Air Force	ACC	E	326
Homestead ARB	Florida	Air Force	AFR	E	376
Kirtland AFB	New Mexico	Air Force	AFMC	E	362
Langley AFB	Virginia	Air Force	ACC	E	396
Laughlin AFB	Texas	Air Force	AETC	E	358
Little Rock AFB	Arkansas	Air Force	AETC	E	357
Luke AFB	Arizona	Air Force	AETC	E	366
MacDill AFB	Florida	Air Force	AMC	E	393
Malmstrom AFB	Montana	Air Force	AFSC	E	319
March ARB	California	Air Force	AMC AFR	E	409
Maxwell AFB	Alabama	Air Force	AETC	E	332
McChord AFB	Washington	Air Force	AMC	E	335
McConnell AFB	Kansas	Air Force	AMC	E	361
McEntire AGS	South Carolina	Air Force	ANG	E	348
McGuire AFB	New Jersey	Air Force	AMC	E	395
Minot AFB	North Dakota	Air Force	ACC	E	314
Moody AFB	Georgia	Air Force	AFSOC ACC	E	332
Mountain Home AFB	Idaho	Air Force	ACC	E	311
Nellis AFB	Nevada	Air Force	ACC	E	374
Offutt AFB	Nebraska	Air Force	ACC	E	373
Otis AGB	Massachusetts	Air Force	ANG	E	361
Patrick AFB	Florida	Air Force	AFSC	E	374
Peterson AFB	Colorado	Air Force	AFSC	E	327
Pope AFB	North Carolina	Air Force	AMC	E	348
Robins AFB	Georgia	Air Force	AFMC	E	323

Scott AFB	Illinois	Air Force	AMC	E	359
Selfridge ANGB	Michigan	Air Force	ANG	E	367
Seymour Johnson AFB	North Carolina	Air Force	ACC	E	342
Shaw AFB	South Carolina	Air Force	ACC	E	334
Sheppard AFB	Texas	Air Force	AETC	E	309
Springfield-Beckley MPT AGS	Ohio	Air Force	ANG	E	365
Stewart IAP AGS	New York	Air Force	AMC ANG	E	386
Tinker AFB	Oklahoma	Air Force	AFMC	E	344
Travis AFB	California	Air Force	AMC	E	452
Tucson IAP AGS	Arizona	Air Force	ANG AMC	E	351
Tyndall AFB	Florida	Air Force	AETC	E	370
Vance AFB	Oklahoma	Air Force	AETC	E	309
Vandenberg AFB	California	Air Force	AFSC	E	414
Westover ARB	Massachusetts	Air Force	AFR	E	359
Whiteman AFB	Missouri	Air Force	ACC	E	329
Willow Grove ARS	Pennsylvania	Air Force	AFR	E	401
Arnold AFB	Tennessee	Air Force	AFMC	I	243
Edwards AFB	California	Air Force	AFMC	I	256
Eglin AFB Main Base	Florida	Air Force	AFMC	I	247
Hanscom AFB	Massachusetts	Air Force	AFMC	I	255
Hill AFB	Utah	Air Force	AFMC	I	231
Niagara Falls IAP ARS	New York	Air Force	AFR AMC	I	233
Pittsburgh IAP ARS	Pennsylvania	Air Force	AFR AMC	I	247
Portland IAP AGS	Oregon	Air Force	ANG AMC	I	227
Wright-Patterson AFB	Ohio	Air Force	AFMC	I	264
Youngstown-Warren Reg APT ARS	Ohio	Air Force	AFR	I	238

Table D2. Installation region vulnerability scores, by mission (Army).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Aberdeen Proving Ground	Maryland	Army	AMC TRADOC	A	268
Boise Air Terminal AGS	Idaho	Army	NGB	A	211
Camp Bullis	Texas	Army	MEDCOM	A	250
Carlisle Barracks	Pennsylvania	Army	TRADOC	A	224
Detrick Fort	Maryland	Army	MEDCOM	A	247
Fort Belvoir	Virginia	Army	MDW	A	251
Fort Chaffee	Arkansas	Army	NGB USARC	A	199
Fort Devens	Massachusetts	Army	USARC	A	233
Fort Dix	New Jersey	Army	USARC	A	242
Fort George G Meade	Maryland	Army	MDW	A	277
Fort Gillem	Georgia	Army	USARC ANG CIDC	A	244
Fort Gordon	Georgia	Army	TRADOC	A	206
Fort Hamilton	New York	Army	MDW	A	267
Fort Huachuca	Arizona	Army	TRADOC	A	223
Fort Indiantown Gap	Pennsylvania	Army	NGB	A	219
Fort Leavenworth	Kansas	Army	TRADOC	A	255
Fort Lee	Virginia	Army	TRADOC	A	243
Fort Lesley J McNair	Washington DC	Army	MDW	A	280
Fort McClellan	Alabama	Army	TRADOC	A	224
Fort McCoy	Wisconsin	Army	USARC	A	208
Fort McPherson	Georgia	Army	FORSCOM USARC	A	217
Fort Monmouth Main Post	New Jersey	Army	AMC	A	262
Fort Monroe	Virginia	Army	TRADOC	A	275
Fort Myer	Virginia	Army	MDW	A	278
Fort Ritchie	Maryland	Army	MDW	A	244
Fort Sam Houston	Texas	Army	MEDCOM	A	249
Fort Story	Virginia	Army	TRADOC	A	312
Fort Totten	New York	Army	MDW	A	284
Soldier Systems Center (Natick	Massachusetts	Army	AMC	A	248
Tripler Army Medical Center	Hawaii	Army	USARPAC	A	272
US Army Garrison Selfridge	Michigan	Army	AMC	A	244
USA Adelphi Laboratory Center	Maryland	Army	AMC	A	271
Walter Reed Army Medical Center	Washington DC	Army	MEDCOM	A	283
West Point Mil Reservation	New York	Army	USMA	A	264
Fort Benning GA	Georgia	Army	TRADOC	E	326
Fort Bliss	New Mexico	Army	TRADOC	E	338

Fort Bragg	North Carolina	Army	FORSCOM	E	358
Fort Campbell	Tennessee	Army	FORSCOM	E	347
Fort Carson	Colorado	Army	FORSCOM	E	302
Fort Drum	New York	Army	FORSCOM	E	320
Fort Eustis	Virginia	Army	TRADOC	E	380
Fort Greely	Alaska	Army	USARPAC	E	318
Fort Hood	Texas	Army	FORSCOM	E	342
Fort Jackson	South Carolina	Army	TRADOC	E	344
Fort Knox	Kentucky	Army	TRADOC	E	364
Fort Leonard Wood	Missouri	Army	TRADOC	E	294
Fort Lewis	Washington	Army	FORSCOM	E	339
Fort Polk	Louisiana	Army	FORSCOM	E	337
Fort Richardson	Alaska	Army	USARPAC	E	358
Fort Riley	Kansas	Army	FORSCOM	E	295
Fort Rucker AL	Alabama	Army	TRADOC	E	343
Fort Shafter	Hawaii	Army	USARPAC	E	454
Fort Sill OK	Oklahoma	Army	TRADOC	E	324
Fort Stewart GA	Georgia	Army	FORSCOM	E	324
Fort Wainwright	Alaska	Army	USARPAC	E	298
Hunter Army Airfield	Georgia	Army	FORSCOM	E	347
Hunter Liggett	California	Army	USARC	E	408
Mickelsen Stanley R SFG MSR	North Dakota	Army	USASMDC	E	328
NTC and Fort Irwin CA	California	Army	FORSCOM	E	380
Pinyon Canyon	Colorado	Army	FORSCOM	E	275
Pohakulua Training Area	Hawaii	Army	USARPAC	E	409
Schofield Barracks	Hawaii	Army	USARPAC	E	450
Yakima Training Center	Washington	Army	FORSCOM	E	299
Anniston Army Depot	Alabama	Army	AMC	I	236
Blue Grass Army Depot	Kentucky	Army	AMC	I	234
Concord-CA-0696A	California	Army	MTMC	I	287
Corpus Christi Army Depot	Texas	Army	AMC	I	253
Deseret Chemical Depot	Utah	Army	AMC	I	220
Detroit Arsenal	Michigan	Army	AMC	I	286
Dugway Proving Ground	Utah	Army	ATEC	I	213
Hawthorne Army Depot	Nevada	Army	AMC	I	204
Holston AAP	Tennessee	Army	AMC	I	220
Iowa AAP	Iowa	Army	AMC	I	206
Kansas AAP	Kansas	Army	AMC	I	209
Kelly Support Center	Pennsylvania	Army	USARC	I	256
Lake City AAP	Missouri	Army	AMC	I	238
Letterkenny Army Depot	Pennsylvania	Army	AMC	I	239
Lima Army Tank PLT	Ohio	Army	AMC	I	257
Lone Star AAP	Texas	Army	AMC	I	228
Louisina AAP	Louisiana	Army	AMC	I	252
McAlester AAP	Oklahoma	Army	AMC	I	221
Milan AAP	Tennessee	Army	AMC	I	231
Military Ocean Tml Sunny Point	North Carolina	Army	MTMC	I	249
Minneapolis-St Paul IAP ARS	Minnesota	Army	USARC AMC	I	243
Mississippi AAP	Mississippi	Army	AMC	I	235
Newport Chemical Depot	Indiana	Army	AMC	I	222
Picatinny Arsenal	New Jersey	Army	AMC	I	282
Pine Bluff Arsenal	Arkansas	Army	AMC	I	223
Pueblo Chemical Depot	Colorado	Army	AMC	I	197
Radford AAP	Virginia	Army	AMC	I	220
Red River Army Depot	Texas	Army	AMC	I	229
Redstone Arsenal	Alabama	Army	AMC	I	250
Riverbank AAP	California	Army	AMC	I	286
Rock Island Arsenal	Illinois	Army	AMC	I	249
Scranton AAP	Pennsylvania	Army	AMC	I	240
Sierra Army Depot	California	Army	AMC	I	224
Tobyhanna Army Depot	Pennsylvania	Army	AMC	I	251
Tooele Army Depot	Utah	Army	AMC	I	207
Twin Cities AAP	Minnesota	Army	AMC	I	248
Umatilla Chemical Depot	Oregon	Army	AMC	I	198
Watervliet Arsenal	New York	Army	AMC	I	235
White Sands Missile Range NM	New Mexico	Army	ATEC	I	237
Yuma Proving Ground	Arizona	Army	ATEC	I	258
Camp Atterbury	Indiana	Army	NGB	T	232
Camp Beauregard	Louisiana	Army	NGB	T	212
Camp Blanding	Florida	Army	NGB	T	226

Camp Crowder	Missouri	Army	NGB	T	206
Camp Dodge	Iowa	Army	NGB	T	201
Camp Edwards	Massachusetts	Army	NGB	T	212
Camp Ethan Allen	Vermont	Army	NGB	T	197
Camp Fogarty	Rhode Island	Army	NGB	T	228
Camp Grafton	North Dakota	Army	TRADOC	T	183
Camp Grayling	Michigan	Army	NGB	T	180
Camp Gruber	Oklahoma	Army	NGB	T	217
Camp Guernsey	Wyoming	Army	NGB	T	169
Camp McCain	Mississippi	Army	NGB	T	194
Camp Minden	Louisiana	Army	NGB	T	235
Camp Navajo	Arizona	Army	NGB	T	230
Camp Parks	California	Army	USARC	T	255
Camp Perry	Ohio	Army	NGB	T	220
Camp Rilea	Oregon	Army	NGB	T	208
Camp Ripley	Minnesota	Army	NGB	T	198
Camp Roberts	California	Army	NGB	T	244
Camp Robinson	Arkansas	Army	NGB	T	218
Camp Shelby	Mississippi	Army	NGB	T	200
Camp Swift	Texas	Army	NGB	T	228
Camp Williams	Utah	Army	NGB	T	213
Florence Mil Res	Arizona	Army	NGB	T	241
Fort AP Hill	Virginia	Army	MDW	T	221
Fort Custer	Michigan	Army	NGB	T	217
Fort Harrison	Montana	Army	NGB	T	190
Fort Nathaniel Greene	Rhode Island	Army	USARC	T	229
Fort Pickett	Virginia	Army	NGB	T	210
Gowen Field and Orchard Range	Idaho	Army	NGB	T	205
Massachusetts Military Reservation	Massachusetts	Army		T	222

Table D3. Installation region vulnerability scores, by mission (Defense Logistics Agency).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Columbus DSCC	Ohio	DLA	AMC	I	253
Richmond DSC	Virginia	DLA	OSD AT&L	I	261
Sharpe DDJC	California	DLA	OSD AT&L	I	284
Susquehanna DDD	Pennsylvania	DLA	OSD AT&L	I	235
Tracy DDJC	California	DLA	OSD AT&L	I	283

Table D4. Installation region vulnerability scores, by mission (Marine Corps).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Albany MCLB	Georgia	Marine Corps	MCLC	A	222
Barstow MCLB	California	Marine Corps	MCLC	A	254
Beaufort MCAS	South Carolina	Marine Corps	TECOM	A	249
Blount Island Command	Florida	Marine Corps	MCLC	A	253
Kansas City MCRSC	Missouri	Marine Corps	MOBCOM	A	238
Quantico MCB	Virginia	Marine Corps	MCCDC MCRC	A	281
San Diego MCRD	California	Marine Corps	TECOM	A	289
Twentynine Palms MAGTFTC	California	Marine Corps	TECOM	A	247
Washington DC MARBKS	Washington DC	Marine Corps	MCCDC	A	280
Bridgeport MCMWTC	California	Marine Corps	TECOM	E	390
Camp Lejeune MCB	North Carolina	Marine Corps	TECOM	E	327
Camp Pendleton MCAS	California	Marine Corps	TECOM	E	437
Camp Pendleton MCB	California	Marine Corps	TECOM	E	432
Cherry Point MCAS	North Carolina	Marine Corps	TECOM	E	337
Miramar MCAS	California	Marine Corps	TECOM	E	450
New River MCAS	North Carolina	Marine Corps	TECOM	E	347
Parris Island MCRD	South Carolina	Marine Corps	TECOM	E	379
Yuma MCAS	Arizona	Marine Corps	TECOM	E	394

Table D5. Installation region vulnerability scores, by mission (Navy).

Installation Region	State	Branch	MACOM	Mission	Vulnerability Score
Annapolis NS	Maryland	Navy	NETC	A	281
Athens Navy Supply Corps School	Georgia	Navy	NETC	A	225
Bethesda Naval Medical Center	Maryland	Navy	NMC	A	265
Cutler NRS	Maine	Navy	NAVFAC	A	208
Dahlgren NSWC	Virginia	Navy	NAVSEA NAVFAC	A	247
Midsouth Millington NSA	Tennessee	Navy	NAVFAC	A	245
Monterey NPS	California	Navy	NETC	A	270
Naval Research Laboratory	Washington DC	Navy	NAVFAC	A	278
Norfolk NSA	Virginia	Navy	NAVFAC	A	277
NS Great Lakes	Illinois	Navy	NETC	A	262
Portsmouth Naval Medical Center	Virginia	Navy	NMC	A	265
San Diego Naval Medical Center	California	Navy	NMC	A	288
Sugar Grove NRS	West Virginia	Navy	NCS	A	210
US Naval Academy Annapolis	Maryland	Navy	USNA	A	283
US Naval Observatory	Washington DC	Navy	USNO	A	279
Washington NSA	Washington DC	Navy	NAVFAC	A	278
Atlanta NAS	Georgia	Navy	NAVAIR	E	375
Bangor NSB	Washington	Navy	NAVSEA	E	333
Bremerton	Washington	Navy	NAVSEA	E	405
Brunswick NAS	Maine	Navy	NAVAIR	E	357
China Lake NAWC	California	Navy	NAVAIR NAVSEA	E	405
Coronado NB	California	Navy	NAVAIR NAVSEA	E	438
Corpus Christi NAS	Texas	Navy	NAVAIR	E	353
El Centro NAF	California	Navy	NAVAIR	E	358
Everett NS	Washington	Navy	NAVSEA	E	322
Fallon NAS	Nevada	Navy	NAVAIR	E	314
Fentress NALF	Virginia	Navy	NAVAIR	E	382
Fort Worth NAS JRB	Texas	Navy	NAVAIR NETC	E	361
Ingleside NS	Texas	Navy	NAVSEA	E	345
Jacksonville NAS	Florida	Navy	NAVAIR NAVSEA	E	388
Key West NAS	Florida	Navy	NAVAIR	E	389
Keyport NUWC	Washington	Navy	NAVSEA NAVSUP	E	340
Kings Bay NSB	Georgia	Navy	NAVSEA	E	319
Kingsville NAS	Texas	Navy	NAVAIR	E	361
Little Creek Naval Amphibious Base	Virginia	Navy	NAVFAC NAVSEA	E	397
Mayport NS	Florida	Navy	NAVSEA	E	412
Meridian NAS	Mississippi	Navy	NAVAIR	E	294
NAS Lakehurst	New Jersey	Navy	NAVAIR	E	385
Naval Air Station Lemoore	California	Navy	NAVAIR	E	434
New London NSB	Connecticut	Navy	NAVSEA	E	360
New Orleans JRB	Louisiana	Navy	NAVAIR NAVSEA NETC	E	391
Newport NAVSTA	Rhode Island	Navy	NAVSEA	E	375
Norfolk NB	Virginia	Navy	NAVSEA	E	420
Oceana NAS	Virginia	Navy	NAVFAC NAVAIR	E	395
Panama City CSS	Florida	Navy	NAVSEA	E	363
Patuxent River NAS	Maryland	Navy	NAVAIR	E	394
Pensacola NAS	Florida	Navy	NAVAIR	E	351
Point Mugu NAS	California	Navy	NAVAIR NAVSEA	E	436
Pt Loma NB	California	Navy	NAVSEA	E	447
San Diego NB	California	Navy	NAVSUP NAVSEA	E	453
Whidbey Island NAS	Washington	Navy	NAVAIR	E	336
Whiting Field NAS	Florida	Navy	NAVAIR	E	337
Willow Grove NAS and JRB	Pennsylvania	Navy	NAVAIR NETC	E	385
Carderock NSWC	Maryland	Navy	NAVSEA NAVFAC	I	277
Charleston NWS	South Carolina	Navy	NAVSUP	I	238
Cheatham Annex NSC	Virginia	Navy	NAVSUP	I	251
Crane NWSC	Indiana	Navy	NAVSEA NAVFAC	I	232
Earle NWS	New Jersey	Navy	NAVSUP	I	293
Gulfport CBC	Mississippi	Navy	NAVSUP	I	235
Indian Head NSWC	Maryland	Navy	NAVSEA	I	286
Indian Island Naval Magazine	Washington	Navy	NAVSUP	I	238
Jacksonville FISC	Florida	Navy	NAVSUP	I	267
Mechanicsburg NSPC Center	Pennsylvania	Navy	NAVSUP NAVSEA	I	245
Norfolk NSY	Virginia	Navy	NAVSUP	I	282

NSY Portsmouth	Maine	Navy	NAVSUP	I	256
Puget Sound NSY	Washington	Navy	NAVSUP	I	215
Seal Beach NWS	California	Navy	NAVSUP	I	306
Yorktown NWS	Virginia	Navy	NAVFAC NAVSUP	I	250
San Clemente Island NR	California	Navy	NAVAIR	T	276
San Nicolas Island NR	California	Navy	NAVSEA	T	245

Appendix E: Interactive Installation Region Vulnerability Scores Spreadsheet

Electronically attached as "AppendixE.xls."

AppendixE.xls

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14. ABSTRACT

A key concern for Department of Defense (DoD) installations is their ability to sustain, and sometimes change or expand, their mission activities. Optimal use of installations in the face of changing missions, closures, and realignments requires an understanding of each installation's capabilities. Regional competition for land, transportation, energy, water, and other resources may put an installation's ability to perform essential activities at risk. This research adapted the Sustainable Installation Regional Resource Assessment (SIRRA) methodology to consider primary military mission as a weighting factor in determining vulnerability to a set of sustainability issues, and to identify the most vulnerable installations within each DoD service, and to determine those installations that would benefit from further study and intervention.

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