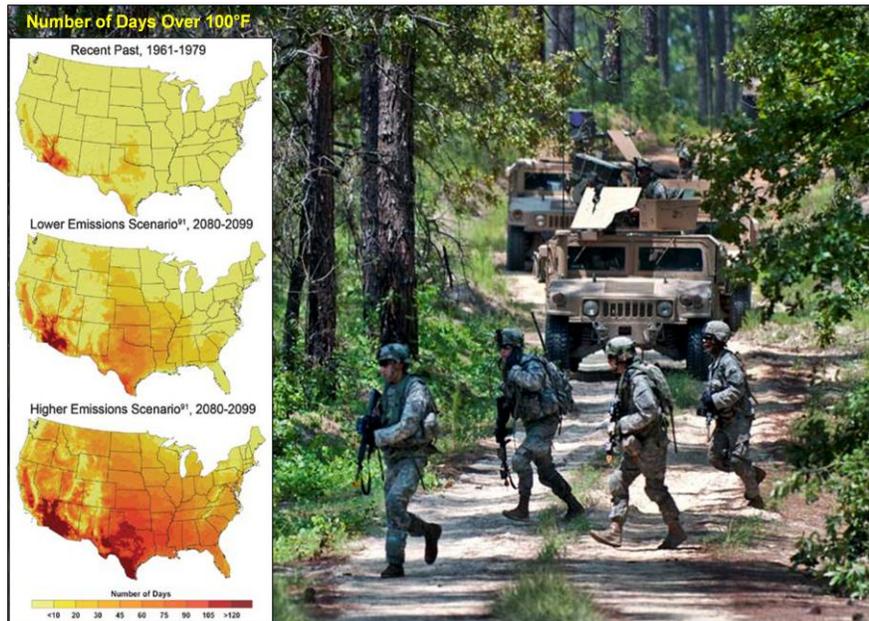




# Department of Army

## High-level Climate Change Vulnerability Assessment



2013

**Prepared for:**

**Office of the Assistant Secretary of the Army (Installations, Energy and Environment)**

**Prepared by:**

**U.S. Army Corp of Engineers  
Engineer Research Development Center**

Timothy J. Hayden  
William D. Goran  
Michael P. Case  
Kelly Burks-Copes  
Paul M. Loechl  
Stephen Pranger  
Anne Dain-Owens  
Steven C. Sweeney  
John W. Weatherly

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## ACRONYMS

ACOM	Army Command
AMC	Army Materiel Command
AR	Army Regulation
ARNG	Army National Guard
ATEC	U.S. Army Text and Evaluation Command
CBNR	Chemical, Biological, Radiological, and Nuclear
CEQ	White House Council on Environmental Quality
CMIP	Coupled Model Intercomparison Project
CONUS	Continental U.S.
DoD	Department of Defense
DRU	Direct Reporting Unit
ERDC	U.S. Army Corps of Engineers, Engineering Research and Development Center
FY	Fiscal Year
GCM	Global Climate Model
GHG	greenhouse gas
HQDA	Headquarters, Department of the Army
IMCOM	U.S. Army Installation Management Command
JBER	Joint Base Elmendorf-Richardson
JBLM	Joint Base Lewis-McChord
MEDCOM	U.S. Army Medical Command
NARCCAP	North American Regional Climate Change Assessment Project
NCA	National Climate Assessment
NGB	National Guard Bureau
NOAA	National Oceanic and Atmospheric Administration
OASA(IE&E)	Office of the Assistant Secretary of the Army for Installations, Energy and Environment
OSTP	White House Office of Science and Technology Policy
QDR	Quadrennial Defense Review
SERDP	Strategic Environmental Research and Development Program
SSPP	Strategic Sustainability Performance Plan
USACE	U.S. Army Corps of Engineers
USAR	U.S. Army Reserve
USFWS	U.S. Fish and Wildlife Service

# 1. Introduction

## 1.1 Background and Requirements

The 2010 Department of Defense (DoD) Quadrennial Defense Review recognized that projected changes in climate will impact installations, operations and missions both within the U.S. and globally. The QDR requires the DoD to “complete a comprehensive assessment of all installations to assess the potential impacts of climate change on its missions and adapt as required.” The DoD Strategic Sustainability Performance Plan (SSPP), mandated by EO 13514 (October 5, 2009), identifies climate change as one of four major challenges to sustainability for DoD installations and missions. The FY2012 DoD SSPP included the DoD’s first Climate Change Adaptation Roadmap.

At the national scale, the Climate Change Adaptation Task Force, co-chaired by the White House Council on Environmental Quality (CEQ), White House Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA), has provided guiding principles and recommended actions for Federal agencies to better understand, prepare for, and respond to climate change (October 5, 2010). This interagency task force released implementing instructions for Federal climate change adaptation planning on March 4, 2011. These implementing instructions tasked Federal agencies to conduct a high-level analysis and report to the CEQ on agency vulnerability to climate change.

The Global Change Research Act of 1990 also requires a periodic national assessment and report on current trends in global climate change and implications for important national sectors, including natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity. The third National Climate Assessment (NCA), coordinated by the U.S. Global Change Research Program, is scheduled for completion in 2013. DoD contributed to the NCA through participation in several advisory committees, including the National Climate Assessment Advisory Committee, the Interagency National Climate Assessment Advisory Committee, and Federal Advisory Committee.

In Fiscal Year (FY) 2011, the Office of the Assistant Secretary of the Army for Installations, Energy and Environment (OASA(IE&E)) formed an Army Climate Change Work Group. In FY2012, the OASA(IE&E) funded the U.S. Army Corps of Engineer, Engineer Research and Development Center (USACE ERDC) to complete a high-level climate change vulnerability assessment for U.S. Army installations and develop an adaptation planning framework that is consistent with CEQ guidance. This report provides the high-level vulnerability assessment for Army installations consistent with the QDR and following the CEQ guidance. Initial drafts of this assessment were submitted by ERDC to OASA(IE&E), and staffed for review and revision through the Army Climate Change Work Group.

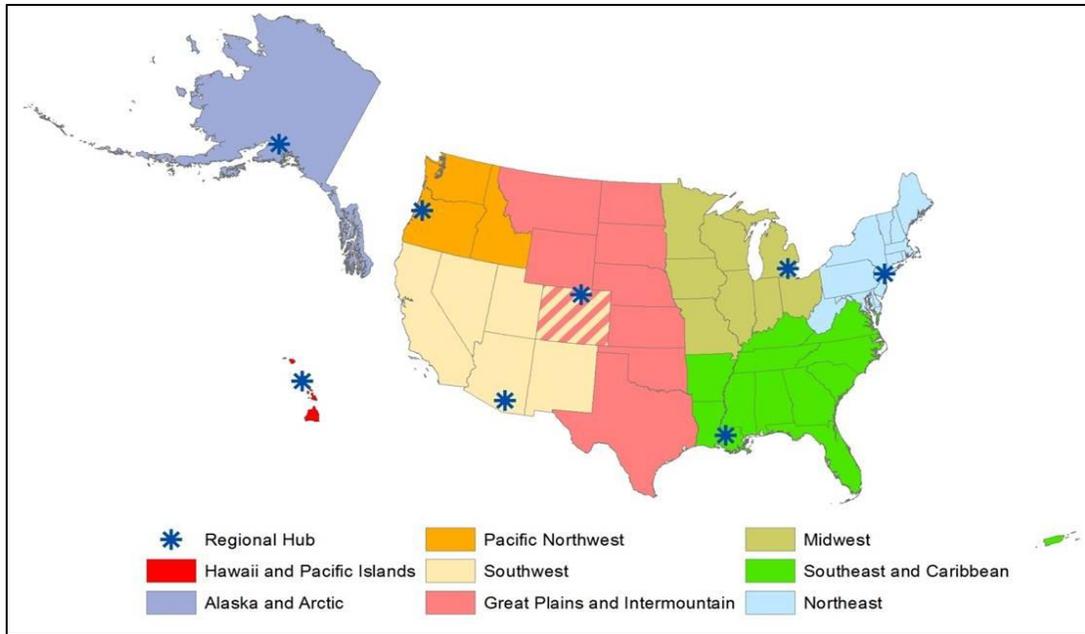
## **1.2 Objective**

This report provides an overview of potential Army installation vulnerabilities to climate change, consistent with the QDR and the CEQ requirement for a high-level analysis of agency vulnerabilities. The report will be used to inform Army leadership and planners at all levels of Army organizations responsible for installation management and missions regarding the potential impacts of climate change on Army training, operations, equipment, and facilities.

## **1.3 Assessment Scope & Organization**

This assessment focuses on installations operated under Army management authorities and the major Army mission activities supported by these installations. Climate information and outlooks in this report are summarized from national and regional climate outlooks that were developed for the third NCA. The climate data presented in this report is intended to provide an overview of the major climate themes from the NCA national and regional outlooks.

A brief overview of the National Climate Outlook and potential continental U.S. (CONUS) Army installation vulnerabilities is presented in this introduction. This introduction is followed by regional assessments organized by NCA Regions (Figure 1) that include regional NCA climate outlooks, the list of Army installations and major missions within the region, and potential vulnerabilities. Tables showing Army installations by region are adapted from Army Command and installation real property records. The rationale for organizing the Army's assessment by NCA region is to provide consistency and comparability with products and reports from the NCA. DoD input for Alaska, Southeast Region, and Southwest Region to the NCA Regional Working Groups, which provide input to the national assessment, served as the basis for the Army regional assessments in this report. The assessments provided in this report are qualitative based on the best professional evaluation by functional area experts and review by members of the Army Climate Change Working Group representative of Army organizational elements. This overview does not provide a formal risk assessment for climate impacts on Army installations, or provide site-specific analyses or climate projections. However, this report is a first step that sets the stage for conducting these detailed analyses contingent on mission needs and availability of resources.



**Figure 1. Third National Climate Assessment Regions**

Table 1 lists the major installation mission support activities, major categories of installation facilities that support mission activities, the Army Commands (ACOMs) and Direct Reporting Units (DRUs) that have installation management functions, and the NCA climate periods and scenarios considered in this assessment. Installation mission support activities represent those major installation mission activities that may be impacted by changing climate conditions. Major installation mission support facilities include the built and natural infrastructure required to support mission requirements. The ACOMs and DRUs listed are those that have significant installation management functions as specified in Army Regulation (AR) 10-87. Installation Management Command (IMCOM) has primary responsibility for management of most Active Army installations. Some IMCOM installations support missions of U.S. Army Material Command (AMC), U.S. Army Medical Command (MEDCOM), or Army Test and Evaluation Command (ATEC). IMCOM shares management responsibilities with the respective ACOM or DRU where the installation primarily supports AMC, ATEC, or MEDCOM missions. AMC also has direct management responsibilities for a number of ‘industrial base’ installations. The National Guard Bureau (NGB) is responsible for Army National Guard (ARNG) installations. The U.S. Army Reserve (USAR) is responsible for a limited number of installations, as well as ‘virtual installations’ made up of numerous smaller locations reporting to regional support commands.

The third NCA provides regional climate outlooks for three time periods: 2021-2050, 2041-2070, and 2070-2099. The NCA outlooks modeled future climate based on two different greenhouse gas (GHG) emissions scenarios: A2 and B1, which represent the high and low bounds for potential future GHG emissions scenarios.

**Table 1. Army Missions & Support Facilities, Management Authorities, & Climate Factors**

Major Installation Mission Support Activities	Major Installation Mission Support Facilities	ACOMs & DRUs with Installation Management Functions	NCA Climate Outlook Time Periods	NCA GHG Emissions Scenarios
Training Testing Industrial Base Operations Logistics and Deployment Support	Built Infrastructure (Buildings, Transportation, Utilities) Lands and Ranges	IMCOM (DRU) AMC (ACOM) ARNG USAR	2021-2050 2041-2070 2070-2099	A2 (High) B1 (Low)

Table 2 shows examples of the relationship between climate phenomena, impacts of changing climate on humans, infrastructure, and the environment, and the implications of these impacts on Army mission on installations. This table is not intended to provide a comprehensive assessment of Army mission impacts, but rather provides an example of how climate phenomena and their associated impacts could have potential mission-relevant impacts on Army installations. Climate phenomena include changing weather patterns and changes in the physical environment (e.g., sea level rise) associated with trends in global warming. Impacts include both direct and indirect effects on humans, built infrastructure, and the natural environment. Potential mission impacts are those potential effects on Army installation facilities and functions, including training, testing, and industrial base operations.

**Table 2. Example Relationship of Climate Phenomena to Impacts on Army Installations Mission Requirements**

Climate Change Phenomena	Potential Impacts	Potential Mission Impacts
<b>Rising temperatures</b>	Increased number of cumulative days with temperatures >95°F; melting permafrost; increased incidences of heat stress; changes in incidence/distribution of vector-borne diseases; vegetation transition (species and biome shifts); wildfire risk, soil warming; electrical grid stress; degradation of equipment performance	Shift in viable test/training mission; potential loss of cold weather training venues; reduced Soldier activity levels; reduced military vehicle access; reduced airlift capacity; reduced live-fire training; change in operational parameters for weapons and equipment development and testing; increased maintenance costs; increased energy costs for building and industrial base operations
<b>Increasing drought frequency</b>	Increases in extent and duration of droughts; increased wildfire risk; altered burn regimes; loss of vegetative cover; impacted soil function and resilience (desertification); soil loss, increased dust; impacts to air quality; infrastructure damage; water supply constraints, impacted groundwater and surface water quality; protected species stress	Reduced land carrying capacity for vehicle maneuvers; increased maintenance costs for roads, runways, and utilities; limits on low-level rotary wing flight operations; increased regulatory constraints on training land access; reduced live-fire training; reduced water availability and greater competition for limited water resources
<b>Increasing storm frequency &amp; intensity</b>	Increases of extreme precipitation events; increased flooding; water quality issues; soil and vegetation loss; impacts to soil function and carbon/nutrient cycling; transportation infrastructure damage	Impacts to Soldier safety; reduced access to military water crossings and river operations; reduced off-road maneuver capacity; increased maintenance costs; increased flood control/erosion prevention measures; increased transportation infrastructure damage

<p><b>Rising sea levels, storm surge expansion onto land</b></p>	<p>Loss of coastal land; damage to physical infrastructure (roads, targets, ranges) and protected ecosystem resources; land subsidence; saltwater intrusion</p>	<p>Degradation or loss of coastal infrastructure; increased infrastructure damage and associated reinforcement and repair costs; impacts to littoral and shore training; increased regulatory constraints on training land access; impacts on supply chain from potential shipping interruptions</p>
<p><b>Altered carbon cycles, sequestration and release</b></p>	<p>Increased stress on protected species; more listed species; spread of invasive species; land management impacts; competing non-military land use; reduced soil function</p>	<p>Reduced training land access; reduced training carrying capacity</p>

#### 1.4 Overview of the NCA’s National Climate Outlook

The draft national climate outlook for the for the third NCA provides projections for temperature and precipitation variables under two GHG emissions scenarios (A2 and B1) and three time periods for the contiguous 48 states. The national outlook also provides projections for several derived meteorological variables including extreme heat and precipitation events, heating and cooling degree days, and length of frost-free season. NCA Regional Climate Outlooks for the U.S. (including Alaska) are provided in separate reports. Appendix A provides additional information on NCA climate models, emissions scenarios, and uncertainties.

Mean temperatures across all periods and emissions scenarios are expected to increase across the nation from the 1971-2000 reference period (Figure 2). The greatest increase in the contiguous 48 states is projected to occur in the upper Great Plains and Midwest. Increases along coastal areas are projected to be less because of moderating ocean effects. Seasonal increases generally are projected to be greater in summer than in other seasons. Median temperature increases from 15 Coupled Model Intercomparison Project 3<sup>rd</sup> phase (CMIP3) simulations range from 3°F for the B1 scenario (2021-2050) to 4.5°F for the A2 scenario (2070-2099). Individual models’ low and high values were 1.6°F and 6.3°F, respectively. Temperature increases for Alaska, particularly interior regions, are projected to be higher than any area in the contiguous 48 states.

The number of consecutive days with temperatures >95°F is expected to increase across the country, particularly in the Southwest U.S. and the southern Great Plains. The number of days <10°F is expected to decrease particularly in higher elevations of the mountain west and along the northern tier of states.

The national climate outlook also indicates changes in precipitation patterns across the nation (Figure 3) with greatest increases in the upper Midwest and northern states and the greatest decrease in the Southwest and southern Great Plains. The North American Regional Climate Change Assessment Program (NARCCAP) simulations for 2041-2070 indicate the greatest seasonal decrease in precipitation in the spring and summer seasons in the southwest U.S. and the greatest seasonal increase in winter in the north-central and northeast U.S. The geographic gradient of change from north to south ranges from mean increases of 8-10% to decreases of 10-12%. However, there is large inter-model variability for precipitation change, which is indicative of the level of uncertainty in these projections.

Most areas of the U.S. are projected to have increases in extreme precipitation events (>25 mm per 24 hours), with the greatest percentage change (>60%) in the number of days with precipitation exceeding 1" during 2041-2070 in areas west of the Rocky Mountains. Change in the consecutive days of low precipitation <3 mm (indicator of drought) is expected to be greatest in the southwest U.S., with increases in southern California and Arizona up to 30 days.

The NCA outlooks are based on a set of climate *projections* of outcomes that could occur under a set of possible scenarios, and not climate *predictions* of specific outcomes. The future trends in emissions and global economic growth rates that can influence these trends are not reliably predictable. These projections represent a range of expected future climate changes based on observed greenhouse gas trends and trends in energy use.

### CMIP3, MULTI-MODEL MEAN, Temperature Difference (F) from 1971-2000

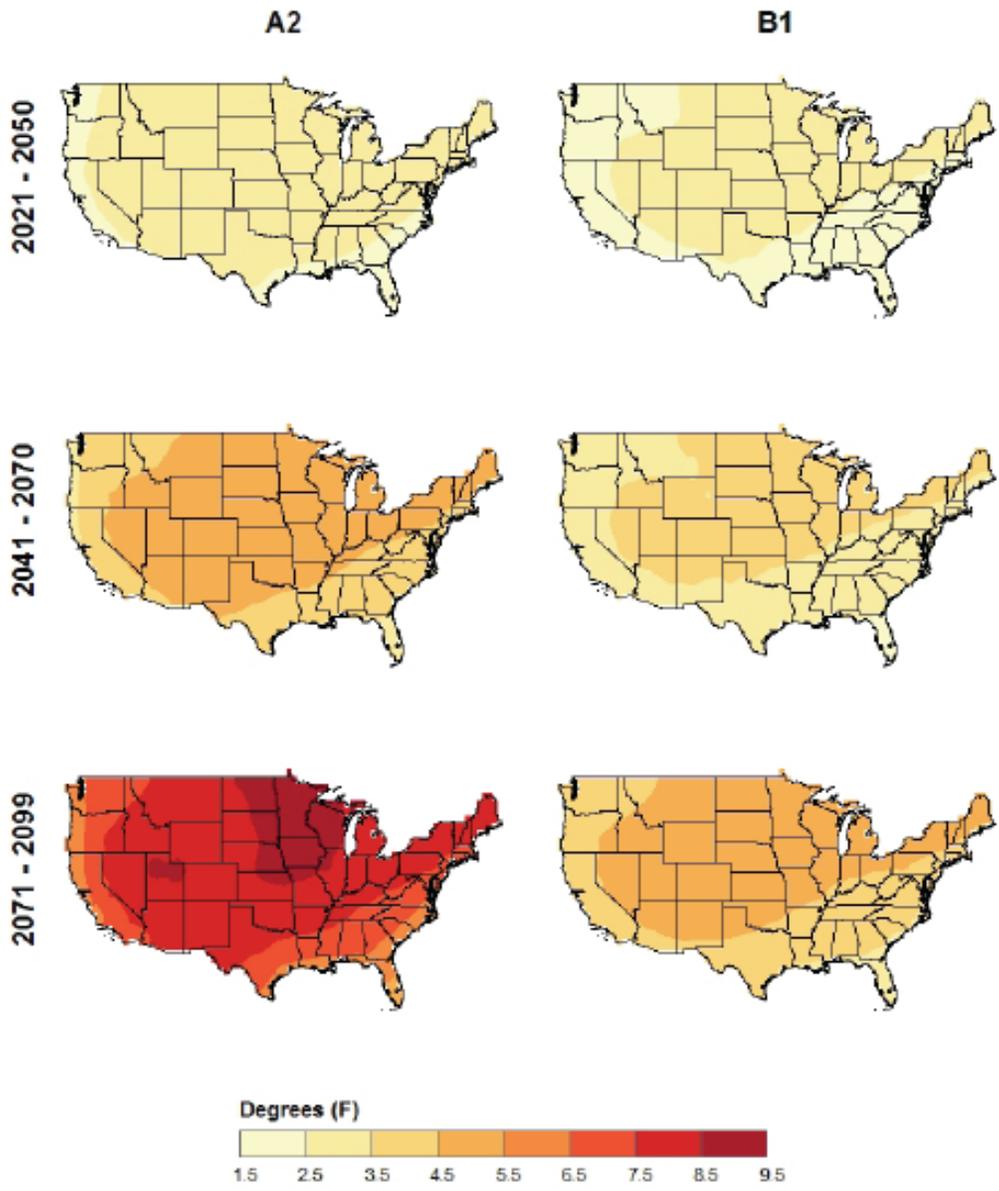


Figure 2. Mean Temperature Projections from Draft Third NCA Climate Outlook

**CMIP3, MULTI-MODEL MEAN,  
Precipitation Difference (%) from 1971-2000**

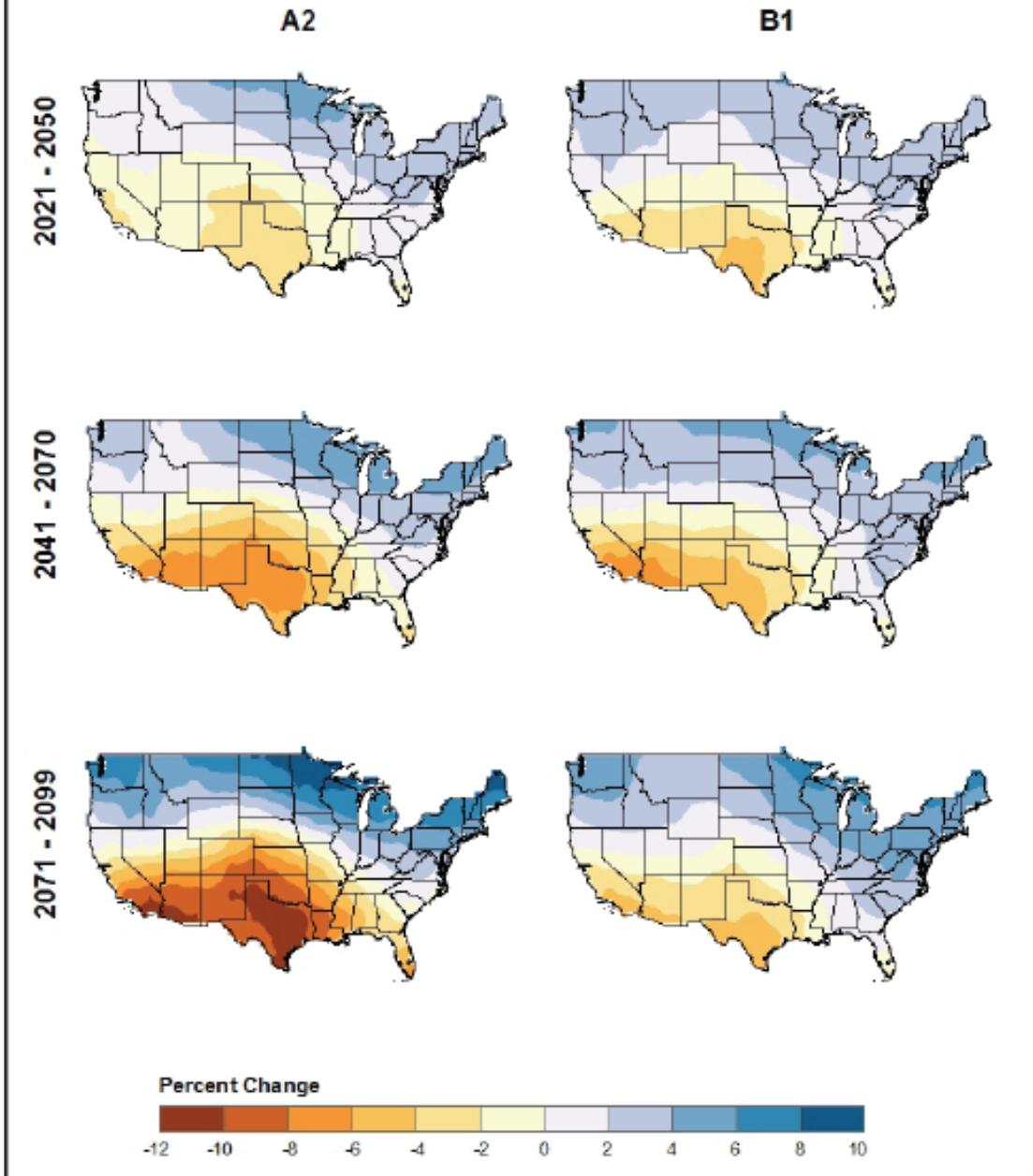


Figure 3. Mean Precipitation Projections from Draft Third NCA Climate Outlook

## **1.5 Overview of CONUS Army Installation Vulnerabilities**

Potential vulnerabilities of CONUS Army installations and operations from projected changes in climate and climate variability are diverse in both consequence and timing of impacts. Three levels of impacts can be identified. At the highest level of impact, an installation may no longer be able to support current and future mission requirements. At the intermediate level of impact, missions could be accomplished, but would require adaptive actions to prevent, remediate, or repair impacts, which could carry high costs and require significant time for planning and implementation. Other impacts at this level could be acute (e.g., flooding and tornado events), with high short-term costs and short-term disruption, but would not prevent mission accomplishment over the long-term. At the lowest level of impact, operations may need to be modified, but could be accomplished within established processes and with no significant commitment of additional resources. These impacts on Army installations can be described through three broad categories: installation missions (including training, testing, industrial base operations, and logistical and deployment support), the built infrastructure, and the lands and ranges that support these installation missions.

### **1.5.1 Installation Mission Activities**

Potential climate change impacts on installation mission activities (including training, testing, industrial base operations, and logistical and deployment support) are diverse. Field training exercises are conducted to replicate real-world combat requirements. Field training exercises range from hours to days to weeks in duration and are inherently subject to the effects of the prevailing climate and weather conditions. Adapting to variability of climate is part of realistic training. Personnel safety concerns or physical constraints on access to training lands and waters resulting from ambient or extreme weather events do have short-term effects on training and operations and can damage roads and other infrastructure. Extreme heat events can require reductions in personnel activity levels. Extreme heat and drought events and/or high fire risk conditions can also preclude use of pyrotechnics, grenade simulators, and live-fire training with tracers to reduce chance of wildfires. Extreme storm events and associated lightening, wind, and flooding risks can temporarily limit access to training lands and other training features such as water crossings. Soil saturation and increased erosion from extreme precipitation events can limit off-road transit by military vehicles and personnel. Engineering operations in support of river crossings and bridging operations are affected by hydrologic cycles and precipitation extremes.

Army air operations (including combat support training, flight training, personnel transport, and logistical support) are affected significantly by prevailing weather and climate conditions. Adverse conditions can significantly disrupt air operations and training activities. For example, higher temperatures affect aircraft lift capacity and performance.

Many current and future weapons systems and military equipment have life-cycles of decades. Performance and reliability of these systems, such as complex electronic and optical systems, are often affected by ambient environmental conditions. Testing of new weapon systems and

military equipment and range modernization initiatives will need to evaluate design and operational criteria for performance under long-term meteorological trends and conditions.

While extreme events in isolation may have only minimal and short-term impacts on operational and training requirements, the cumulative impact of extremes of high temperature, storm-related events, and precipitation with climate change will affect the ability of installations to sustain operational tempos and could potentially reduce scheduling flexibility. Many installations are gaining missions and tenant units with force restructuring and demands of overseas contingency operations. Installation capacity to support increased mission requirements and operational safety margins would be compromised if constraints on training access and scheduling flexibility increase as a result of future climate change.

### **1.5.2 Built Infrastructure**

The built infrastructure required to support military missions on Army installations is extensive. Built facilities include air fields, port facilities, and support infrastructure comparable to small cities, including commercial buildings, medical facilities, public safety facilities, housing, communication networks, roads, bridges, railways, and supporting utilities (e.g., power, water, sewer). This extensive military installation infrastructure is subject to the same climate conditions and vulnerabilities identified in the second NCA for analogous civilian-built infrastructure. In addition, most Army installations are highly interdependent on civil regional public utilities, transportation, and communications networks.

Sea level rise and increased storm surge are expected to alter harbor topography, bathymetry, currents, and salinity, which may impact access to ports. Logistical support activities for Army contingency operations are dependent on reliable access to port facilities. The land-base elevation of some Army installations is largely at or just above sea level. Coastal installations and facilities, if not subject to some level of inundation, would also be subject to increased ground water salinity, higher water table, and increases in periodic flooding, which would require increased storm water pumping and drainage capacity, maintenance for corrosion control, and flood protection. Increased temperature and potential increases in precipitation can increase maintenance costs for vehicles and aircraft due to corrosion effects and impacts of ambient weather conditions on delicate electronic systems. Anticipated increases in cooling degree days and/or decreases in heating degree days would also alter energy usage. Generally the change in cooling degree days are expected to be greater relative to the change in heating degree days, which potentially results in increased direct costs. Implementation of energy conservation standards and building or retro-fitting of energy-efficient construction will be an increasing priority.

Increases in extreme precipitation events would also require increased storm sewer capacity and flood control and erosion control structures. The regional interdependency of installations with surrounding civil power and communication networks, roads, railways, and water systems may result in increased installation vulnerability to climate impacts on systems and facilities

external to the installation. With a high percentage of installation and mission personnel living off-base, access to installations is of critical importance.

### **1.5.3 Lands & Ranges**

The lands, airspace, and waters of Army installations are vitally important to support Army mission requirements, including training and testing. Army installations also have significant responsibilities for managing natural resources to maintain lands and vegetative cover for training and testing activities, and compliance with environmental regulatory requirements (e.g., Endangered Species Act, Clean Air Act, Clean Water Act). Geophysical and hydrological effects, habitat transitions, and direct physiological impacts of increasing temperatures and altered precipitation patterns resulting from climate change will have significant consequences for Army land, water, and environmental management programs and regulatory compliance. Erosion control and maintenance of vegetative cover are important for training lands access, maintaining military line of sight, and meeting water quality requirements. Many installations conduct extensive prescribed burning programs in upland habitats for training range maintenance, endangered species habitat management, wildlife management, and invasive species control. Effects of climate on the ability to conduct burn programs would have implications for endangered species and Clean Air Act compliance.

Endangered species compliance on Army installations is one of the greatest environmental compliance issues affecting military training and operations through restrictions on access to training lands and waters. The majority of Army installations with training and testing missions support populations of one or more federally-listed species as well as state-listed species and species of conservation concern. There is a significant emphasis and investment on Army installations to minimize regulatory restrictions by intensive habitat management and reduction of impacts on resident endangered species populations resulting from military activities. Habitat transition or modification as a result of climate change will increasingly challenge the ability of installations to maintain status of current endangered species populations and may result in increased listings of species that are currently at risk.

## 2. Regional NCA Outlooks & Installation Vulnerabilities

### 2.1 Northeast NCA Region

#### 2.1.1 Description of Northeast Region Army Installations & Missions

Relative to other regions, Army installations in the NCA Northeast Region (Table 3) predominantly support command, supply, manufacturing, medical, schools, and research functions. Within this region, major combat training facilities for Active Army units are primarily located at Fort Drum, NY. Fort Dix, NJ, Fort Edwards, MA, Fort Indiantown Gap, PA, and Fort Dawson, WV, support training and deployment activities for Army National Guard (ARNG) and Army Reserve (USAR) units. The land area of these installations are relatively small compared to the large expanses of installations found in other U.S. regions. Most installations in the NCA Northeast Region have relatively small land areas and are often located in highly urbanized settings. For example, Fort Hamilton is embedded in the New York borough of Brooklyn.

Army installations in the Northeast are also representative of some of the oldest military installations in the nation and often have buildings and sites of national historical significance. The two major Army medical facilities, Fort Detrick and Walter Reed Medical Center, are located in the region. Two of the Army’s most important educational institutions are located in the NCA Northeast Region: West Point is located in upstate New York, and the Army War College is located at Carlisle Barracks, PA.

**Table 3. Army Installations Located in NCA Northeast Region**

Management Responsibility	Installation	State
IMCOM	Aberdeen Proving Ground *	MD
	Carlisle Barracks	PA
	Fort Detrick **	MD
	Fort Drum	NY
	Fort Hamilton	NY
	Fort George G Meade	MD
	Picatinny Arsenal *	NJ
	US Army Adelphi Laboratory Center *	MD
	West Point Military Reservation	NY
AMC	Letterkenny Army Depot	PA
	Scranton Army Ammunition Plant	PA
	Tobyhanna Army Depot	PA
	Watervliet Arsenal	NY

<b>ARNG</b>	Camp Dawson – Kingwood	WV
	Camp Edwards	MA
	Ethan Allen Range	VT
	Fort Indiantown Gap Training Site	PA
	Stones Ranch Military Reservation	CT

\* IMCOM installations with significant AMC missions

\*\* IMCOM installations with significant MEDCOM missions

### **2.1.2 Northeast Region NCA Climate Outlooks**

The NCA Northeast Region climate is highly diverse with large spatial variability resulting from influences of the Atlantic Ocean, the Great Lakes, and the Appalachian Mountains. Summers are warm and humid, but relatively moderate in the northern latitudes. Overall, the region is relatively cool compared with other regions. The NCA Northeast Region has strong seasonal cycles and is impacted by a variety of extreme weather events including ice storms, floods, droughts, hurricanes, and nor'easters. Heavy snowfalls and precipitation events can occur because of lake effects on the lee side of Lakes Ontario and Erie and the orographic effects of mountain ranges. Snowfall totals are higher in the northern latitudes, high altitudes, and more inland regions.

The third NCA Northeast Region Climate Outlook projects increases in mean temperatures across the region and across all time periods and scenarios. Projected temperature increases through the 2070-99 period range from 4-5°F under low-emission scenarios (B1) to 7-9°F under high-emission scenarios (A2). Seasonal temperature increases are projected to be greater in summer than winter, which would result in increased frequency of extreme heat events and heat waves (number of consecutive days >95°F), with larger absolute increases in the number of days greater than 95°F in the southern latitudes. Reductions in the number of days <10°F are projected across the region, with the greatest reductions occurring in the northern latitudes and higher altitudes. Seasonal changes in temperature will increase the number of cooling degree days at a proportionally higher percentage than the projected decrease in heating degree days. NARCCAP projections for the 2041-70 period indicate a mean increase in the frost-free season of 26 days across the region, with increases >27 days in high elevation areas.

Precipitation is expected to be greater across the NCA Northeast Region, but the median percentage increase is small (~2%) and individual models show both negative and positive trends for precipitation. NARCCAP simulations for the period 2041-70 indicate the winter season will exhibit the largest increases in precipitation relative to other regions. NARCCAP simulations for the 2041-70 period indicate an increase in extreme precipitation events for all thresholds from a 21% increase (>1 in) to 65% (>4 in). The greatest percent increase in extreme precipitation events is across the northern tier of the region. Models indicate the change in consecutive number of days with precipitation <0.3 mm (drought) is minimally changed.

### **2.1.3 Potential Vulnerabilities of Northeast Region Army Installations to Climate Change**

The NCA Northeast Region is the most densely populated of all U.S. regions, with several significant metropolitan areas. More than in any other region, Army installations in the Northeast are located in highly urbanized settings. Because of this, the impacts of climate change on these installations may be contingent on the impacts on the regional infrastructure and planning and response of surrounding state and municipal government agencies. The ability of many installations in the region to mediate and adapt to climate impacts may be heavily interdependent on the capabilities of their associated civil authorities, and their vulnerabilities need to be assessed in this regional context to a greater extent than for other U.S. regions.

These urban landscapes and populations in the NCA Northeast Region are particularly susceptible to impacts on built infrastructure, communication and transportation networks, and human safety from extreme weather events including flooding, ice storms, heavy snowfall, heat waves, nor'easters, and tropical cyclones. It is relatively uncertain the extent to which climate change will alter patterns of these extreme events, but any increase would tax existing regional capabilities to mitigate effects and, by extension, impacts on Army facilities in the region. Impacts on Army facilities could include flooding of facilities and transportation networks, disruption of transportation networks that would affect deployment activities and ability of personnel to reach work sites, damage to buildings, power lines and communications networks, and risks to personnel safety.

As in other NCA regions, higher temperatures and increased cooling degree days will result in higher energy costs and requirements for increasing energy efficiency of buildings and manufacturing processes.

Anticipated climate change effects on natural systems in the Northeast Region include shifts in species distributions, changes in community structure, and additional stressors on sensitive systems. The relatively urbanized and small land areas of Army installations in this region suggests these impacts on natural systems will have limited direct effects on most installations, particularly with regard to regulatory constraints. Some installations like Fort Dix are representative of the limited remaining undeveloped landscapes in the region and may become increasingly important as regional reservoirs of biodiversity and green space. Installations like Fort Drum have federally-listed species and species of concern, and additional stressors on these species may increase regulatory compliance requirements and constrain training missions.

## **2.2 Southeast NCA Region**

### **2.2.1 Description of Southeast Region Army Installations and Missions**

The NCA Southeast Region has the largest number of Army installations of any NCA region (Table 4). Many of the largest and most important Army installations for Active Army training

and force projection are located in the NCA Southeast Region including Fort Bragg, NC, Fort Stewart, GA, and Fort Benning, GA. Fort Jackson, SC provides basic combat training for approximately 50 percent of entry-level Soldiers annually. Fourteen ARNG and one USAR installations are located in the NCA Southeast Region. These installations support all the major land and air training, operations, and testing missions of the Army and are major support facilities for U.S. contingency operations. Seven AMC military munitions and equipment manufacturing facilities are located in the Southeast, including Military Ocean Terminal Sunny Point, which is an important Army staging and shipping center for overseas contingency operations.

Land-based operations in the NCA Southeast Region include road and off-road maneuver training by dismounted Soldiers and tracked and wheeled vehicles to simulate real-world combat operations. Live-fire training from small caliber direct-fire personal weapons systems to large caliber indirect fire by artillery and missile systems and aircraft delivered munitions is conducted on designated ranges on installations. Army air operations include combat support training, flight training, personnel transport, and logistical support.

The built infrastructure required to support Army requirements at installations in the NCA Southeast Region is extensive. Built facilities include airfields, port facilities, manufacturing facilities, and support infrastructure comparable to small cities, including commercial buildings, medical facilities, public safety facilities, and housing, as well as supporting utilities (e.g., power, water, and sewer, communication networks), roads, and railways. Most Army installations in the NCA Southeast Region are highly interdependent with civil regional public utilities, transportation, and communications networks.

Army installations in the NCA Southeast Region also have significant responsibilities for managing natural resources for maintenance and sustainability of training lands, including compliance with environmental regulatory requirements. Southeast Army installations conduct extensive prescribed burning programs in upland habitats for training range maintenance and habitat maintenance, primarily for endangered species habitat management. Endangered species compliance on southeast U.S. Army installations is one of the greatest environmental compliance issues affecting military training and operations. Most military installations in the southeast U.S. support populations of one or more federally-listed species as well as state-listed species and species of conservation concern. Many of these installations support U.S. Fish and Wildlife Service (USFWS)-designated primary recovery populations, such as Red-cockaded Woodpeckers on Fort Stewart, Fort Bragg, Fort Benning, and Fort Polk.

**Table 4. Army Installations Located in NCA Southeast Region**

<b>Management Responsibility</b>	<b>Installation</b>	<b>State</b>
<b>IMCOM</b>	Fort A P Hill	VA
	Fort Belvoir	VA
	Fort Benning	GA
	Fort Bragg	NC
	Fort Buchanan *	PR
	Fort Campbell	KY
	Fort Gordon	GA
	Fort Jackson	SC
	Fort Knox	KY
	Fort Lee	VA
	Fort Polk	LA
	Fort Rucker	AL
	Fort Stewart	GA
	Joint Base Myer-Henderson Hall	VA
	Redstone Arsenal	TN
	US Army Garrison Miami	FL
<b>AMC</b>	Anniston Army Depot	AL
	Blue Grass Army Depot	KY
	Holston Army Ammunition Plant	TN
	Milan Army Ammunition Plant	TN
	Military Ocean Terminal Sunny Point	NC
	Pine Bluff Arsenal	AR
	Radford Army Ammunition Plant	VA
<b>ARNG</b>	Camp Beauregard	LA
	Camp Blanding	FL
	Camp Butner	NC
	Camp McCain	MS
	Camp Minden	LA
	Camp Joseph T Robinson	AR
	Camp Santiago	PR
	Camp Shelby	MS
	Camp Villere	LA
	Fort Chaffee Training Center	AR
	Fort Pickett Training Center	VA
	Volunteer Training Site Catoosa	GA
	Volunteer Training Site Milan	TN
	WH Ford Regional Training Center	KY

\*IMCOM installation with significant U.S. Army Reserve mission

### **2.2.2 Southeast Region NCA Climate Outlooks**

The third NCA Southeast Region Climate Outlook presents climate projections that relate to potential vulnerabilities for Army operations, training, facilities, and natural resources on installations in the region. Increases in mean temperatures are projected across the region and across all time periods and all emissions scenarios, with a regional average range of 2-6°F by 2100 and increases of up to 10°F for interior states of the region. Of particular relevance for the Army is projected change in extreme temperatures, specifically the change in number of days >95°F, increases in consecutive very warm days (i.e., heat waves), and warmer winter temperatures. Seasonal changes in temperature are projected to increase the number of cooling degree days at a proportionally higher percentage than the projected decrease in heating degree days.

Forecasts of mean changes in precipitation are more ambiguous for the NCA Southeast Region than temperature projections, with relatively small changes in multi-model means and a large range from decreased to increased precipitation projections across individual models. However, model projections indicate increased extreme precipitation events across all areas of the region. Projections for changes in consecutive number of dry days (<3 mm) are variable across the region. Although not specifically addressed in the NCA Southeast Region Climate Outlook, potential changes in the incidence of extreme weather events (characterized by tornadoes, hurricanes, and other storm events) would have a major relationship to installation vulnerabilities. Indirect effects of climate change related to sea level rise, increased storm surge, and changes in chemical properties of ocean waters (e.g., increased acidification) and fresh water (e.g., salt intrusion) also factor significantly into potential vulnerabilities of Army installations.

### **2.2.3 Potential Vulnerabilities of Southeast Army Installations to Climate Change**

Field training exercises conducted by dismounted and mechanized units and use of installation firing ranges is a significant mission requirement for many of the major Army installations in this region. Because of personnel safety concerns or physical constraints on access to training lands and waters, extreme weather events do have short-term effects on training and operations and can damage roads and other infrastructure. Extreme heat events can require reductions in personnel activity levels. Extreme heat and drought events and/or high fire risk conditions can also preclude use of pyrotechnics, grenade simulators, and live-fire training with tracers to reduce chance of wildfires. Extreme storm events typical of the NCA Southeast Region with associated lightning, wind, and flooding risks can temporarily limit access to training lands and other training features such as water crossings. Subsequent soil saturation and increased erosion can limit off-road transit by military vehicles and personnel. Flight operations are highly dependent on weather, and adverse conditions can significantly disrupt operational and training requirements. An increase in the incidence of these extreme events in the NCA Southeast Region as a result of climate change would compromise the ability of southeast Army installations to maintain operational tempos and reduce scheduling flexibility and safety margins.

Impacts of climate change on an installation's built infrastructure and equipment used to conduct and support operational and training requirements will be both military-unique and analogous to anticipated impacts on equivalent civilian infrastructure and systems. Sea level rise and increased storm surge are expected to alter harbor topography, bathymetry, currents, and salinity, which may impact operations of Military Ocean Terminal Sunny Point. The land-base of Fort Stewart is largely at or just above sea level and, if not subject to some level of inundation, could be subject to increased ground water salinity, higher water table, and increases in periodic flooding. These impacts would require increased storm water pumping and drainage capacity, maintenance for corrosion control, flood protection, and reduced access to training lands. Increased temperature and potential increases in precipitation will increase vehicle and aircraft maintenance costs due to corrosion effects and impacts of ambient weather conditions on delicate electronic systems particularly in the hot, humid conditions of the NCA Southeast Region. The anticipated increase in cooling degree days relative to a decrease in heating degree days in the NCA Southeast Region will increase energy usage, resulting in increased direct costs, implementation of energy conservation standards, and building or retrofitting of energy efficient construction. Increases in extreme precipitation events would require increased storm sewer capacity and flood control structures. The regional interdependency of installations with surrounding civil power and communication networks, roads, railways, and water systems may result in increased installation vulnerability to climate impacts on systems and facilities external to the installation.

On most NCA Southeast Region Army installations, endangered species have a direct mission impact through restrictions on access to training lands and waters. There is a significant emphasis and investment on NCA Southeast Region installations to minimize regulatory restrictions by intensive habitat management and reduction of impacts on resident endangered species populations resulting from military activities. Habitat transition or modification as a result of climate change will increasingly challenge the installations' ability to maintain the status of current endangered species populations and may result in increased listings of species that are not currently considered at risk. Increased temperatures and potential changes in precipitation patterns may require modification of prescribed burn programs, which are an important component of endangered species management on many NCA Southeast Region installations and for range maintenance and soldier access. Changes in prescribed burning programs and higher temperatures would also have implications for meeting Clean Air Act emissions standards for particulates and ozone. Increased run-off and subsequent erosion from extreme precipitation events can increase sediment loads in installation streams, which can result in non-compliance with water quality regulations. The construction of compensatory sediment control features can be costly, particularly on installations in the Fall-line Sandhills region that already have significant erosion control challenges.

## **2.3 Great Plains NCA Region**

### **2.3.1 *Description of Great Plains Army Installations and Missions***

Major installations in the NCA Great Plains Region are located primarily in the middle and lower plains (Table 5). Fort Hood, TX, Fort Sill, OK, and Fort Riley, KS are the largest Active Army installations in the NCA Great Plains Region. Although the administrative headquarters of Fort Bliss is in Texas, major maneuver ranges are located in New Mexico; therefore, Fort Bliss is considered in the NCA Southwest Region assessment. Fort Hood has one of the largest censuses of active duty Soldiers among CONUS installations and supports all aspects of mechanized maneuver, infantry training, and Army air operations. Fort Sill is the Army's premier installation for artillery training. Fort Riley supports mechanized training and is the only major Army installation where the dominant vegetative cover is prairie grasslands. Fort Leavenworth primarily supports classroom facilities, most notably the Command and General Staff College and the Army Combined Arms Center. All of these installations have significant built infrastructure including housing, roads, rail, and airfields. Ten ARNG installations and three AMC installations are located in the Great Plains region. Corpus Christi Army Depot is a major repair, staging, and shipping facility for equipment of units deploying from Fort Hood, Fort Riley, and Fort Bliss. Army facilities are minimal in the upper Great Plains, which includes Nebraska, North and South Dakota, and the plains of Montana and Wyoming.

Erosion control and maintenance of vegetative cover are important for training exercise access and meeting water quality requirements. Army installations that conduct land-based training in the NCA Great Plains Region (Fort Hood, Fort Sill, and Fort Riley) are heavily dependent on prescribed burning in upland habitats for training range maintenance and habitat maintenance, including habitat management for endangered species. These installations support populations of one or more federally-listed species as well as state-listed species and species of conservation concern, including USFWS recovery populations for endangered golden-cheeked warblers (Fort Hood) and black-capped vireo (Fort Hood and Fort Sill).

**Table 5. Army Installations Located in NCA Great Plains Region**

<b>Management Responsibility</b>	<b>Installation</b>	<b>State</b>
<b>IMCOM</b>	Fort Bliss	TX
	Fort Hood	TX
	Fort Leavenworth	KS
	Fort Riley	KS
	Fort Sill	OK
<b>AMC</b>	Corpus Christi Army Depot	TX
	McAlester Army Ammunition Plant	OK
	Red River Army Depot	TX
<b>ARNG</b>	Camp Ashland	NE
	Camp Grafton	ND
	Camp Gruber	OK
	Camp Guernsey	WY
	Camp Maxey	TX
	Camp Rapid	SD
	Camp Swift	TX
	Fort William Henry Harrison Training Site	MT
	Fort Wolters Training Center	TX
	Greenlief Training Site	NE

**2.3.2 Great Plains Region NCA Climate Outlooks**

The third NCA Great Plains Region Climate Outlook projects increases in mean temperatures across the region and across all time periods and scenarios. Projected temperature increases through 2090 range from 2.5°F under low-emission scenarios (B1) up to 13°F under high-emission scenarios (A2). Seasonal temperature increases are projected to be greater in summer than winter, which are projected to result in increased frequency of extreme heat events and heat waves (number of consecutive days >95°F). Seasonal changes in temperature will increase the number of cooling degree days at a proportionally higher percentage than the projected decrease in heating degree days.

Precipitation is expected to be greater in northern states of the NCA Great Plains Region and lower in the southern latitudes, with greater decreases in precipitation from east to west. Army installations are located predominantly in the southern states of the region; therefore most are expected to experience decreased precipitation through the end of this century. The combination of increased temperatures and lower precipitation would lead to increased frequency and duration of drought events.

Installations in the southern plains currently are subject to extreme weather events including lightening storms, hail, and tornadoes. Potential changes in these extreme weather events are likely to influence installation vulnerabilities. Changes in patterns of tropical cyclones may influence monsoonal precipitation patterns particularly for Texas installations. Sea level rise could impact facilities and missions of the Corpus Christi Army Depot on the Gulf Coast of Texas.

### ***2.3.3 Potential Vulnerabilities of Great Plains Army Installations to Climate Change***

Anticipated future trends for temperature and precipitation patterns are projected to affect the installations' ability to support training and operational requirements. An increase in frequency and duration of extreme heat events in the southern NCA Great Plains Region can require reductions in personnel activity levels. This will especially impact installations that support field training activities at high operational tempos such as Fort Hood, Fort Sill, and Fort Riley. Higher temperatures and increased dust under drought conditions would also affect aircraft lift capacity and performance in support of training operations. Increased temperatures and lower precipitation would increase the difficulty of maintaining adequate vegetation cover of training ranges and increase costs to mitigate erosion potential, which would affect the ability to conduct off-road vehicle maneuvers. Extreme heat and drought events and/or high fire risk conditions can also preclude use of pyrotechnics, grenade simulators, and live-fire training with tracers to reduce chance of wildfires. While extreme heat and drought in isolation may have only minimal and short-term impacts on operational and training requirements, the cumulative impact of extremes of high temperature, storm-related events, and precipitation are increasingly likely to affect the ability of installations in the southern NCA Great Plains Regions to meet operational tempos and will reduce scheduling flexibility. Installation capacity to support increased mission requirements and operational safety margins would be compromised if range access and scheduling flexibility are compromised as a result of climate change.

Outlooks for climate change in the NCA Great Plains Region are expected to affect the built infrastructure and equipment at installations in the region. Increased temperature and potential dust problems associated with increased drought frequency will increase maintenance costs for facilities, vehicles, equipment, and aircraft due to corrosion and contamination effects. The anticipated increase in cooling degree days relative to a decrease in heating degree days in the NCA Great Plains Region would increase energy usage, resulting in increased direct costs, implementation of energy conservation standards, and building or retrofitting of energy efficient construction. Installations in the NCA Great Plains Region are interdependent with surrounding civil power and communication networks, roads, railways, and water systems, which may result in increased installation vulnerability to climate impacts on systems and facilities external to the installation. It is uncertain whether the monsoonal pattern of precipitation associated with tropical cyclones and depressions will be altered in the southern NCA Great Plains Region. Decreases in monsoonal rains would exacerbate effects of drought on the ability of installations to meet water requirements. Increases in monsoonal rains and attendant high volume precipitation events would alter design requirements for

water control and diversion structures. The anticipated decrease in average precipitation in the southern plains is increasingly likely to stress the ability to provide adequate water supplies regionally. Most water is obtained from storage reservoirs and aquifers. The latter source is being depleted and is cause for concern throughout the region. Further decreases in water recharge due to lower precipitation would increase the need for alternative water resources. Installations could increasingly have to compete for water resources used by surrounding municipalities and agriculture. Water conservation and reuse would be increasingly advantageous to installations under future climate conditions.

Prescribed burning is a dominant management action for natural resources on most of the major installations of the southern NCA Great Plains Region. Prescribed burn programs are implemented to maintain military access and sight lines, manage endangered species habitat, maintain native plant species, and control invasive species. Increased temperatures and reduced precipitation may require modification of prescribed burn programs, with consequences for the installations' ability to meet regulatory management requirements for endangered species and support of training access and range maintenance. Changes in prescribed burning programs and higher temperatures could also have implications for meeting Clean Air Act emission standards for particulates and ozone. Currently most installations with significant burning programs are not located in non-attainment zones.

Endangered species have the most direct impact through restrictions on access to training lands and waters. There is a significant emphasis and investment on NCA Great Plains Region installations, particularly Fort Hood, to minimize regulatory restrictions by intensive habitat management and reduction of impacts on resident endangered species populations resulting from military activities. Habitat transition or modification as a result of climate change will increasingly challenge the installations' ability to maintain the status of current endangered species populations and may result in increased listings of species that are not currently considered at risk. Drought-caused reduction in vegetative cover can increase erosion with a subsequent increase in sediment loads in installation streams, which potentially can result in non-compliance with water quality regulations.

## **2.4 Southwest NCA Region**

### ***2.4.1 Description of Southwest Region Army Installations and Missions***

Army installations have a significant land and air footprint in the NCA Southwest Region (Table 6). Most of the major Army land holdings and Military Operations Areas are located in the desert regions of the southern tier of the NCA Southwest region. The desert southwest provides a critical asset for the U.S. military — open space with fewer encroachment issues relative to other more populated regions. Installations in the desert southwest tend to be much larger than the installations in other regions of the nation, with several in excess of one million contiguous acres. This open space asset has historically allowed the military to establish large training areas and ranges on installations and to define expansive air maneuver regions above these ranges and above the vast public lands of other agencies.

The largest Army land holding in New Mexico is the White Sands Missile Range, which is a major weapon systems test range. Fort Bliss' administrative headquarters is in Texas (NCA Great Plains Region), but it has large training ranges in New Mexico and is more associated with NCA Southwest Region climate patterns. In Arizona, Yuma Proving Ground and Fort Huachuca are the largest Army land holdings. Dugway Proving Ground, at approximately 800,000 acres, is the largest DoD installation in Utah. Fort Carson and Pueblo Chemical Depot are the only Army installations located in Colorado.

California hosts the greatest number of Army installations in the NCA Southwest Region with eight installations. The largest of these installations by land area is Fort Irwin, located in the Mojave Desert region of southern California. Fort Irwin is the Army's major 'force on force' maneuver armored combat training center. Fort Hunter Liggett (located on the western edge of the central valley in California) is the largest USAR installation in the U.S. and supports training from Combat Support and Combat Service Support units from across the Army.

Of particular note for Army installations in the NCA Southwest Region relative to other U.S. regions are the extensive test ranges for weapons systems and services (including missile systems) and the large ranges available for air-to-ground weapons systems training. This is due to the availability of large contiguous land areas with low population densities, limited encroachment from urban areas, and availability of large military airspaces.

Land-based operations in the NCA Southwest Region at installations such as Fort Irwin, Fort Bliss, and Fort Carson include road and off-road maneuver training by dismounted Soldiers and tracked and wheeled vehicles to simulate real-world combat operations. Live-fire training from small caliber direct-fire personal weapons systems to large caliber indirect fire by artillery, missile systems, and aircraft delivered munitions is conducted on designated ranges on installations.

A significant issue for NCA Southwest Region Army installations is competition for finite and scarce water resources with adjacent municipalities and other civilian users, including agriculture. Army installations in the southwest U.S. also have significant responsibilities managing environmentally-sensitive natural resources to meet environmental regulations, and maintaining and sustaining lands and vegetative cover for training operations. Endangered species compliance on southwest U.S. military installations is one of the greatest environmental compliance issues affecting military training and operations in the region. These military installations in the southwest U.S. support populations of one or more federally-listed species as well as state-listed species and species of conservation concern. They also support designated U.S. Fish and Wildlife primary recovery populations, such as the Desert Tortoise on Fort Irwin.

**Table 6. Army Installations Located in NCA Southwest Region**

<b>Management Responsibility</b>	<b>Installation</b>	<b>State</b>
<b>IMCOM</b>	Fort Huachuca	AZ
	National Training Center and Fort Irwin	CA
	Presidio of Monterey	CA
	Fort Carson	CO
	Dugway Proving Ground	UT
<b>AMC</b>	Military Ocean Terminal Concord	CA
	Sierra Army Depot	CA
	Hawthorne Army Depot	NV
	Deseret Chemical Depot	UT
	Tooele Army Depot	UT
	White Sands Missile Range	NM
	Yuma Proving Ground	AZ
<b>USAR</b>	Fort Hunter Liggett/Combat Support Training Center	CA
	Camp Parks	CA
<b>ARNG</b>	Camp Navajo	AZ
	Camp Roberts	CA
	Camp San Luis Obispo	CA
	Camp Williams	UT

**2.4.2 Southwest Region NCA Climate Outlooks**

The NCA Southwest Region is characterized by high topographical diversity, extensive coastal areas, and continental interior regions. Climate in the region is a complex interaction of mountain ranges, coastal zones, oceanic circulations, and subtropical weather systems. The region is represented by some of the hottest and driest desert regions in the U.S., some of the wettest regions in the U.S., and a Mediterranean-like climate along the southern Pacific coast. This complexity makes generalizing climate and climate impacts across the region difficult. The impacts of climate trends in the NCA Southwest Region on Army installations will vary based on the geographical location and elevation gradients of the installation. However, the majority of installations in the NCA Southwest Region are located in lower altitude desert regions and along the California coast.

Important climate factors identified in the NCA Southwest Region outlook include drought, heat waves, winter storms, and floods. The NCA outlook for the Southwest Region generally anticipates hotter and drier conditions across the region. Temperature increase in coastal areas is slightly less than inland areas. Regional annual average temperatures are projected to rise by 2-6°F by 2041-2070 under the B1 emission scenario, and by 5-9°F by 2070-2099 under the A2

emissions scenario, with the greatest increases in the summer and fall. Temperature increases in summer are projected to be higher than in other seasons across the midpoints of all scenario time periods (2021-2050, 2041-2070, and 2070-2099) but temperature variability is projected to be higher in winter across all time periods relative to summer variability. The observed trend of a longer frost-free period during the last century will continue, with projected increases of up to 40 days over current numbers in far west inland areas by the 2041-2070 time period. Heating degree days are expected to decrease across the region with the greatest decrease in higher altitude regions, and cooling degree days will increase with the greatest increase in the hottest areas such as southern California and Arizona. The percent increase in cooling degree days is proportionally greater than the decrease in heating degree days across the region. The outlook expects the largest increase in the number of days >95°F and the number of consecutive days >95°F in the interior, southern portions of the region primarily in Arizona and New Mexico. The annual number of days <10°F are expected to decrease most markedly in higher altitudes regions of the inland north.

As in many other NCA regional outlooks, changes in future precipitation patterns are somewhat more ambiguous than for temperature. The multi-model means for the region indicate a gradient of precipitation change from north to south with slightly greater precipitation in northern regions and the largest decreases in the southern regions. However, the percentage changes in mean precipitation are relatively small. The variability in seasonal projections of precipitation among the 15 CMIP3 models indicates large uncertainty in seasonal precipitation changes. Multi-model means of precipitation indicate increased variability of precipitation across the region. NARCCAP regional models for the period 2040-2070 show an increase in extreme precipitation events (annual number of days >1") predominantly in northern Utah and Nevada, and an increase in maximum consecutive number of days <3 mm in southern Arizona and California.

### ***2.4.3 Potential Vulnerabilities of Southwest Region Army Installations to Climate Change***

Extreme temperatures, drought affecting water availability, and alteration of burn regimes resulting from the interaction of climate change and non-native invasive grasses will likely have the greatest implications for NCA Southwest Region Army installations. Potential vulnerabilities of southwest Army installations and operations will depend on geographical location, elevation gradients, and timing of anticipated climate change.

NCA Southwest Region installations located mainly in desert environments with significant land-based training missions (Fort Irwin and Fort Bliss) are currently subject to high temperatures and dry conditions. Units training in these environments are already adapted to operating in extreme desert environments. However, to the extent that extreme heat events currently require reductions in personnel activity levels or exceed equipment performance parameters, projected temperature changes would increase heat-related constraints on land-based training activities. Although intermittent flash flooding can temporarily disrupt land-based training operations, this currently is not a significant operational constraint, and the outlook for changes in precipitation patterns does not suggest a significantly greater future

impact. NCA Southwest Region installations generally have low exposure to other extreme weather events that are more typical of eastern U.S. regions, such as tornadoes, lightning storms, and hurricanes. The NCA Southwest Region outlook does not address whether there will be a significant increased risk of these types of extreme weather events from the current baseline.

Army air training and operations use the extensive military air space available in the NCA Southwest Region. Extreme high temperatures can affect aircraft lift capacity and performance, which will be an increasingly important factor under future climate outlooks, particularly for air operations conducted from bases located in interior desert environments.

The changing fire dynamics in the NCA Southwest Region from the interaction of higher temperatures, drought, historical fire suppression, and non-native invasive grasses are likely to increase fire risk on many NCA Southwest Region installations. Increased frequency of high fire danger conditions can preclude use of pyrotechnics, grenade simulators, and live-fire training with tracers to reduce chance of wildfires. Similarly, high fire danger can cause restrictions on use of air-delivered weapon systems and on testing programs for a variety of ordnance and missile systems.

Most southwest Army installations are inland and will not be directly affected by sea level with the exception of access and use of port facilities for Army military shipments.

The extensive military installation built infrastructure in the NCA Southwest Region is subject to the same climate conditions and vulnerabilities identified for analogous civilian-built infrastructure. The effects of increased temperature and altered precipitation patterns on water availability are likely to be a predominant impact of climate change on installation built infrastructure and ability to support the Army testing and training missions in the region. Water is currently a limiting resource across much of the NCA Southwest Region and many Army installations are located in the most arid regions of the southwest. To meet current water needs, Army installations are implementing water conservation and reuse programs. With increasing civil water demands and potentially reduced water availability because of climate change, Army installations will be subject to increased costs as well as conflict over water resource allocation.

Design and operational criteria for new weapon systems increasingly will need to account for more extended periods of high temperature. Operational limits of delicate electronic systems will be challenged by increasing temperatures and increased dust conditions under dryer conditions. Anticipated increase in cooling degree days relative to a decrease in heating degree days in the NCA Southwest Region would increase energy usage, resulting in increased direct costs, implementation of energy conservation standards, and building or retro-fitting of energy efficient construction. The regional interdependency of installations with surrounding civil power and communication networks, roads, railways, and water systems may result in increased installation vulnerability to climate impacts on systems and facilities external to the installation.

Habitat transition and direct physiological impacts of temperature, precipitation trends, and variability resulting from climate change are expected to have consequences for installation environmental management programs and regulatory compliance. Federally-listed threatened and endangered species have the most direct impact through restrictions on access to training and testing lands. Army installations in the NCA Southwest Region try to minimize regulatory restrictions by management of populations and habitats and reduction of military impacts on resident listed species populations. Habitat transition or modification as a result of increased temperature, drought, altered hydrology, and alteration of fire regimes with climate change will complicate the ability of installations to maintain status of currently listed species populations and may result in increased listings of species that are currently considered at risk but not yet listed. Increased temperatures and potential changes in precipitation patterns may require modification of fire management programs. Warmer winters and longer growing seasons may relax cold constraints on the upper and northern limits of native species and invasive species, most of which originate from Mediterranean, tropical, and subtropical regions of the world. Shifts in species phenology because of longer growing seasons may disrupt obligate mutualisms such as pollinator networks, which may increase the vulnerability of currently listed and at-risk species. Installation natural resources management costs could increase to address increased incidence of invasive species and increases in listed and at-risk species.

## **2.5 Northwest NCA Region**

### ***2.5.1 Description of Northwest Region Army Installations and Missions***

Joint Base Lewis–McChord (JBLM) located near Olympia, WA at the southern end of Puget Sound and JBLM sub-installation Yakima Training Center (YTC) located in south-central Washington near Yakima are the major Army installation facilities in the NCA Northwest Region (Table 7). JBLM was formed by the merger of Fort Lewis and McChord Air Force Base by the 2005 BRAC and is under Army administrative control. JBLM is approximately 142 square miles in area and is home to the 2<sup>nd</sup> Infantry Division, as well as support and Headquarters units of the Army's I Corps. YTC, with its 505 square miles, provides land and air gunnery and artillery ranges for JBLM tenant units as well as Air Force and Reserve units.

Several significant ARNG facilities are located in the region. Camp Murray is adjacent to JBLM, Camp Rilea is located on the northern Oregon coast, and Camp Adair is located in the Willamette valley near Corvallis, OR. Orchard Range in Idaho is the largest of the ARNG installations in the region at 138,051 acres. The Orchard Range is located in a relatively unpopulated area along the Snake River approximately 14 miles south of Boise and provides maneuver and firing ranges for armored units of the Idaho National Guard and Guard units from surrounding states.

**Table 7. Army Installations Located in NCA Northwest Region**

<b>Management Responsibility</b>	<b>Installation</b>	<b>State</b>
<b>IMCOM</b>	Joint Base Lewis-McChord (JBLM)	WA
	Yakima Training Center (JBLM sub-installation)	WA
<b>ARNG</b>	Orchard Range	ID
	Camp Rilea	OR
	Camp Murray	WA

**2.5.2 Northwest Region NCA Climate Outlooks**

Climate patterns of the NCA Northwest Region are spatially diverse, caused by the predominant west to east progression of weather systems off the Pacific Ocean and the interaction with the north-south oriented Coastal and Cascade Ranges. Climate west of the Cascade Range is characterized by high precipitation with a strong seasonal pattern with peak amounts during late fall and winter seasons. Coastal regions record some of the highest rainfall totals of the conterminous U.S., and the Cascade Range records some of the highest snow totals. Temperatures east of the Cascades are moderated by cool temperature of ocean surface waters. The Cascades present a rain shadow effect resulting in significantly lower precipitation totals in the eastern portion of the region, with desert conditions prevailing particularly at lower elevations. Temperatures east of the Cascade Range are also more seasonally variable with summer temperature much higher because of the mountains blocking the moderating marine influence. Winter temperatures east of the Cascade Range are generally moderate because of the blocking effect of Arctic air masses by the Rocky Mountain ranges to the east.

The climate outlook for the NCA Northwest Region indicates warmer temperatures across the region, with the largest increase in mean temperatures occurring west of the Cascades Range and especially in southwest Oregon and southern Idaho. Average annual temperatures may increase by 3.3-9.7°F across emissions scenarios. Temperature increases in summer are projected to be higher than in other seasons across the midpoints of all scenario time periods, but temperature variability is projected to be higher in winter for the 2041-2070 and 2070-2099 time periods relative to summer variability. The observed trend of a longer frost-free period during the last century will continue across the region, with projected increases >40 days over current numbers in some areas west of the Cascades Range by the 2041-2070 time period. Heating degree days are expected to decrease across the region with the greatest decrease in eastern Idaho where the current number of heating degree days is highest. Cooling degree days are expected to increase across the region with the greatest increase in southern Idaho and Oregon and southeastern Washington. The percent increase in cooling degree days is proportionally greater than the decrease in heating degree days across the region. The outlook expects the largest increase in the number of days >95°F and the number of consecutive days

>95°F (heat waves) in southern Oregon and Idaho and southeast Washington. The annual number of days <10°F would decrease most markedly in eastern Idaho.

The CMIP3 multi-model medians for the region indicate an increase in precipitation for all time periods and scenarios along a north-south gradient with northern parts of the region having the greatest increase. However, the percent increase is relatively small and the range of projections across model simulations is relatively wide with some models showing decreases in precipitation. NARCCAP simulations of seasonal variability for the 2041-2070 period show increases in precipitation for most of the region occurring primarily in winter and decreases across the region in summer. NARCCAP multi-model model simulations indicate an increase in extreme precipitation events (>1"/24 h) by the 2041-2070 period. The greatest percentage increase occurs in regions east of the Cascade Range (i.e., in areas that currently have low numbers of extreme precipitation events). Simulations show the greatest percentage increase for the more extreme thresholds (>4"). The NARCCAP simulations show an increase in the multi-model mean for a consecutive number of days with precipitation <0.1 inches across the region, with the greatest increase of up to an additional 10-15 days in western Oregon.

### ***2.5.3 Potential Vulnerabilities of Northwest Army Installations to Climate Change***

JBLM, YTC, and Orchard Range represent opposite ends of the NCA Northwest Region climate spectrum. The habitat of JBLM is representative of dense conifer woodlands and Puget prairie/Garry oak woodlands characteristic of the high-rainfall Southern Puget Sound lowlands of Washington State. JBLM is largely surrounded by urban development and has some of the best remaining remnants of Puget Sound lowland habitats. YTC and Orchard Range are representative of more arid conditions characteristic of the region east of the Cascade Range. Vegetation communities of both YTC and Orchard Range are typically desert grasslands and shrub lands, primarily sage brush.

The increase in temperature, incidence of heat/cold waves, and precipitation projected for installations west of the Cascades Range is modest compared with other regions because of moderating oceanic effects. As a result, impacts from these climate factors on facilities, energy requirements, and training and operations on these installations are expected to be minimal. The greatest impact of future climate on JBLM and other ARNG installations west of the Cascades Range will likely result from the significant increase in the frost-free season. A longer frost-free season may result in greater incidence of damaging insect outbreaks, particularly those that increase mortality of conifers. If there is widespread conifer die-out, fire risk would increase, especially if outlooks for lower summer precipitation are realized. An increased growing season may also disrupt phenologies of species of concern. Of particular concern would be mutualistic interactions of host plant/butterfly species. Federally-listed and candidate butterfly species occur on JBLM and the ARNG installations, and if the mutualistic relationship of these species with the host is disrupted by a change in growing season, this will increase the costs and effectiveness of recovery efforts. On JBLM the presence of these species is already limiting training activity on the few open grassland areas available for mechanized training.

With the exception of Camp Rilea, sea level rise is not expected to impact Army installations in the NCA Northwest Region. Camp Rilea is adjacent to the Pacific Ocean with three miles of beach frontage on the Clatsop Plains. The installation topography is characterized by a series of active and inactive sand dune complexes with a maximum elevation of 30 meters. The installation's low elevation, beach frontage, and highly erodible sand dunes make facilities and training land susceptible to impacts of increased sea level and associated increased tidal and wave surge with storms. Increased salt water intrusion will also be a factor in sensitive interdunal wetlands.

Army installations east of the Cascade Range are more susceptible to impacts of higher mean temperatures, extreme heat events, and alteration of precipitation patterns. YTC and Orchard Training area primarily support mechanized maneuver training and weapons live-fire training areas. To the extent that extreme heat events currently require reductions in personnel activity levels or create challenges for equipment performance, projected temperature changes increase heat-related constraints on land-based training activities. The combination of increased extreme heat events and longer dry periods would increase potential for high fire danger. Increased frequency of high fire danger conditions can preclude use of pyrotechnics, grenade simulators, and live-fire training with tracers to reduce chance of wildfires. Increased wild fire potential would also impact sensitive shrub land habitats, especially sagebrush vegetative communities that support species of concern, such as the federally-listed sage grouse on YTC. Increased cooling days are expected to increase utility costs for these installations. Water availability is not expected to be significantly impacted given the magnitude of projected precipitation changes, and the proximity to major river systems and storage potential of mountain rain and snowmelt run-off.

## **2.6 Midwest NCA Region**

### ***2.6.1 Description of Midwest Region Army Installations and Missions***

The NCA Midwest Region hosts several significant installations that provide training, deployment support, and weapons development and manufacturing for the Army (Table 8). Fort Leonard Wood in south-central Missouri is home to the Maneuver Support Center of Excellence, which provides schools, training facilities, and deployment support for combat support services including Engineer, Military Police, and Chemical, Biological, Radiological, and Nuclear (CBRN) units. Camp Grayling, MI, at 147,000 acres, is the largest National Guard installation in the nation and provides air and ground training facilities and ranges used by National Guard units from all surrounding states. Camp Atterbury, Indiana is a major facility for training and preparation of National Guard, Reserve, and Active Army units deploying overseas for contingency mission. Fort McCoy is the Army's only Total Force Training facility and has the mission to train and support deployments for Army Reserve and Active units.

Several important military manufacturing, development, and storage facilities under IMCOM and AMC command are located across this NCA region. These facilities manufacture a wide spectrum of munitions, weapons, and military vehicles and components. The Detroit Arsenal is

home to the Tank Automotive Research, Development and Engineering Center (TARDEC) and the Joint Manufacturing Center Lima currently produces the M1 Abrams tank. Rock Island Arsenal is the world’s largest government-owned weapons manufacturing arsenal in the world, manufacturing a wide selection of weapon systems and components. The other AMC facilities manufacture a variety of military ordnance.

**Table 8. Army Installations Located in NCA Midwest Region**

Management Responsibility	Installation	State
IMCOM	Detroit Arsenal	MI
	Fort Leonard Wood	MO
	Fort McCoy*	WI
	Rock Island Arsenal	IL
AMC	Iowa Army Ammunition Plant	IA
	Crane Army Ammunition Activity	IN
	Lake City Army Ammunition Plant	MO
	Joint System Manufacturing Center Lima	OH
ARNG	Camp Dodge Johnston	IA
	Marseilles Training Site	IL
	Camp Atterbury	IN
	Camp Grayling	MI
	Fort Custer Training Center	MI
	Camp Ripley	MN
	Camp Crowder Neosho	MO
	Camp Clark Nevada	MO
	Camp Perry	OH
	Ravenna Training And Logistics Site	OH

\*IMCOM installation with significant U.S. Army Reserve Mission

### **2.6.2 Midwest Region NCA Climate Outlooks**

The climate of the NCA Midwest Region is primarily influenced by its central location in the North American continent, lack of mountain ranges, and proximity to the Great Lakes. These characteristics allow incursions of cold arctic air masses from the north in winter and warm, humid air masses from the Gulf of Mexico in summer. The result of these influences is highly variable seasonal differences in weather and severe weather events. Midwest summers are typically warm and humid. The polar jet stream in winter brings frequent storm systems, clouds, windy conditions and precipitation, with significant snow events. The seasonal transition in spring and early summer from Arctic to subtropical influence results in a high frequency of severe thunderstorms, hail, and tornadoes. All seasons can have damaging high winds. Flood-producing rainstorms are frequent, but severe droughts do occur. Temperatures

generally increase across the region on a north to south gradient. Average annual precipitation totals generally increase along a northwest to southeast gradient. The Great Lakes tend to moderate near shore weather conditions in both winter and summer. However, “lake effect” snows along southern and eastern Great Lakes shorelines can result in very large snowfall amounts.

As in the other regions, temperatures in the NCA Midwest Region are projected to increase across all time periods and scenarios that were modeled. Temperatures may increase by approximately 5.6°F by 2100 under the B1 emission scenario, and 8.5°F for the A2 emission scenario. There is relatively little spatial variability for projected temperature increases across the region. Simulations show temperature increases in summer and winter to be slightly higher than in spring and fall. The number of days with extreme temperatures and consecutive days of high temperatures (>95°F) generally increase along a north to south axis, with increases of up to 30 days of extreme temperatures and an additional increase of consecutive days of up to 18 days projected in southern Missouri. Increases are projected to be <5 days for extreme heat across the northern tier of the region. The greatest decrease in the absolute number of days <10°F is in the northern part of the range with less of a decrease along a north to south gradient across the range. Likewise the change in the number of cooling degree days increases along a north to south axis, and the projected decrease in the number of heating degree days across the region is greatest in the northern states of Minnesota, Wisconsin, and Michigan. NARCCAP projections for 2041-70 indicate a mean increase in the frost-free season of 23 days across the region, with the largest increase of up to 30 days in northern Michigan.

Multi-model mean projections for precipitation change generally show a north-south gradient, with the greatest percent increase in northern Minnesota and a decrease in precipitation in southwestern Missouri. However, the model simulations show both decreases and increases in precipitation and the median percent changes are relatively small (<3%). NARCCAP multi-model seasonal simulations for 2041-2070 show an increase in precipitation across the region in both fall and winter, but decreases in precipitation in summer across the southern portion of the range up through the Ohio River valley. NARCCAP simulations for the 2041-70 period indicate an increase in extreme precipitation events for all thresholds from a 23% increase (>1 in) to 94% (>4 in). The greatest percent increase in extreme precipitation events is across the northern tier of the range. The annual maximum number of days with precipitation <3 mm for the period 2041-70 is only slightly reduced in the northern part of the region to no change in other parts of the region.

The NCA regional outlook does not provide projections for change in extreme weather events associated with convective thunderstorms, hail, wind, tornadoes, or extreme snow events. Recent observed data presented in the NCA outlook showed lower incidence of extreme cold waves, but little change in the frequency of heat waves. The intensity and incidence of extreme precipitation events is trending higher. Observed data do not show a change in wind intensity. The occurrence of very high snowfall seasons has decreased across the southern Midwest, but increased in Iowa, Minnesota, Wisconsin, and Michigan. The period of ice cover on the Great Lakes has been trending shorter.

### **2.6.3 Potential Vulnerabilities of Midwest Region Army Installations to Climate Change**

The potential vulnerabilities of NCA Midwest Region Army installations will be a function of geographical location; however, the potential impacts are perhaps more uncertain than for other NCA regions because the role of extreme weather events in the Midwest and the ambiguity and lack of projections for these events. An increase in extreme heat events will primarily affect installations with ground-based training missions in the southern Midwest, which would include Fort Leonard Wood and Camp Atterbury. At these installations, to the extent that current training activities are affected by extreme heat events, this likelihood will increase under future climate conditions. Reductions in extreme cold spells in the upper Midwest may increase training availability for installations such as Fort McCoy and Camp Grayling. Fire risk is generally not high for most Midwest installations because of relative high humidity and precipitation during warm seasons. Projections generally trending for higher future precipitation and lower drought risk suggest that fire risk will not significantly increase for Midwest installations under future climate conditions.

If an increase in intensity and incidence of extreme precipitation events is realized, installations associated with river systems (which are most Midwest installations and notably Rock Island Arsenal) are likely to have increased flood risk and associated prevention and mitigation costs. If there is an increase in high snowfall seasons, this would affect training range access during winter months and increase facility maintenance and snow removal costs.

Increased cooling degree days will increase energy costs for installations; however, the energy required for the manufacturing activities of facilities such as the ammunition plants may proportionally overwhelm any increase in energy requirements resulting from climate change.

All NCA Midwest Region installations with significant land area host federally-listed species and other sensitive habitats and species of concern. As in other NCA regions, changes in temperature and growing season will alter community composition and structure and will be an additional stressor to ecological systems and species. One example of particular relevance to NCA Midwest Regions installations is the increasing incidence of white-nose syndrome in bat species that may in part be a function of increasing temperatures. Many NCA Midwest Region installations provide hibernacula and maternity habitat for a variety of bat species. Another example is the potential for increased insect outbreaks because of warmer winter temperatures that damage forest communities that are a dominant habitat type on most NCA Midwest Region installations.

The biggest current climate-related threat to facilities and personnel safety on NCA Midwest Region installations is from extreme weather events including lightening, tornadoes, straight-line high winds, and hail. It is not known to what extent the frequency or intensity of these events might change in the NCA Midwest Region as a function of climate change. However, if future climate conditions enhance the atmospheric instabilities that generate these extreme events, the expectation would be an increase in these events. Because future risk from these

events is uncertain, installations should continue to implement and update emergency response plans and safety training for personnel.

## 2.7 Alaska NCA Region

### 2.7.1 Description of Alaska Region Army Installations and Missions

The Army’s Alaska assets include Fort Wainwright and Fort Greely (under the jurisdiction of Fort Wainwright) (Table 9). Fort Richardson (now part of Joint Base Elmendorf Richardson, or JBER) is under USAF operational control, as well as JBER’s smaller sub-installations at Seward, Whittier, Eklutna Glacier, Gulkana, Haines, and Tok.

The built infrastructure required to support military operations in Alaska associated with these installations is significant. Most installations are able to operate entirely on their own with constructed facilities that include air fields, medical facilities, housing, and all supporting utilities (e.g., power, water, sewer, and communication networks). The installations and their host communities, however, are highly interdependent for justification, funding, and operations and maintenance of large infrastructure investments such as ports and harbors, rail, pipeline, and highway transportation projects.

Army installations in Alaska also have significant responsibilities for managing environmentally sensitive natural resources to meet environmental regulatory requirements and for maintaining and sustaining lands and vegetative cover for training operations. The U.S. Army manages approximately 1.5 million acres of training lands in Alaska to include impact ranges, aerial bombing ranges, drop zones, assault air strips and landing zones, and the Battle Area Complex, an instrumented live-fire tactical training range able to accommodate single infantry soldiers to mechanized battalion exercises. Many of the training areas have seasonal use restrictions due to land cover, seasonal hydrologic conditions, permafrost, or wildlife migration. The Cook Inlet sub-species of beluga (*Delphinapterus leucas*) represents an endangered species compliance issue affecting the use of the Eagle River Flats Impact area.

**Table 9. Army Installations Located in NCA Alaska Region**

Management Responsibility	Installation	State
IMCOM	Fort Greely	AK
	Fort Wainwright	AK

### **2.7.2 Alaska Region NCA Climate Outlooks**

The NCA Alaska Region Climate Outlook presents climate projections that relate to potential vulnerabilities for Army operations, training, facilities, and natural resources on installations in the region. Alaska represents a large area with many different climates, ranging from temperate rain forest in the southeast to extreme cold and dry conditions in the Arctic. As such, the predicted changes in temperature and precipitation differ over the state. Overall, increases in mean temperatures are projected across the state and across all time periods and scenarios. Projections indicate that larger changes would occur for more northern areas and that the greatest temperature increases are projected for the winter months. Under the B1 emission scenario, temperatures may increase by 6-8°F in the north and 4-6°F in the rest of the state by 2100. Under the A2 emission scenario, temperatures may increase by 10-12°F in the north, 8-10°F in the interior, and 6-8° in the rest of the state by 2100.

Precipitation is also predicted to increase over all areas of the state with the largest increases occurring in the summer and fall, except for southeast Alaska where the largest increases would occur over the winter. The incidence of storm events along the western and Arctic Alaska coast is predicted to remain the same, but the number occurring during times when a shorefast ice cover protecting the shoreline is absent would increase. Indirect effects of climate change related to sea level rise are difficult to assess due to the non-uniform isostatic rebound (uplift) in many regions of the state (especially southeast Alaska). The combined impacts of the retreat of the Arctic sea ice cover, thawing permafrost along the coast, and storm wave-induced erosion are significantly greater than for sea level rise alone.

### **2.7.3 Potential Vulnerabilities of Alaska Army Installations to Climate Change**

Warming temperatures and changes in precipitation will have a variety of implications for Army installations throughout Alaska. The majority of built facilities and training lands are located in south-central and interior Alaska. The greatest implications can result from the retreat of sea ice and warming/thawing of permafrost soils. Sea ice retreat results in longer periods when permafrost soils along the coast are not protected by shorefast ice, making them more vulnerable to erosion from storms. Projected increases in the depth of the permafrost active layer will result in changes to surface and subsurface hydrology, resulting in increased surface drainage and/or wetland transition. Even with the predicted increase in precipitation, increased drainage would promote soil drying with increased incidence of forest and tundra fires.

Impacts on an installation's built infrastructure and equipment will vary depending on its location within the state. Although increased temperatures are expected to result in fewer heating requirements, they also will result in degradation of permafrost in interior Alaska and along much of the western and northern coasts, potentially damaging foundations, roads, pipelines, and communications structures. Building and structure foundations, roads, and pipelines may require retrofits to protect their integrity due to increased active layer thickness of permafrost soils. Increased precipitation may come as rain in south central Alaska but will

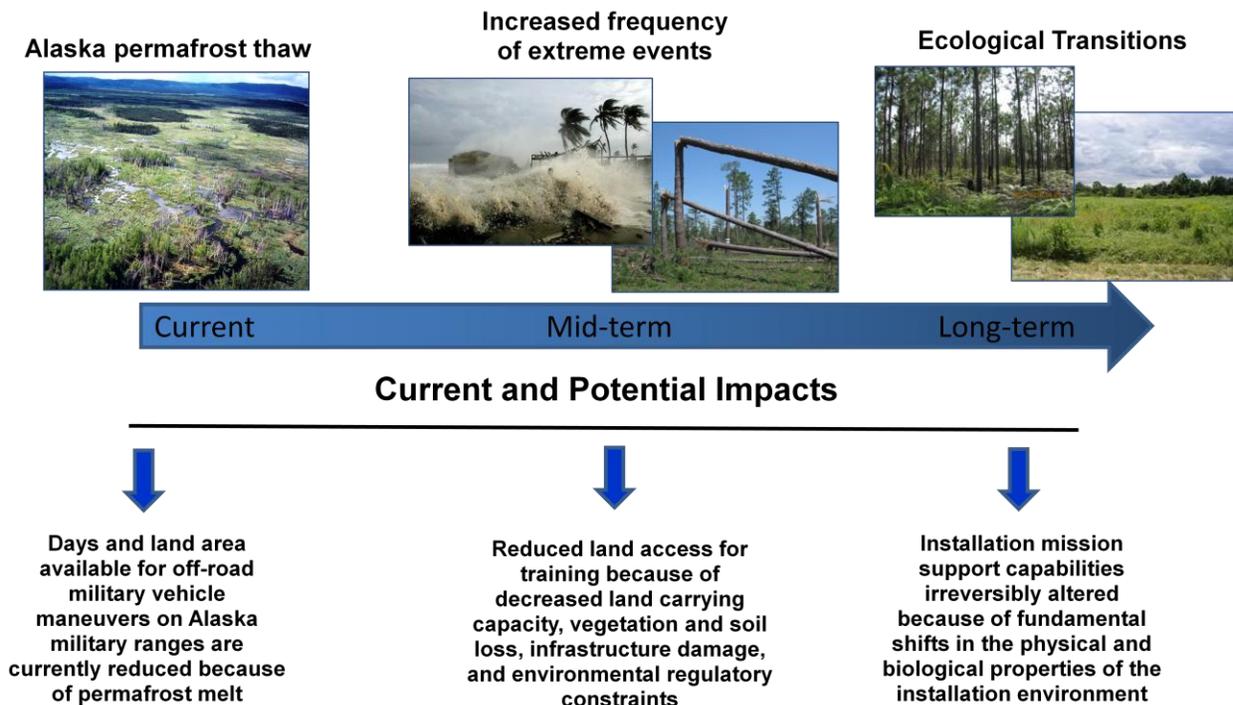
result in more snow in the interior and coastal areas, resulting in increased snow loads on structures with the potential need for design adaptations for existing buildings and increased maintenance costs of snow removal.

Whereas impacts on air-based training and operations are expected to be minimal, land-based training are likely to be affected mostly by changes in access to training areas. Many of the training areas in interior Alaska are utilized for winter training when wetland areas and permafrost soils are frozen and snow covered. Access to some of these training lands is by ice bridges constructed in the winter over the Tanana and Delta Rivers. Increases in temperature and changes to permafrost would result in shorter durations of training access with some training areas becoming unusable. Increased drying conditions may result in some impact areas being unavailable for incendiary or pyrotechnic rounds. Live-fire exercises also may be curtailed.

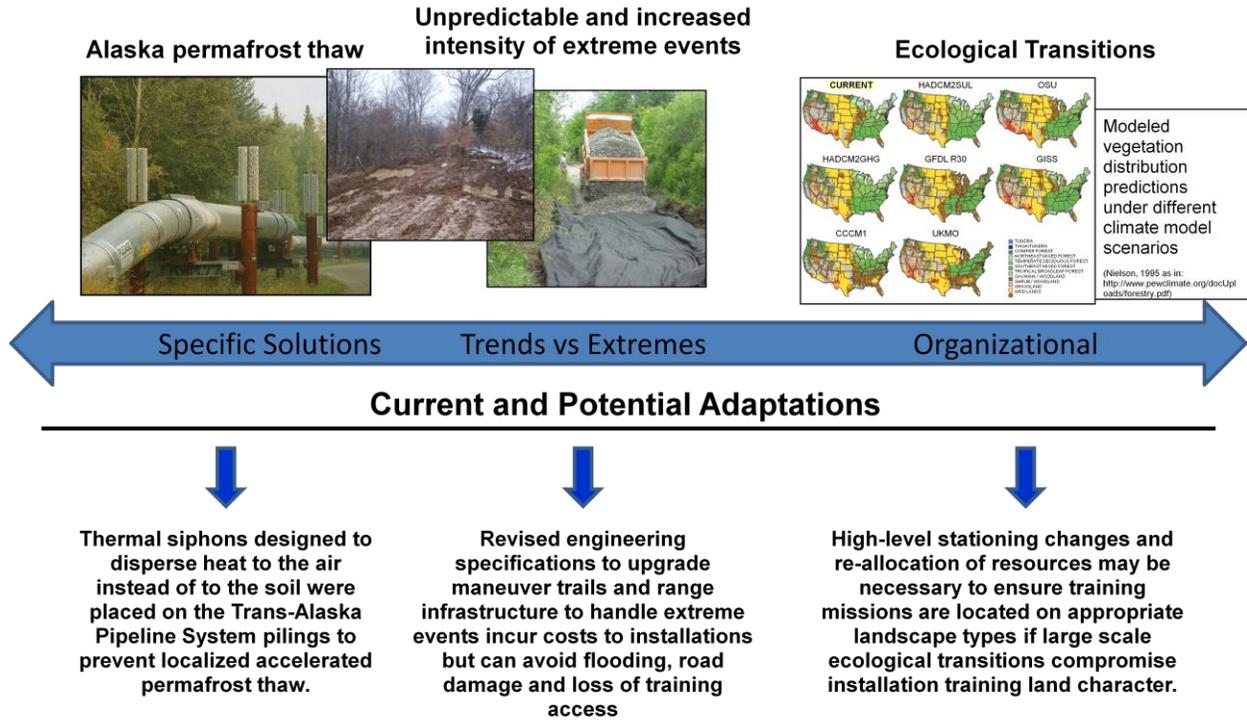
Installation environmental management of natural resources and regulatory compliance programs are likely to be directly impacted by physiological impacts of temperature and precipitation trends, as well as the resulting change in permafrost and soil moisture. Federally-listed species (as well as at-risk species that could be listed) have the most direct impact through restrictions on access to and utilization of training lands. Habitat transition or modification as a result of increased temperature, drought, altered hydrology, and alteration of fire regimes with climate change will complicate the ability of installations to maintain the status of federally-listed species populations. Warmer temperatures may expand the northern limits of native and invasive species, resulting in species interaction and ecosystem changes. Changes in permafrost and soil moisture may result in entire ecosystem shifts in interior Alaska, with permafrost wetlands draining and transitioning to a willow/scrub habitat.

### 3. IMPLICATIONS OF ANTICIPATED TIMING, SCALE, & TYPE OF IMPACTS

How vulnerabilities to Army mission and facilities from climate change are realized will depend on the timing, spatial scale, and type of the impacts. These factors will also influence at what Army organizational-level planning and actions would need to be taken to adapt to impacts. Figure 4 shows a conceptual example of potential impacts as a function of the timing of climate phenomena. Current localized impacts such as permafrost thaw may initially require only local and modest actions to effectively cope with changed conditions. However, as longer-term trends are realized, impacts may be more widespread and irreversible requiring decisions and actions at higher decision levels within the Army. The type of adaptive response and level of organizational responsibility will also depend on the characteristics of the impact as illustrated in Figure 5. Localized impacts, extreme events, and widespread climate-related transitions will all require different technological solutions, planning criteria, and decision processes to effectively adapt to dynamically changing future climate conditions.



**Figure 4. Relationship of Timing of Climate-Related Phenomena and Impacts on Training and Testing**



**Figure 5. Adaptation Approaches and Responsibility as a Function of Type of Impact**

#### 4. ARMY ADAPTATION PLANNING APPROACH

To meet the potential challenges of future climate impacts on Army installations and missions, OASA(IE&E) is developing an Army climate change adaptation planning framework. A key aspect of this framework is integration of climate change adaptation planning into current installation-level plans and assessments including Installation Sustainability Plans, Real Property Master Plans, Range Complex Master Plans, Integrated Natural Resources Management Plans, and Critical Infrastructure Assessments. This framework will incorporate the CEQ's implementing instructions and OSD guidance as it is issued and will provide a standardized framework that enables Command and Army-wide evaluation and roll-up. The framework was piloted at two installations in FY2013 and feedback is being incorporated. Guidance for implementation of the framework will be developed in FY2014.

#### 5. ARMY POLICY CONSIDERATIONS FOR CLIMATE CHANGE ASSESSMENT AND ADAPTATION PLANNING

This high-level overview of potential Army vulnerabilities to climate change and development of an Army Adaptation Planning Framework provides a starting point for identifying policy requirements and technical guidance. More specific and quantitative analyses of installation and mission vulnerabilities and development of necessary decision support and planning capabilities is required. The DoD Strategic Environmental Research and Development Program (SERDP) has identified five key policy questions for climate change assessments and adaptation planning for DoD and the military Services in the report "Assessing Impacts of Climate Change on Coastal Military Installations: Policy Considerations," dated January 2013. These SERDP policy considerations provide a context for this vulnerability assessment and Army initiatives to develop an adaptation planning framework and demonstration through installation pilot workshops. Evaluation of Army initiatives in the context of these policy questions may also provide consistency with evolving DoD policy guidance for climate change assessments and planning. The SERDP policy questions and relevant Army initiatives are:

**Policy Question 1: Integrating climate change considerations.** *How can DoD and the military Services best integrate climate change considerations into planning and decision processes to ensure military readiness?*

Development of the Army's Adaptation Planning Framework provides a mechanism for integrating adaptation planning in established installation planning processes that may be impacted by climate factors. This approach will facilitate installation planners in assessing site-specific vulnerabilities and determining appropriate adaptation approaches. Additional work and guidance will be required to scale this approach for planning and programming requirements at the enterprise and HQDA levels such as annual budgeting, base alignment, or stationing decision processes.

**Policy Question 2: Technical guidance required.** *What technical guidance is required from DoD and the military Services to enable high quality assessment and adaptation planning to support planning and management decisions?*

It is anticipated that wide-scale implementation of these vulnerability assessment and adaptation planning capabilities at the installation level Army-wide will require technical support capabilities at the enterprise level. Successful technical transfer will require flexibility to incorporate new guidance from Federal, Defense, or Army levels, and any new relevant capabilities emerging as future climate information products and decision support tools become more targeted and precise. This may require establishment of an enduring Army capability to help evaluate and prepare relevant data and analyze vulnerabilities and risks that is responsive and synced with installation planning cycles and command decision processes, such as future base alignment and stationing initiatives. One of the planned outcomes of the FY2013 installation adaptation planning workshops is to identify installation technical support requirements that will meet assessment and planning needs across the Army installations and commands.

**Policy Question 3: Degree of regional consistency.** *How can DoD and the military Services best balance the need for comparable assessment results across diverse regions, installations, and mission purposes, with the need for flexibility in assessment approaches to address regional/local conditions and priorities?*

Comparability of information across the diverse missions and geographical diversity of Army installations will be a challenge for making decisions at higher command levels and HQDA. In this assessment, use of NCA regional climate outlooks and scenarios provides a common baseline for evaluation of relevant climate factors and installation vulnerabilities. Balancing unique installation-specific information requirements and vulnerabilities with Service-level information requirements will require consistency of approaches across regions. Maintaining a focus on translating installation climate vulnerabilities to impacts on military mission and operations will help provide a common denominator for Service-level decision and information requirements.

**Policy Question 4: Ensuring military resilience.** *How can DoD and military Services investments at extant military installations as well as potential future base realignment and closure investments be made so that such decisions, at the installation level and in the aggregate, ensure resilience of the military to climate change?*

This assessment identifies some key considerations for including climate factors in decisions and priorities for capital improvements, facility upgrades, base alignment and stationing, and budgeting. These considerations include support of military mission capabilities, projections for timing of critical climate thresholds, required lead time for planning processes, and life-cycle of affected facilities, facility maintenance, upgrades, or equipment. A critical objective of the Army's adaptation planning framework is to assist installation stakeholders in establishing the relationship between climate change

impacts on their installation's built infrastructure, lands, and ranges with potential implications for military readiness activities.

**Policy Question 5: Coordination with civilian activities.** *How can DoD and the military Services ensure that external / civilian activities that may affect DoD installations and military readiness are effectively accounted for in installation and civilian strategies under climate change?*

As noted in this assessment, Army installations are highly interdependent on local economies, transportation and communications networks, and utilities, including water, energy, and waste systems. Engagement in regional adaptation planning processes will be a critical aspect of successful installation vulnerability assessment and adaptation planning. As part of the Army installation pilot workshops, a review of regional climate change vulnerability assessment and adaptation planning initiatives will be conducted to assess applicability for requirements of the pilot installation in that region. Access to and use of technical support capabilities, information resources, and technical expertise will reduce redundancy and ensure efficiencies in Army adaptation planning processes. It will also be desirable for Army policies and approaches to be compatible with other Federal agency and Services' approaches. For example, the current USACE adaptation planning recommendations for Civil Works can be evaluated and adapted for military requirements.

The Army's continuing efforts related to the policy considerations above will require addressing several technical and organizational issues. Assessment approaches will need to be flexible enough to accommodate site- and region-specific differences while providing enough comparability to support decision-making at the Service level. Assessment and planning approaches must also address the different spatial and temporal scales at which decisions are made across the Army. This assessment provides a high-level overview of potential Army vulnerabilities to climate change. Detailed assessments are still required that identify specific installation and mission vulnerabilities, critical thresholds, and specific adaptation response approaches. Consensus among Federal agencies, DoD, and the Services on appropriate selection and use of climate projections and scenarios needs to be established. Incorporating uncertainty, both in climate projections and system response, as an integral component of risk evaluation and adaptation planning will be a critical requirement. Very importantly, policies and processes established for climate change assessment and planning must recognize and be robust enough to accommodate the dynamic and rapidly evolving climate science, decision-support capabilities, and Army mission requirements.

## Appendix A

### Summary of Models, Scenarios, & Uncertainties

The National Climate Assessment (NCA) is based both on long-term observational climate data from weather stations across the United States, and on a suite of global climate model simulations of present and future climate, from multiple international research institutions. These model simulations all use an agreed upon common set of greenhouse-gas (GHG) concentrations for the 20<sup>th</sup> and 21<sup>st</sup> Centuries, based on a number of possible high- and low-emission scenarios. There is an inherent amount of uncertainty in any set of climate projections, as they are products of current research and understanding of the climate system. The section below summarizes these models, scenarios, and uncertainties, and the important distinction between the NCA's climate *projections* and climate *predictions*.

#### NCA Climate Models

The global climate models (GCMs, also known as general circulation models) used in the NCA have been developed by research institutions and agencies from multiple nations, including the United States (NOAA, NCAR, NASA), United Kingdom (UK Met Office/Hadley Center), the European Center, and Australia (CSIRO). These models have some common features, such as equations for heat, moisture, and winds in the atmosphere, ocean temperature, salinity, and currents. However, these models produce varying simulations of present-day climate features, such as tropical precipitation, arctic ice cover, or snow cover. The Coupled Model Intercomparison Project (CMIP) under the Dept of Energy created an archive of international GCM results to facilitate the validation and comparison of these models and produce the climate projections that are averaged over multiple models.

Fifteen GCMs from the CMIP-version 3 had the appropriate set of features and simulations to be used in the NCA. These models' results were used to make the multi-model averages under each scenario. In addition, these models were used to create *downscaled data sets*, which are higher-resolution (spatial and temporal) representations of the climate variables, typically temperature and precipitation. The first type of downscaling used for the NCA is *statistical downscaling*, which combines the changes in the long-term averages from the GCMs with daily observed mean variables to produce projections such as the number of days above 95°F at approximately 12-km grid spacing.

The second type used was *dynamic downscaling*, produced by using regional models that simulate the hourly and daily weather variables like a GCM, but at a higher grid resolution than what is feasible for a decades-long GCM scenario. The North American Regional Climate Change Assessment Project (NARCCAP) produced the dynamic downscaled data from the CMIP-3 models with regional climate models at a 50-km resolution for the A2 emission scenario only.

## Scenarios

The scenarios used by the models in the NCA are different timelines of future GHG concentrations in the atmosphere from the present observations through the year 2100. The scenarios each follow a different ‘story line’ of fossil-fuel and nonfossil-fuel use, population growth, industrial aerosols and other factors in the scenarios emissions. The scenario authors (*Nakicenovic et al. 2000*) consider each of them to be of equal probability. The scenarios used in the NCA can be summarized as:

- A2: High-emission scenario. This has CO<sub>2</sub> (or equivalent CO<sub>2</sub> amounts) increasing from 350 to 870 ppmv by year 2100, based on fossil-fuel growth, and has been called the ‘business-as-usual’ scenario as recent trends most closely resemble this.
- B1: Low-emission scenario. This has CO<sub>2</sub> increasing from 350 to 550 ppmv by 2100, with significant reductions in CO<sub>2</sub> emissions beginning around 2050 from nonfossil-fuel energy sources.

The GHGs in the scenarios include carbon dioxide, methane, ozone, nitrogen oxides, and chlorofluorocarbons. Water vapor is the most prevalent greenhouse gas, but it is not pre-determined in the models as it is computed as part of the modeled hydrologic cycle.

## Uncertainties in NCA Projections

There are uncertainties that are inevitable in any climate model simulations and in the NCA projections of future climate. The first distinction to make is the difference between these climate *projections* and a climate *prediction* of a specific outcome:

- Climate *projections* are simulations of possible outcomes that *could occur, if* the greenhouse gas concentrations follow one of the emission scenarios in the models. There is no assumption that either the A2 or B1 scenarios are more likely than any other, they are simply two possibilities. Since global energy use, economic growth rates, and policies that might influence emissions are not reliably predictable, there is no direct method to assign the probability of any one scenario to occur.
- Climate *predictions* are usually called forecasts from an initial starting point of what is most likely to occur. Predictions and forecasts can be measured against the endpoint observations and against other forecasts, and evaluated with a numerical value of skill.

The GCM simulations themselves have an inherent amount of uncertainty in the results, due to the limitations of the physics of numerical modeling, in the spatial and temporal resolution, and in the details of phenomena that interact in complex ways, such as clouds, radiation, ecosystems, and carbon absorption. As a result, each GCM in the NCA produces different simulations of present and future climate. There are some consistent features in the climate projections across most of the NCA models, suggesting greater confidence in these features:

- The large-scale temperature increase across the U.S. is the most consistent feature across the NCA models.
- The decrease in precipitation (mostly in summer) in the southwest U.S.
- The increase in precipitation in the northern tier of U.S. (west, central, and north).

The change in average precipitation across the central latitude band of the U.S. and in the southeast varies the greatest among the NCA model projections. As a result, there is less confidence in the specific sign and magnitude of this change in regional precipitation.

**References:**

Nakicenovic et al., 2000. *Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change.* Cambridge University Press: Cambridge. 599 pp.