Highlights and Examples

Department of Defense Climate Adaptation Plan

OCTOBER 12, 2021

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FOREWORD[1]

We in the Department of Defense (DOD) know first-hand the national security risk posed by climate change because it affects the work we do every day. Around the world, climate change is a destabilizing force, demanding new missions of us and altering the operational environment. At the same time, climate-related extreme weather affects military readiness and drains our resources. In just the past few years, wildfires have forced evacuations at bases in the western United States, while hurricanes on the East Coast and flooding in the Midwest have inflicted billions of dollars of damage on facilities that are home to key warfighting capabilities.

On January 27, 2021, President Biden issued Executive Order (EO) 14008, Tackling the Climate Crisis at Home and Abroad, making it administration policy that climate considerations will be an essential element of United States foreign policy and national security. The EO calls on federal agencies, including the DOD, to prioritize climate change in all our activities and incorporate its security implications into analyses as well as key strategy, planning, and programming documents.

Planning for today and into the future is our business, and we would not be doing our job if we weren't thinking about how climate change will affect what we do. This Climate Adaptation Plan provides a roadmap to ensure the Department maintains the ability to operate under changing climate conditions while preserving operational capability and protecting systems essential to our success.

As I stated when the EO was issued, going forward, the Department will include the security implications of climate change in all our risk analyses, strategy development, and planning. We will incorporate climate risk into planning; into modeling, simulation, and wargaming; and into key documents like the National Defense Strategy. These are essential steps, not simply to meet a requirement, but to defend the nation under all conditions.

Lloyd J. Austin III, Secretary of Defense

[1] Foreword from the DOD Climate Adaptation Plan: https://media.defense.gov/2021/Oct/07/2002869699/-1/-1/0/DEPARTMENT-OF-DEFENSE-CLIMATE-ADAPTATION-PLAN-2.PDF. Department of Defense, Office of the Undersecretary of Defense (Acquisition and Sustainment). 2021. Department of Defense Draft Climate Adaptation Plan. Report Submitted to National Climate Task Force and Federal Chief Sustainability Officer. 1 September 2021.

This companion document to the Department of Defense (DOD) Climate Adaptation Plan (CAP) highlights the Department's past successes and ongoing initiatives to address climate change considerations in the Department's plans, strategies, operations, and infrastructure. **This companion document represents just a few examples from a larger compilation of adaptation efforts across the Department.**

Aligned with the structure of the CAP, examples cover the five Lines of Effort (LOE):

1. Climate-Informed Decision-Making
2. Train and Equip a Climate-Ready Force
3. Resilient Built and Natural Installation Infrastructure
4. Supply Chain Resilience and Innovation
5. Enhance Adaptation and Resilience Through Collaboration

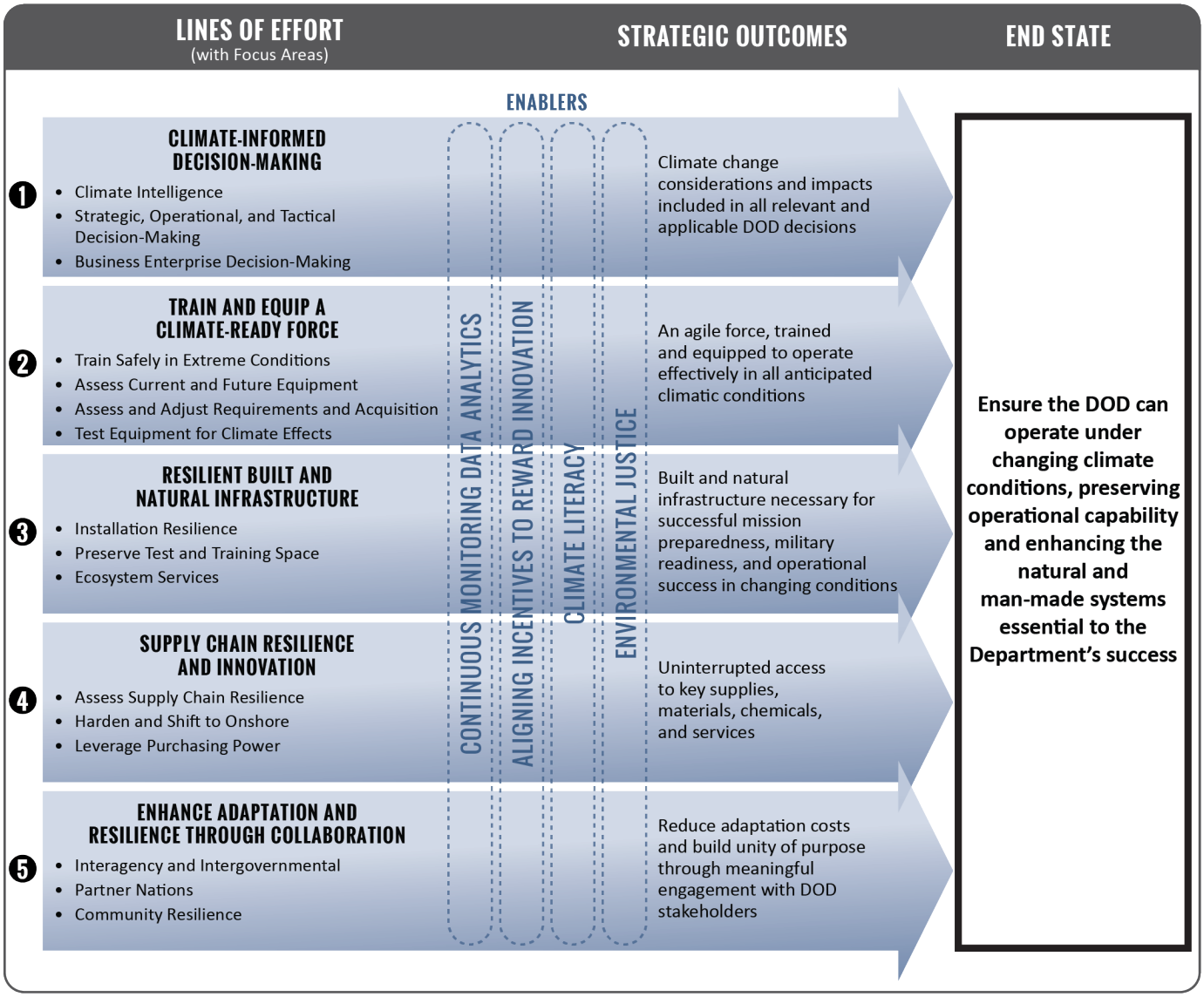
Adaptation: Adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative efforts.

Resilience: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.

— DODD 4715.21, Climate Change Adaptation and Resilience

Mitigation: Measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide from the atmosphere.

— U.S. Global Change Research Program

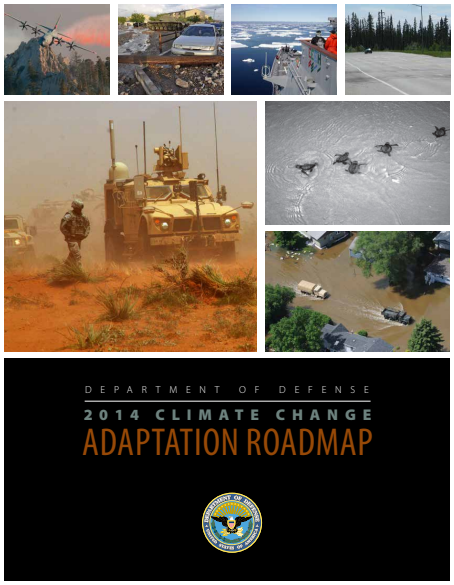


The Department's Climate Adaptation Plan outlines a strategic framework for achieving climate change adaptation and resilience. It contains five major Lines of Efforts (LOE), each with an intended strategic outcome, all working toward one desired end state. Four key enablers cut across and integrate actions of each LOE.

LOE 1. CLIMATE-INFORMED DECISION MAKING

DOD CLIMATE CHANGE ADAPTATION ROADMAP

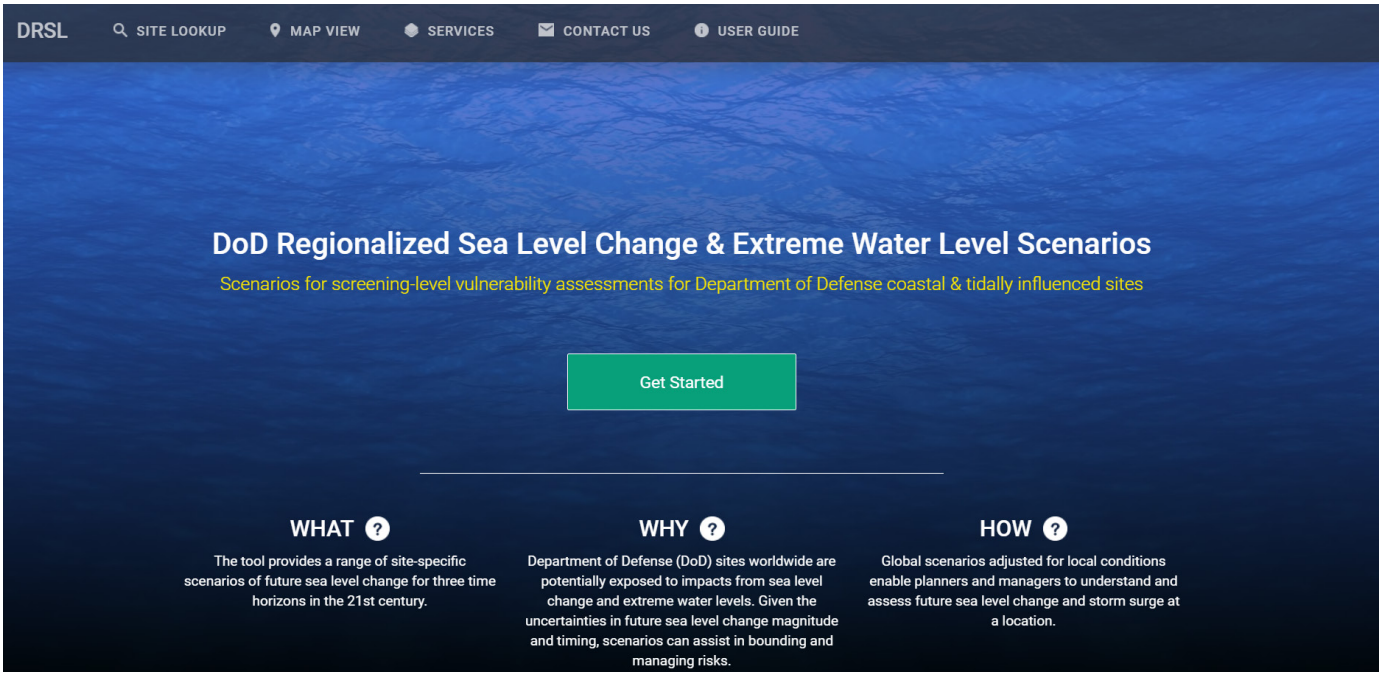
Climate change impacts threaten U.S. national security and the DOD's ability to defend the Nation. The Department is responding to climate change in two ways: adaptation to enhance resilience to the effects of climate change; and mitigation to reduce greenhouse gas (GHG) emissions (see definitions on previous page). The 2014 Climate Change Adaptation Roadmap focuses on the Department's climate change adaptation activities. The CAP builds upon the actions and the activities outlined in the DOD 2014 Climate Change Adaptation Roadmap.



Cover photo of the 2014 DOD Climate Change Adaptation Roadmap.

DOD REGIONALIZED SEA LEVEL (DRSL) DATABASE

In February 2021, the DOD made publicly available the DRSL Database (https://drsl.serdp-estcp.org/). The database provides regionalized sea level scenarios and extreme water level (EWL) statistics for three future time horizons (2035, 2065, and 2100) for more than 1,700 DOD sites worldwide. A multi-agency team of researchers developed an internal DOD database and published a report in 2016: "Regional Sea Level Scenarios for Coastal Risk Management: Managing the Uncertainty of Future Sea Level Change and Extreme Water Levels for Department of Defense Coastal Sites Worldwide." The database provides access to site-specific future sea level projection values for each of the three future timeframes, based on five global sea-level rise scenarios ranging from 0.2 meters to 2.0 meters rise by the year 2100, starting from 1992. Users can map and evaluate these scenarios to determine potential impacts and develop risk management strategies. Additional engineering analyses are appropriate for design purposes.



DOD's "DOD Regional Sea Level (DRSL) Change and Extreme Water Level Scenarios" online database tool, was developed to enhance and increase the efficacy of screening-level vulnerability and impact assessments for DOD coastal sites worldwide.

NAVY REGION SOUTHWEST FACILITY PLANNING USES THE NAVFAC CLIMATE CHANGE INSTALLATION ADAPTATION AND RESILIENCE PLANNING HANDBOOK

Navy Region Southwest facility planning efforts now incorporate adaptive planning measures from a variety of government agency sources, including NAVFAC's Climate Change Installation Adaptation and Resilience Planning Handbook. Regional planners are working with the National Oceanic and Atmospheric Administration and the Scripps Institute of Oceanography to study potential vulnerabilities at the Naval Amphibious Base. Sea level rise data for 2100 was used during the environmental planning and design phases of the Coastal Campus Project. The design configuration of five buildings was modified to resist a moderate sea level rise event over their forecasted lifecycle.

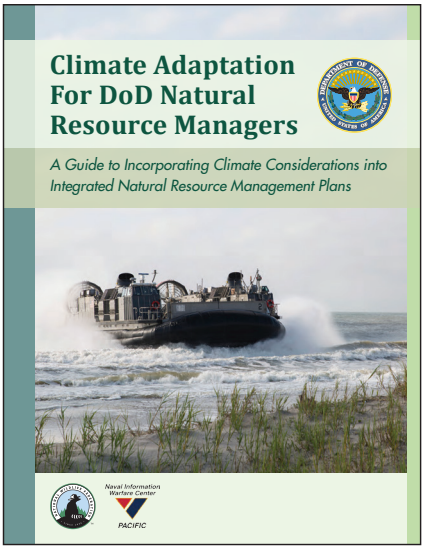
DOD INTEGRATED NATURAL RESOURCE MANAGEMENT PLANS (INRMPS)

In 2019, DOD issued Climate Adaptation for DOD Natural Resource Managers (DOD 2019b): A Guide to Incorporating Climate Considerations into INRMPs. This comprehensive guide will aid installations and natural resources managers with preparing for and reducing installation climate risks through the INRMP planning and implementation process.

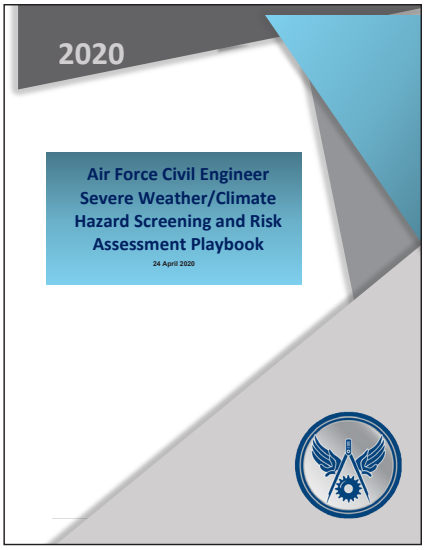
AIR FORCE CIVIL ENGINEER SEVERE WEATHER/CLIMATE HAZARD SCREENING AND RISK ASSESSMENT PLAYBOOK

The purpose of this playbook is to provide a consistent and systematic framework to screen and assess severe weather, climate hazards, and their associated current/future risks at a Department of Air Force installation. The playbook establishes a minimum list of severe weather and climate hazards, and provides methods to determine an installation's exposure, susceptibility, and relative risk to such phenomena. The playbook explores how to integrate the screening and risk assessment outputs into existing processes, such as planning products, building projects, emergency management plans, and mission sustainment risk reports (MSRRs). Individual planners, weather flight personnel, and cross-functional teams, such as the Installation Emergency Management Working Group (IEMWG) or Installation Mission Sustainment Team (IMST), can use this playbook to screen and assess severe weather and climate hazards.

Cover photo of the NAVFAC Climate Change Installation Adaptation and Resilience Planning Handbook.



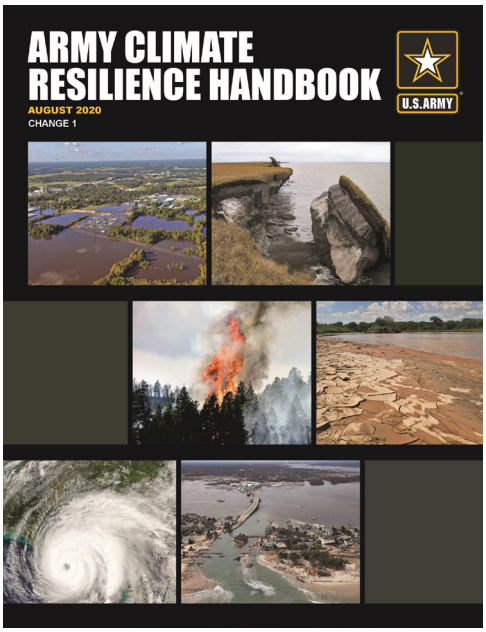
Cover photo of the DOD Integrated Natural Resource Management Plan (INRMP).



Cover photo of the Air Force Civil Engineer Severe Weather/Climate Hazard Screening and Risk Assessment Playbook.

ARMY CLIMATE ASSESSMENT TOOL AND ARMY CLIMATE RESILIENCE HANDBOOK

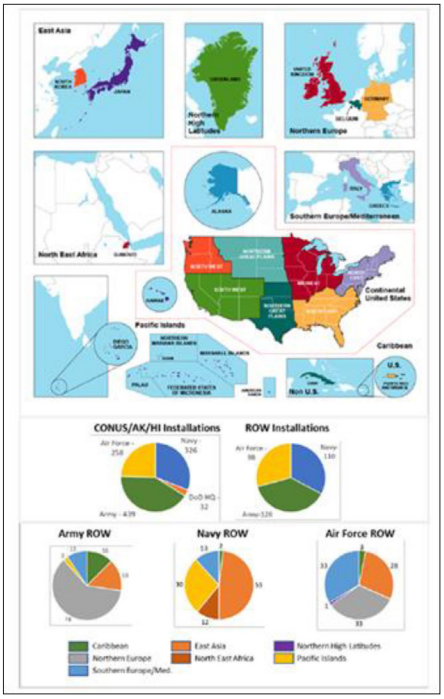
The effects of a changing climate are currently (and will continue to be) a national security issue impacting Department of Army installations, operational plans, and overall missions. In response, the Army develop a web-based Army Climate Assessment Tool (ACAT) that assesses installation exposure to projected climate impacts such as coastal and riverine flooding, drought, heat, wildfire, land degradation, and energy demand, in addition to historical extreme weather conditions. The ACAT was launched in 2020 with information on climate exposure for 116 Army installations. It was also adopted by DOD for Department-wide implementation.



Cover photo of the Army Climate Assessment Tool and Army Climate Resilience Handbook.

As a companion to the ACAT, the Army issued the Army Climate Resilience Handbook (ACRH). This handbook provides Army installation planners with a clear methodology for using authoritative climate data to inform their planning processes and can serve as a desktop reference to guide climate-informed Army installation resilience decisions. To ACRH takes Army planners through the process to systematically assess climate hazard exposure risk and incorporate this knowledge and data into existing installation planning processes such as master plans, consistent with Department of Defense guidance per 10 United States Code (U.S.C.) § 2864 (Master Plans for Major Military Installations, April 2020).

To ensure Army-wide adoption, both the ACAT and ACRH were formalized in Army Directive 2020-08 (U.S. Army Installation Policy to Address Threat Caused by a Changing Climate and Extreme Weather). This policy directive instructs installations to plan for energy and climate resilience efforts by identifying the installation's vulnerability to climate-related risks and threats. Army installation managers and planners will use the ACAT and ACRH to incorporate climate resilience measures into their real property master plans, INRMPs, installation energy and water plans, emergency management plans, continuity of operations plans, and standard operating procedures.



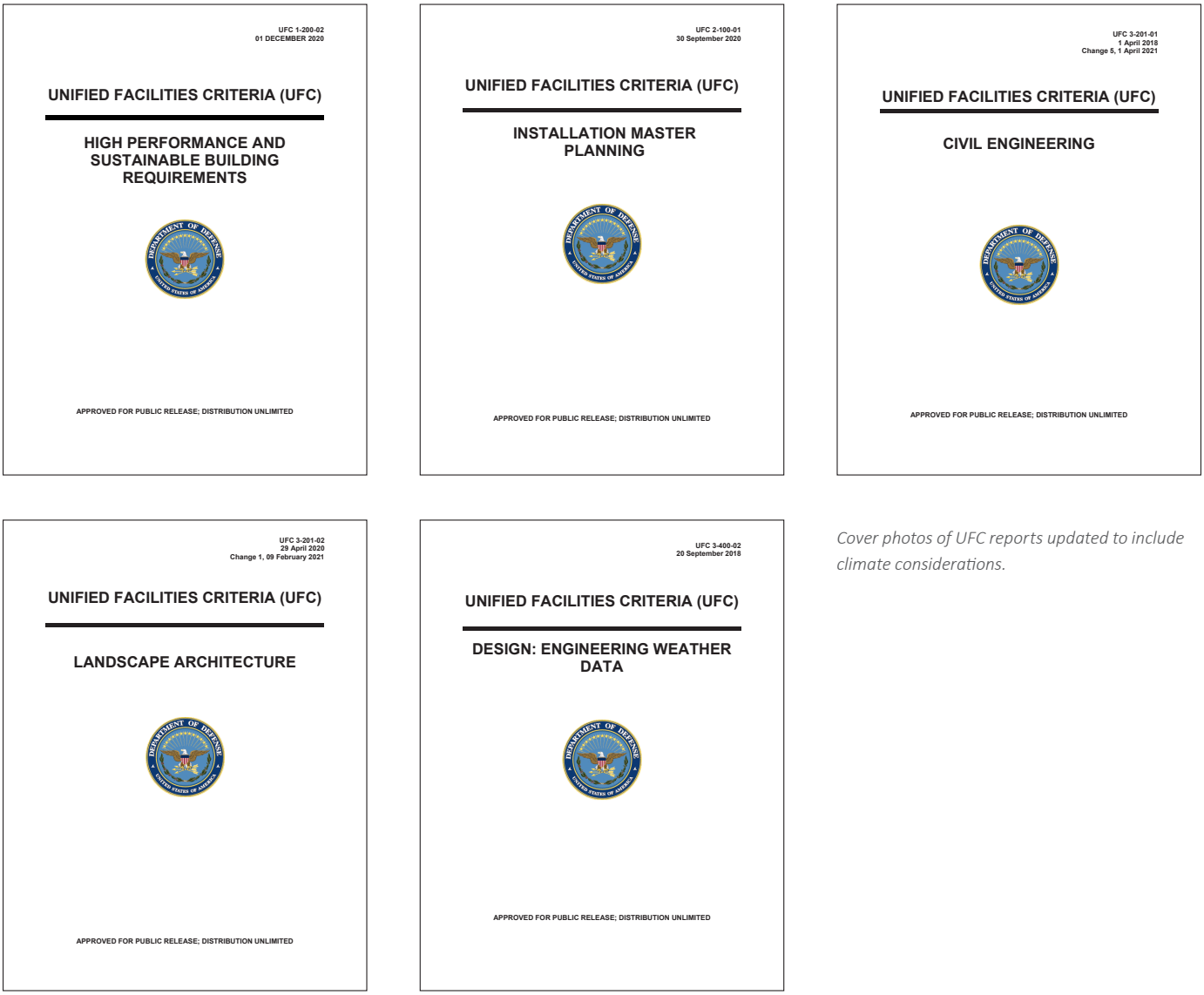
DOD CLIMATE ASSESSMENT TOOL (DCAT)

DOD's Office of Acquisition and Sustainment recently completed an assessment of almost 1,400 DOD sites for exposure to climate-related hazards using the DOD Climate Assessment Tool (DCAT). The tool was launched in the fall of 2020 and is being rolled out across the Department for use by installation planners and others. DCAT sets the Department up for substantial progress in meeting the stated goals and intent of EO 14008. The report will include analysis and summary information from the tool.

Map and pie charts showing installation and site locations in the DCAT. Top: Map showing the three geospatial regions included in the DCAT: CONUS, AK, and HI in the current DCAT, as depicted by the red dotted line and the ROW. Middle: Pie charts showing the number of installations by Department in the DCAT by geospatial region. Bottom: Pie charts showing the number of installations by ROW subregion for each Department in the DCAT.

UNIFIED FACILITIES CRITERIA (UFC) UPDATES

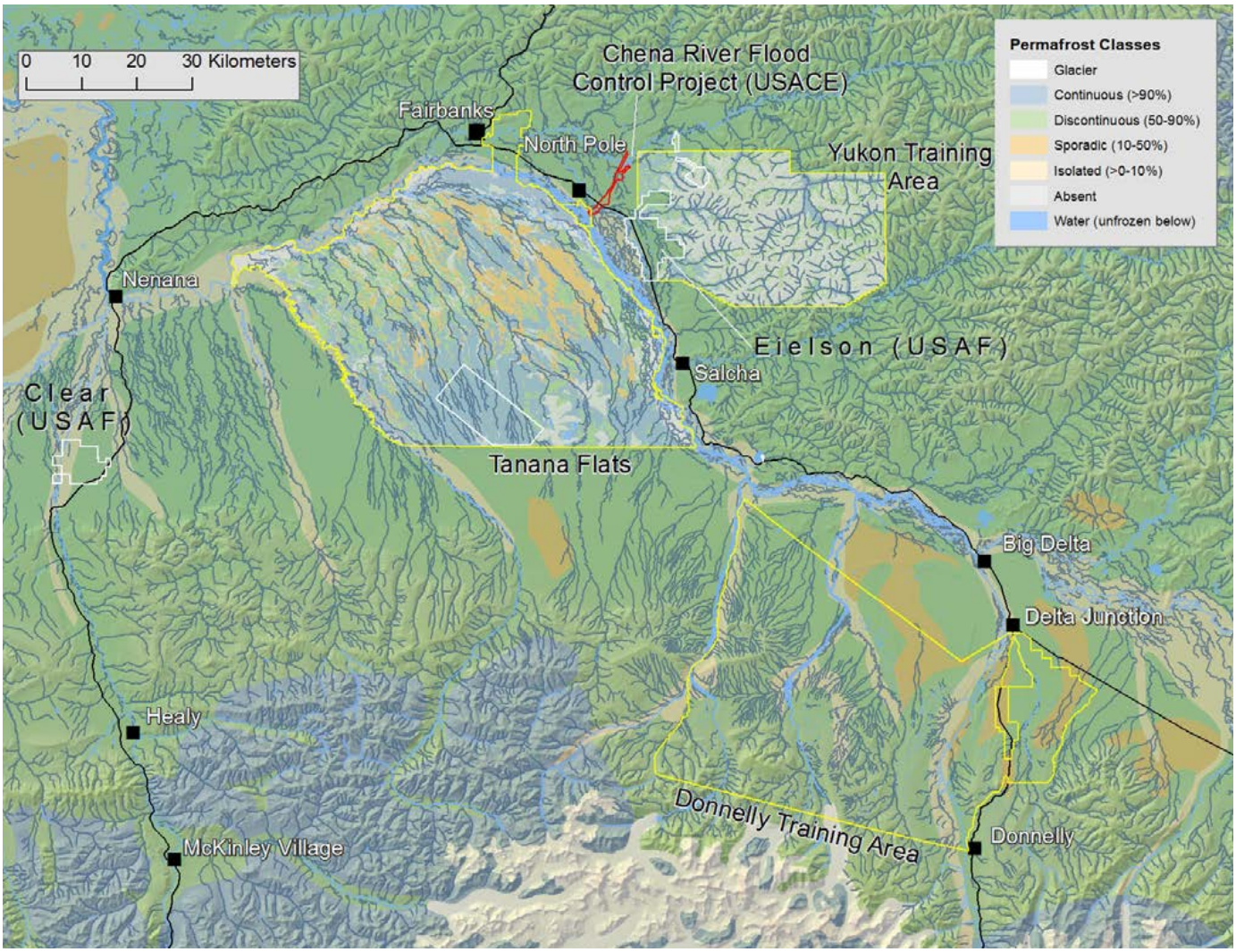
UFCs provide planning, design, construction, sustainment, restoration, and modernization criteria and apply to the military services, the defense agencies, and the DOD field activities. Between 2017 and 2020, UFCs were updated to include climate change considerations in Installation Master Planning (UFC 2-100-01), Civil Engineering (UFC 3-201-01), Landscape Architecture (UFC 3-201-02), Engineering Weather Data (UFC 3-400-02), and High-Performance Sustainable Building Requirements (UFC 1-200-02). UFC 2-100-01 includes language requiring master planners to identify and assess risks to the installation from the effects of extreme weather and climate change and develop plans to address and reduce those risks that may impact new and existing facilities and infrastructure. The UFC on Landscape Architecture is being updated to support installation water resilience through resilient planting design, reduction or elimination of potable/domestic water for landscape maintenance, and water-efficient irrigation. UFC 3-201-01 Civil Engineering supports evaluation of flood risk and sea level rise hazards to siting and design of facilities and infrastructure—and when flood events cannot be prevented, flood-resistant design requirements are provided. In addition, UFC 3-400-02 directs installation planners to request engineering weather data (EWD) from the Air Force's 14th Weather Squadron (WS) that focuses on climate variables including temperature, humidity, precipitation, winds, and more. Recently the 14th WS moved from a 20- to 10-year period of record to more accurately capture climatic means (i.e., temperature, precipitation, winds) at a particular location.



Cover photos of UFC reports updated to include climate considerations.

GEOGRAPHIC INFORMATION SUPPORTING MILITARY OPERATIONS (GISMO)

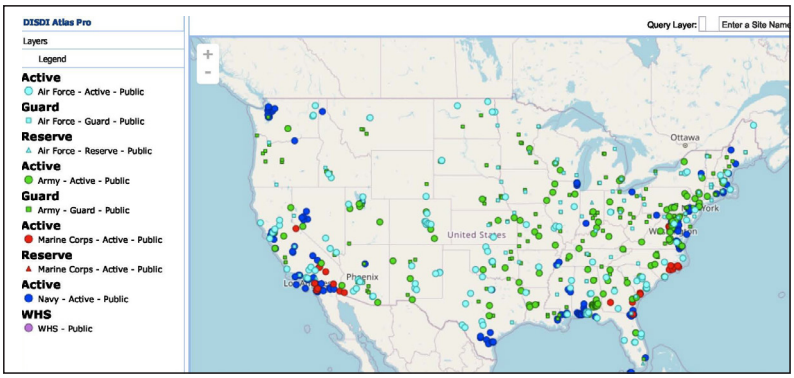
The U.S. Army is the largest DOD land user in Alaska, overseeing 1.5 million acres of training range and cantonment lands. The training ranges and cantonments are underlain by a complex mosaic of discontinuous permafrost and its presence (or absence) plays a major role in soil thermal, hydrologic, and vegetation regimes. A Strategic Environmental Research and Development Program (SERDP) Project (EC-2110) was conducted to identify the potential impacts of climate warming on U.S. Army Alaska training lands and to provide land managers with scientifically based information to help them plan for a warmer future. Results were linked with a broad array of historical and projected meteorological and climatological information to develop a geospatial decision support system to help the DOD manage its lands in a potentially warmer future.



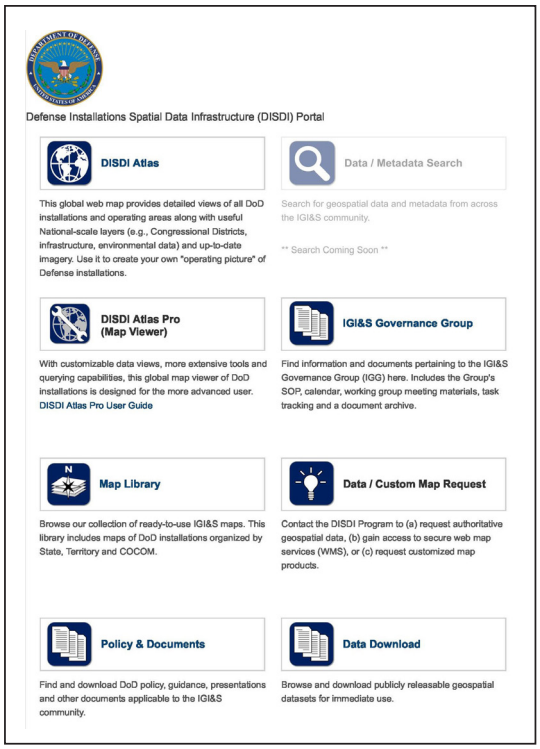
The extent and type of permafrost for interior Alaska DOD lands. U.S. Army Corps of Engineers project lands are outlined in red; Army lands are delineated by yellow; and Air Force lands are marked by white. Permafrost classes range from continuous to absent.

DEFENSE INSTALLATIONS SPATIAL DATA INFRASTRUCTURE (DISDI) PORTAL

The DISDI portal provides detailed views of all DOD installations and operating areas along with useful National-scale layers (e.g., Congressional Districts, infrastructure, environmental data) and up-to-date imagery. The portal provides valuable geospatial information on installation exposure to several climate change hazards including riverine and coastal inundation as well as permafrost thawing. Additional geospatial layers in the tool also include national drought monitors and sea level rise scenarios. The information on the portal feeds into the DCAT assessment and can be used to create an "operating picture" of defense installations exposed to climate change hazards.



A map of installations by Service in the DISDI web portal.



The online DISDI portal page.

WEATHER EFFECTS ON THE LIFECYCLE OF DOD EQUIPMENT REPLACEMENT (WELDER) SERDP/ESTCP PROJECT (RC 19-5264)

Given increasing threats of extreme weather events, facility planners and policymakers need state-of-the-art information that projects long-term environmental risk and informs how these events may alter the replacement schedules and the performance profiles of individual facilities and their constituent systems and components. The BUILDER Sustainment Management System—the lifecycle management tool used by the DOD to consistently and comprehensively assess and forecast facility conditions—does not currently consider vulnerability to extreme weather events. The Weather Effects on the Lifecycle of DOD Equipment Replacement (WELDER) Project will develop an application programming interface (API) plug-in for BUILDER. WELDER will help users make informed decisions about facility sustainment, restoration, and modernization activities under different extreme weather and adaptive response scenarios. WELDER will also provide policymakers with the ability to aggregate the costs of these repair and replacement activities—under different threat and response scenarios—to the system-, facility-, site-, and DOD service-levels. This will help decision makers achieve the goal of a more resilient, cost-efficient, and productive portfolio of facilities.

Logo for the BUILDER Sustainment Management System—the lifecycle management tool used by the DOD to consistently and comprehensively assess and forecast facility conditions, and for the WELDR-Weather Effects On The Lifecycle Of DOD Equipment Replacement.

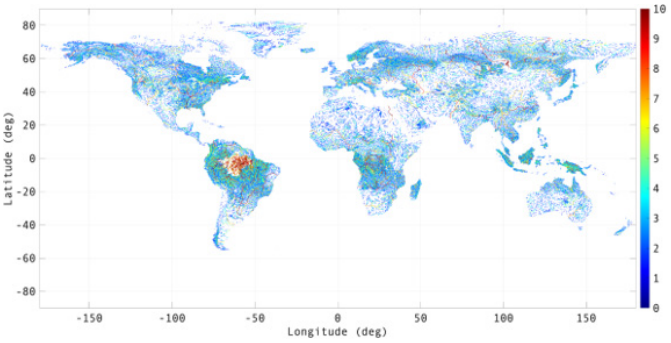
SMART INFRASTRUCTURE FOR A CHANGING ARCTIC ENVIRONMENT USING DISTRIBUTED FIBER-OPTIC SENSING METHODS SERDP/ESTCP PROJECT (RC-2437)

Permafrost environments are a unique setting for built infrastructure, an environment in which small thermal perturbations can have dramatic impacts on structural stability ranging from foundation settling to catastrophic failure of roads, bridges, and runways due to thermokarst generation. A substantial global temperature change is expected within the next century with a higher degree of variability predicted in arctic regions (approximately 4°C) where substantial DOD resources are currently located. The non-linear coupling of future changes in air temperature, surface insolation, and surface/subsurface hydrology to soil mechanics generates a high degree of uncertainty as to the environmental changes that built infrastructure will actually experience.

Infrastructure failure scenarios in permafrost environments.

The objective of this project is to develop and validate a fiber-optic geophysical sensing package capable of providing real-time information on subsurface conditions relevant to infrastructure performance and failure in permafrost environments. The system will consist of a combination of three fiber-based distributed sensing methods—distributed temperature sensing (DTS), distributed strain sensing (DSS), and distributed acoustic sensing (DAS)—designed to be embedded in (or near) built infrastructure and to detect regions of progressive permafrost thaw induced by subsurface flow, surface water accumulation, or changes in system thermal behavior. The resulting information will be provided on a quasi-real time basis to system decision makers for incorporation into maintenance planning.

GLOBAL HYDROLOGIC INTELLIGENCE MODEL

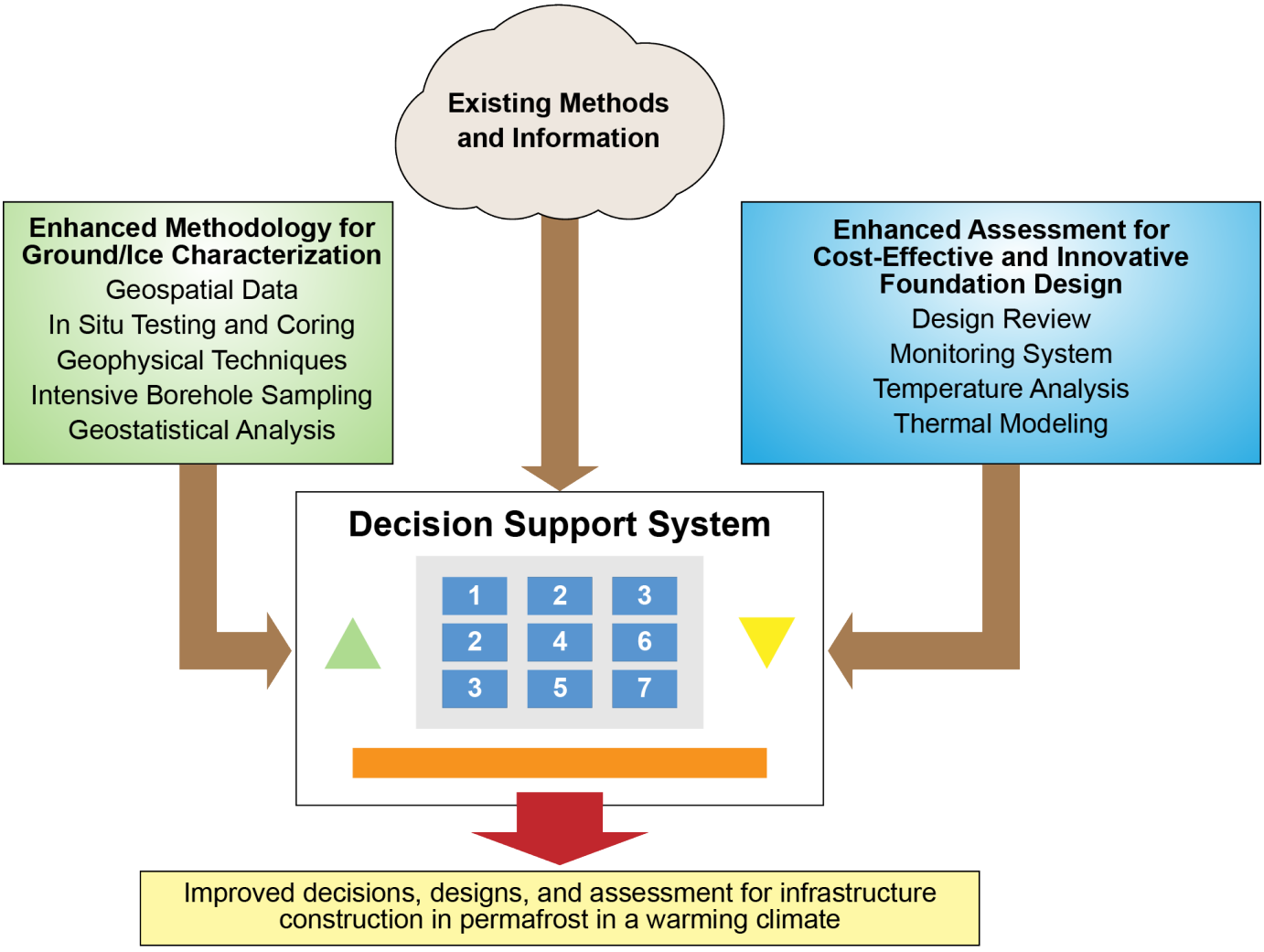


A map of the global streamflow monitoring and prediction modeling.

The Department of the Air Force has a partnership with the U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC), Oak Ridge National Laboratory (ORNL), National Aeronautics and Space Administration (NASA), National Geospatial-Intelligence Agency (NGA), United Kingdom Meteorological Office (UK MET Office), and Navy Research Laboratory (NRL) to develop and provide routinely available, authoritative hydrological data to support the Combatant Commands and the Department of State country teams for accurate assessments of land surface and hydrological conditions. These datasets will include global streamflow monitoring and prediction for 200+ global watersheds and inundation mapping in near-real time (0–12 hours before an event), medium-range (0–14 days before an event), and sub-seasonal-to-seasonal (predictions 0–12 months out). This tool will help decision makers with flood risk reduction for resource protection, water security assessments, and cross-country mobility for logistical operations. Initial operating capability for near-real-time analysis and medium range streamflow predictions for 50+ top priority overseas watersheds and a seasonal-to-sub-seasonal (S2S) hydrology assessment component is anticipated in 2022.

PERMAFROST FOUNDATION DECISION SUPPORT SYSTEM (PFFDSS) SERDP/ESTCP PROJECT (RC 2436)

DOD operates numerous Arctic and subarctic installations. Climate warming is occurring, and new methods are required for construction to ensure longevity and robustness against degrading permafrost threats. This research outlines new methods for ground ice detection and delineation, methods for early warning detection of thawing permafrost under infrastructure, and an outline of a decision support system to determine the most applicable foundation design for warming and degrading permafrost. These three tasks address the immediate needs to advance the ability for effectively constructing mission-critical infrastructure on permafrost terrains—Arctic and subarctic.



Flowchart illustrating an integrated approach for improved decisions, designs, and assessments for infrastructure construction in permafrost environments.

LOE 2. TRAIN AND EQUIP A CLIMATE-READY FORCE

FORT HUACHUCA REPI PROJECT

Training and testing often requires the use of live fire, which can initiate wildfire. A pilot study at Fort Huachuca was awarded more than $2 million in Readiness and Environmental Protection Integration Program (REPI) Challenge funding to reduce wildfire risk to more than 2,000 acres of working ranges and forests outside of the installation. Portions of this land will contribute to existing hazardous fuels reduction projects occurring in adjacent forests, including U.S. Forest Service lands used for important testing activities. The Fort Huachuca Sentinel Landscape partners, including Arizona Land and Water Trust and the U.S. Department of Agriculture's Natural Resources Conservation Service, will use their REPI Challenge award to protect Fort Huachuca's water supply and promote compatible land-use surrounding the installation.

Department of the Army's Fort Huachuca webpage.

Test vehicles for the Warfighter Information Network-Tactical.

Soldiers training at the Joint Center of Excellence for Human Intelligence Training at Fort Huachuca.

FORT HOOD FLOOD HAZARD WARNING SYSTEM

Fort Hood is the Army's premier installation to train and deploy heavy forces. A 214,968-acre installation, Fort Hood is the only post in the United States capable of stationing and training two armored divisions. The rolling, semi-arid terrain is ideal for multifaceted training and testing of military units and troops. Fort Hood has taken active steps in the communication of flood hazards. Due to a changed risk caused by higher rainfall, increased rainfall intensities and flash flooding, more care needs to be taken at low water crossings that have not had flooding in the past. Fort Hood took steps to raise awareness in a collaboration with the United States Geological Survey and establishing and supporting the operation and maintenance of stream gauges for several low water crossings. Fort Hood is an example of an installation that installed flood hazards signs at low water crossings (Fort Riley is another). Many safety measures have been put into place to prevent issues caused by flash floods, including new bridges being built over low-water crossings, water gauges to show the current amount of water in a certain area, and closing off roadways when there is a sign of flash flooding.

Installed flood hazards signs at low water crossings which give an indication of any water on the road. Red means DO NOT attempt to cross. If green, use caution if water is on the road.

DEPARTMENT OF THE AIR FORCE WILDLAND FIRE TRAINING

Crews conducted prescribed burns at Edwards Air Force Base, California. The prescribed burn removed old decadent fuels susceptible to wildfire, and for habitat restoration at Piute Ponds at the southwest corner of the base. The burns thinned out Tully grass, which is considered an invasive species and competes with native species for natural resources. (U.S. Air Force photo by Harley Huntington)

The Department of the Air Force manages over 9.8 million acres of land across 96 installations that require INRMPs. A significant portion of this land, especially in the southeast, west, and Alaska is comprised of fire-hazard ecosystems or areas where wildland vegetation and fuels pose a hazard to infrastructure and land uses. In Fiscal Year (FY) 2020, the Air Force Wildland Fire Branch taught 57 courses to 796 students for the Air Force and partner organizations.

The Air Force also partners with the Army Wildland Fire Program to deliver 12 additional higher-level wildland fire training courses to develop over 40 Air Force natural resources and Fire and Emergency Services personnel annually (5-year average). Training and qualifications follow national standards in wildland fire management set by the National Wildfire Coordinating Group (which is also utilized by the U.S. Forest Service, Department of Interior, and National Association of State Foresters).

DEPARTMENT OF THE NAVY AND CAL FIRE JOINT WILDFIRE TRAINING

Camp Pendleton, California (May 15, 2014). An MH-60S Seahawk helicopter with Helicopter Sea Combat Squadron (HSC) 3 lifts off to assist the California Department of Forestry and Fire Protection. HSC-3 provided aircrews flying specially-equipped MH-60S helicopters to conduct aerial water drops against wildfires in San Diego County. (U.S. Navy photo by Mass Communication Specialist 1st Class Joan E. Jennings/Released)

In August 2011, U.S. Third Fleet, Naval Air Forces Pacific and Navy Region Southwest entered into a memorandum of understanding with CAL FIRE Air Program, a firefighting aviation program. Helicopter Sea Combat Wing Pacific prepares ready, trained, and certified resources to combat wildfires. Crews conduct semi annual training with CAL FIRE to ensure an immediate response capability in support of local authorities for emergency events. The assigned crews are capable of being airborne within 4 hours of receiving a request for assistance to combat fires. The agreement promotes joint training opportunities in an effort to protect key infrastructure and communities within San Diego County. Navy squadrons conduct semi-annual joint training with CAL FIRE to ensure interoperability and an immediate response capability in support of local authorities for 13 emergency events. At the installation level, natural resource managers work to evaluate the threat of wildfires to key resources and promote sustainable management practices, such as the development and implementation of fire management plans for major facilities and aligned special areas.

HH-60W JOLLY GREEN II IN CLIMATIC LAB

An HH-60W Jolly Green II sits under bright lights used to create heat in the McKinley Climatic Lab at Eglin Air Force Base, Florida (Mar. 19, 2020).

The DOD must have prepared combat forces capable of operating under the most extreme and adverse weather and terrain conditions. The nonlinear impacts of climate change require us to expand this work by anticipating, training, and equipping for emerging environmental conditions different from the range of environments existing today. This includes compounding effects of climate hazards together or with other disruptions (e.g., the pandemic). The evolving operational environment and the need to operate in new, more extreme environments may require changes to where and how U.S. Forces train for future conflict. The need for new and advanced training systems capabilities may be necessary to meet readiness requirements. This will be reflected in the Department's efforts across activities related to developing, acquiring, fielding, and sustaining equipment and services. The DOD will develop a list of adaptation concepts to test in crises action planning, tabletop, and command post exercises. Integrating adaptation concepts into existing major exercises informs the joint force of how to adjust current operational and contingency plans, while identifying scenarios that should have their own individual plan.

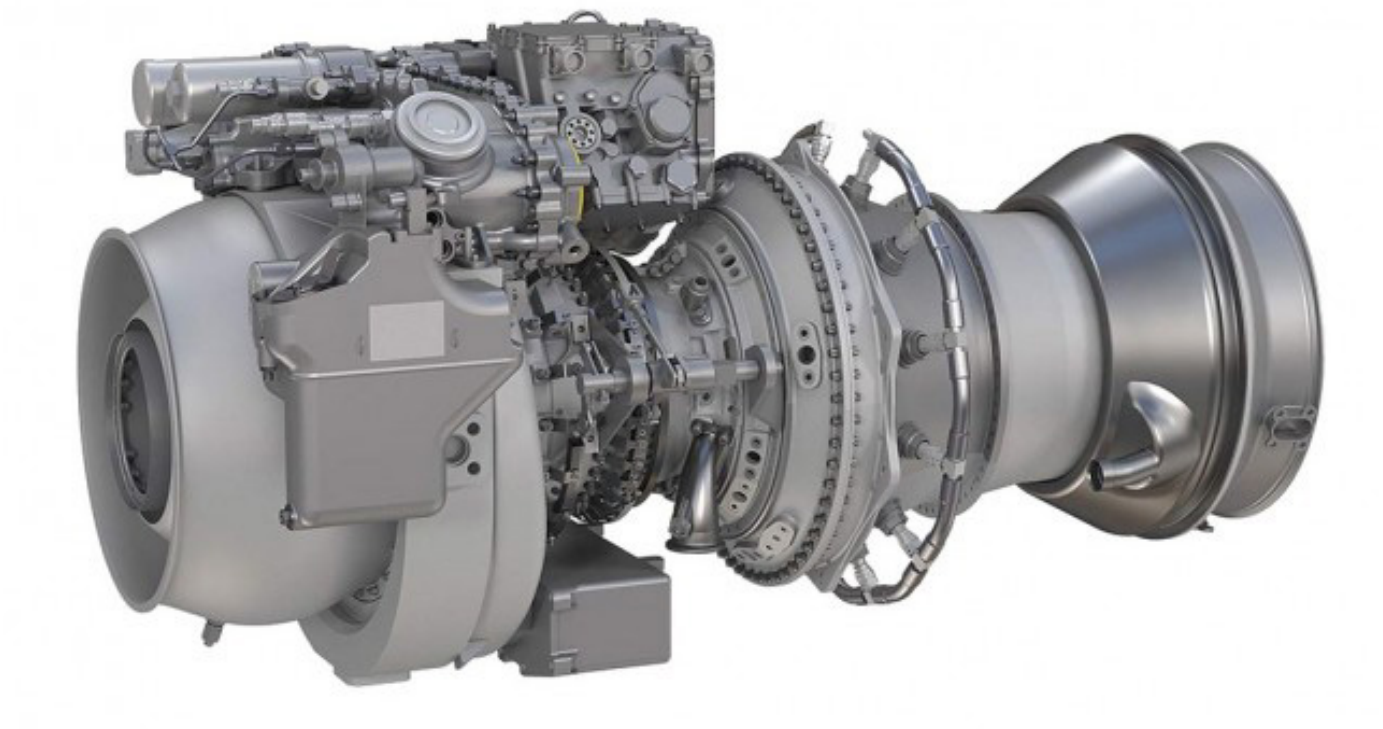
TACTICAL VEHICLES

The Department of the Army is engaging in a number of efforts to develop tactical vehicles that support a climate-ready force. These include the following:

- Tactical Vehicle Electrification Kit (TVEK): A power generation and energy storage technology used to retrofit vehicles with intelligent controls to provide anti-idle capability and reduced fuel consumption. The TVEK has been demonstrated on the Heavy Expanded Mobility Tactical Truck and provides 25% fuel reduction. The citation for the article is https://www.army.mil/article/181692/driving_the_armys_energy_efficient_future

Heavy Expanded Mobility Tactical Truck.

- Improved Turbine Engine: The Army is developing, integrating, testing, and qualifying an Improved Turbine Engine to retrofit UH-60 and AH-64 fleets and the Future Attack Reconnaissance Aircraft. The improved engine provides greater fuel efficiency and 50% more power with 30% less maintenance, enabling aircraft to fly higher, faster, and further, extending range and loiter time.



The Army's Improved Turbine Engine (ITE).

LOE 3. RESILIENT BUILT AND NATURAL INFRASTRUCTURE

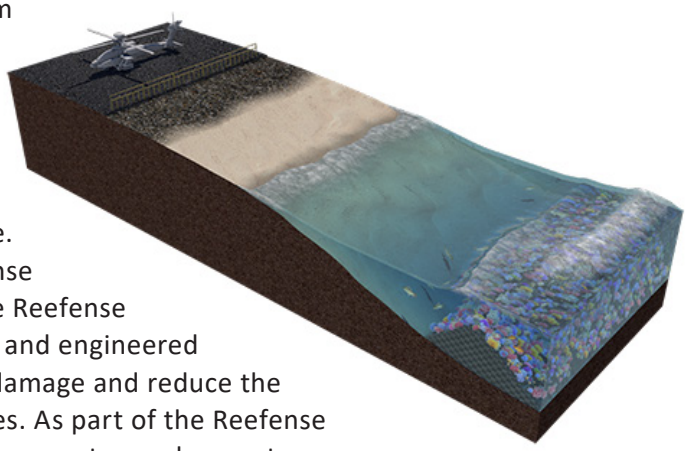
NORFOLK NAVAL SHIPYARD FLOOD RESILIENCE

Flooding at Norfolk Naval Shipyard, Virginia.

In 2018, shipyard officials designed a project to increase the installation's resilience to storm-induced flooding, including building a floodwall to protect the dry docks that are used to perform maintenance on ships and submarines. Norfolk Naval Shipyard experiences extreme high tides three to five times a year on average and a significant hurricane on average once a year, and flooding has been increasing over time in the area as relative sea levels have risen. The floodwall will enclose the dry docks, providing protection to critical assets and electrical utilities while they are in dry dock, among other infrastructure. Flooding into dry docks poses risks to the ships being serviced there and to the performance of the base's mission of servicing and maintaining Navy ships and submarines.

Portsmouth Naval Shipyard, Kittery, Maine, June 22, 2021: The USS Virginia (SSN 774) successfully exits the dry dock at the shipyard. The Virginia is at the shipyard for a scheduled maintenance period.

REEFENSE PROGRAM TO REDUCE RISK TO COASTAL FLOODING, EROSION, AND STORM DAMAGE



3D model illustrates connection of coastal installations to the offshore hybrid biological and engineered reef-mimicking structures.

Sea level rise and wave-induced flooding during increasingly frequent storm events threaten sustainability of the more than 1,700 DOD-managed military installations in coastal areas worldwide. Despite previous efforts to implement storm risk reduction solutions, damage due to storm surge and flooding continues to impact military infrastructure. Current DOD coastal protection measures, including bulkhead and coastal seawalls, may reflect wave energy, exacerbate flooding, create downstream sediment loss, and restrict water exchange. To protect DOD personnel and infrastructure, the Defense Advanced Research Projects Agency has established the Reefense Program, which aims to develop novel hybrid biological and engineered reef-mimicking structures to mitigate wave and storm damage and reduce the ecological impact of current coastal protection measures. As part of the Reefense Program, custom wave-attenuating base structures will promote coral or oyster settlement and growth, which will enable the structures to be self-sustaining and address the infrastructure-related impacts of sea level rise over time. Program performers will employ recent innovations in materials science, hydrodynamic modeling, and adaptive biology to optimize these structures for responding to a changing environment.

JOINT BASE LANGLEY-EUSTIS FLOOD RISK REDUCTION

Joint Base Langley-Eustis uses several methods to combat the effects of flooding. It uses a flood visualization tool to understand flooding impacts across the base, prepare for pending storms, and determine where it is most fruitful to invest in risk reduction measures. By modeling different storm flooding elevations, Joint Base Langley-Eustis staff are able to determine which buildings would be better served with door dams, which are installed more quickly with less labor than using sandbags, reducing the required number of sandbags by 70%. All new development is constructed at a minimum elevation of 10.5 feet above sea level with several new projects being planned at higher elevations due to the need for greater hardening and protection.

Flash flooding and standing water at Langley Air Force Base.

Door dams are set at buildings in preparation for Hurricane Florence at Joint Base Langley-Eustis, Virginia, Sept. 13, 2018.

STABILIZING PERMAFROST AT EIELSON AIR FORCE BASE

Most of Alaska sits on a thick bed of frozen soil, rock, and sediment called permafrost. However, that permafrost is thawing due to impacts from climate change. When permafrost is present, there are three options to stabilize existing infrastructure and design/engineer foundations for future infrastructure: thaw the permafrost, freeze the permafrost and keep it frozen, or excavate all of the soil. Sometimes thawing permafrost or excavating is too expensive, and it is more cost-effective to keep the permafrost frozen. A thermosyphon system proved to be a cost-effective method at Eielson Air Force Base of maintaining a stable surface without having to change the special design of the bunkers to contain explosions that can cause a chain reaction to the other earth-covered magazines nearby.

Munition bunkers at Eielson Air Force Base, Alaska, are built on a flat-loop thermosyphon system to stabilize the permafrost beneath infrastructure.

REDSTONE ARSENAL ENERGY RESILIENCE

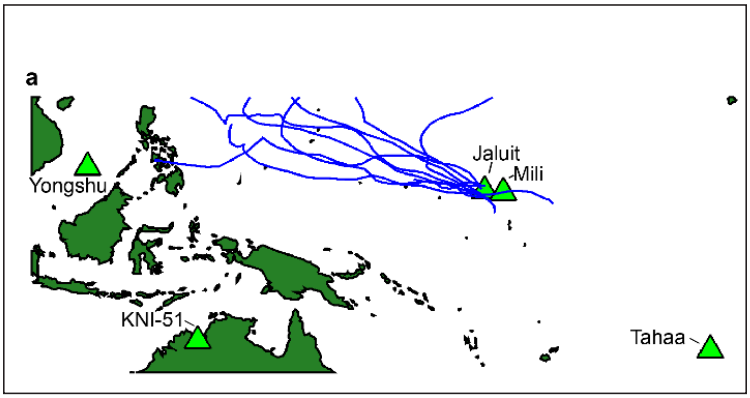
At Redstone Arsenal, Alabama, a 1 MW / 2 MW-hour battery energy storage system is combined with a 10 MW onsite solar array and generates onsite, fuel-free power; a portion of that power is stored via battery and is used to offset power and demand charges during peak rate times. The project enhances resilience through energy diversity and was engineered and built for compatibility with a future microgrid.

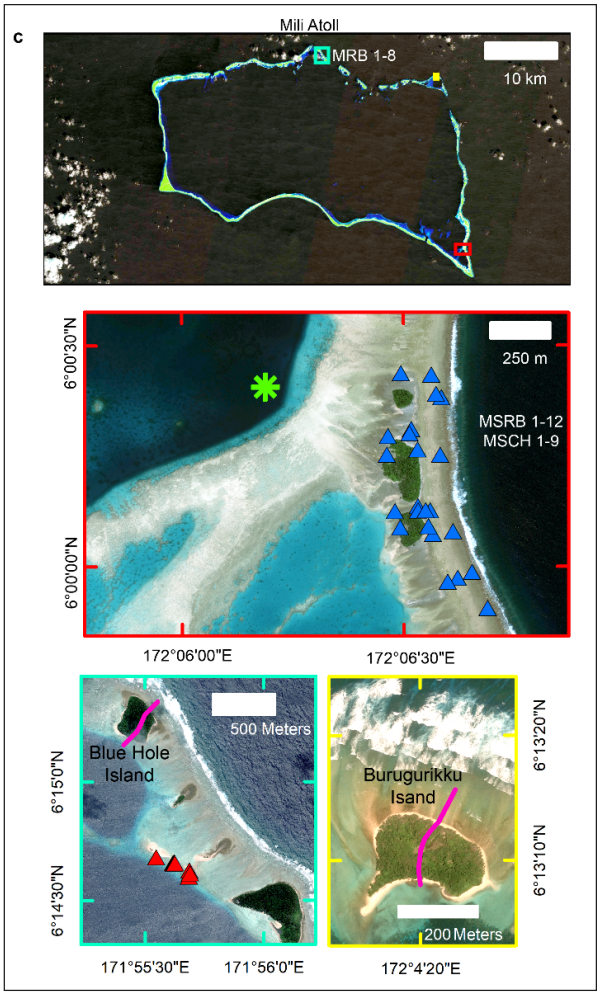
A 1 MW-/2 MW-hour battery energy storage system combined with a 10 MW onsite solar array.

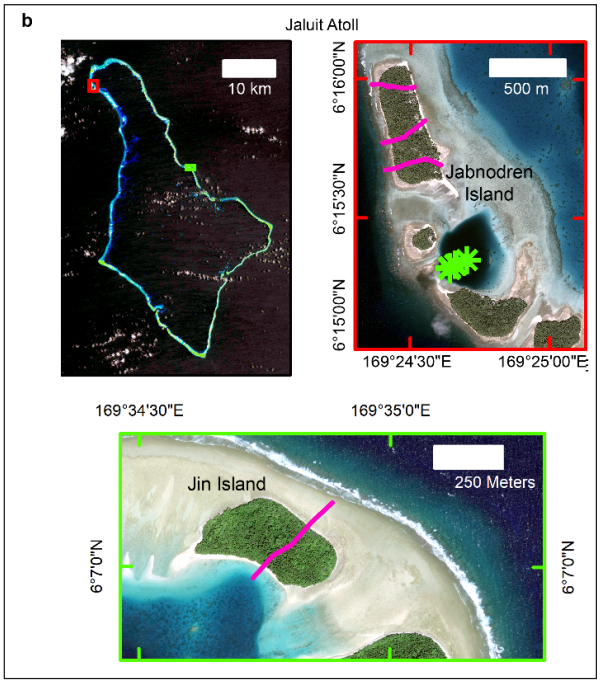
DOD PACIFIC ISLANDS INSTALLATION CLIMATE EXPOSURE (SERDP PROJECT 2336)

DOD installations on Pacific islands face multiple climate-related threats, including tropical cyclones, droughts, floods, and increased rates of sea level rise. Understanding and preparing for how future climate change may contribute to changes in the likelihood of extreme events, loss of coastal land including protective landforms, and changes in freshwater resources are significant challenges facing DOD planners. With the SERDP RC-2336 Project, the project team led by Woods Hole Oceanographic Institution provides probabilistic information on potential climate-related threats that might arise from changes in water availability, sea level rise, and changes in tropical cyclone activity for DOD bases across the Pacific over the 21st Century. The project provided probabilistic information on potential climate-related threats for DOD installations across the Pacific over the next century, including those that might arise from hydrological changes, sea level change, and changes in tropical cyclone activity. These results can be used for planning adaptation strategies to make DOD assets more resilient to these threats and provide motivation for developing alternatives if vulnerable assets are likely to lack resilience.

Satellite images and locations of the sites discussed in this research. (a) Locations of tropical cyclone reconstructions in the western Pacific and the storm tracks of all tropical cyclones passing within 100 km of Mili Atoll or Jaluit Atoll. (b) Jaluit Atoll, the locations of sediment cores (green asterisks) and topographic surveys (magenta lines). (c) Mili Atoll, the locations of sediment cores (green asterisks), dated reef blocks (red and blue triangles) and topographic surveys (magenta lines).







Satellite images and locations of the sites discussed in this research. (a) Locations of tropical cyclone reconstructions in the western Pacific and the storm tracks of all tropical cyclones passing within 100 km of Mili Atoll or Jaluit Atoll. (b) Jaluit Atoll, the locations of sediment cores (green asterisks) and topographic surveys (magenta lines). (c) Mili Atoll, the locations of sediment cores (green asterisks), dated reef blocks (red and blue triangles) and topographic surveys (magenta lines).

FORT HOOD ENERGY RESILIENCE

Energy and water are fundamental elements to the readiness and resilience of the U.S. Army. The occurrence of a major power grid outage may be out of the Army's control, but preparing for a disruption and the aftermath is not. Potential threats to Army energy, water, and land resources are growing in scope and complexity at home and abroad. Army energy systems are vulnerable to cyberattacks, progressively sophisticated enemy weapons, and increasingly frequent and severe weather events.

Given these potential threats, the Army is working to move beyond energy and water projects that just increase generation options or save money—to projects that incorporate resilience—including microgrids and combined heat and power systems. These projects will advance U.S. Army warfighting capabilities, reduce risk, and provide commanders with increased mobility and freedom of action.

As an example, a privately financed energy project at Fort Hood, Texas, includes a 15 MW solar array and a 50 MW wind farm. The project provides supply diversity, reduces emissions through renewable power generation, is microgrid compatible, and provides long-term price stability and cost avoidance. Based on 2020 production data, the solar and wind facilities have resulted in a combined 385,783 tons of CO_2 emissions reduction compared to conventional energy generation since the start of commercial operations. The project saves the Army approximately $2 million per year and is expected to reduce costs by more than $100 million over the term of the 28-year power purchase agreement.

Fort Hood, Texas: 15 MW Onsite Solar Array and 50 MW Offsite Wind Facility in Floyd County, Texas.

LOE 4. SUPPLY CHAIN RESILIENCE AND INNOVATION

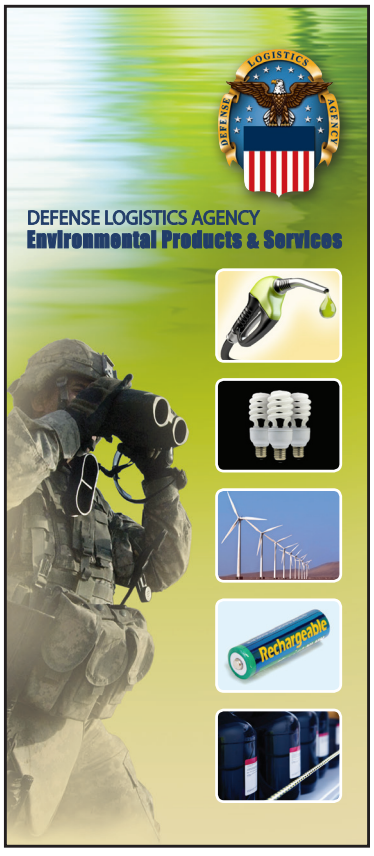
DOD DEFENSE LOGISTICS AGENCY (DLA) SUPPLY CHAIN RESILIENCE

As the nation's combat logistics support agency, the Defense Logistics Agency (DLA) manages the global supply chain—from raw materials to end user to disposition—for the Army, Marine Corps, Navy, Air Force, Space Force, Coast Guard, 11 combatant commands, other federal agencies, and partner and allied nations. DLA's Supply Chain Sustainability and Hazardous Materials Minimization Team supports the development of green products to enhance supply chain resilience and ensure uninterrupted access to key supplies, materials, chemicals, and services. Additionally, DLA's portfolio of innovative environmental products and services can help the Department of Defense reduce the risk and speed of future climate change.

DEPARTMENT OF THE AIR FORCE DEMAND-SIDE OPTIMIZATION

A climate-resilient supply chain is one in which the Department has ensured that key suppliers and industries can still operate though impacted by climate change. The DOD must also consider logistical support of supply chains (e.g., fuel, power requirements) especially in austere locations that are more vulnerable to the effects of climate change. To remain agile and flexible in responding to changing conditions, actions will include energy demand reduction to reduce logistics requirements and establish metrics and measures for tracking progress. The DOD acquisition system must consider operational energy as stated in the Operational Energy Key Performance Parameters (10 U.S.C. 2911) that reduces the logistical footprints of contingency locations. Other optimization of logistical support requirements (e.g., water) can improve resilience and make supply lines less vulnerable to the effects of climate change and adversaries.

Air Force Airman loads pallets of water into a C-17 Globemaster at Joint Base San Antonio, Kelly Field, Texas.



DLA's Environmental Products and Services.

DLA AND FEMA SIGN AGREEMENT TO SUPPORT EXTREME WEATHER EVENTS RELIEF

The DLA has a strong commitment to providing critical lifesaving supplies and services to the Federal Emergency Management Agency (FEMA). DLA is a source for various commodities and services, including DLA Distribution's expeditionary capability to manage and operate FEMA incident support bases.

The agreement between both parties gives DLA the flexibility to process and deliver supplies and services ahead of any defined requirements, ensuring critical supplies and services are in place and available when needed. Today's expeditionary environment requires FEMA and DLA to anticipate requirements well before either agency knows the full impact of a disaster.

DLA provides items like meals, fuel, tents, and medical supplies for FEMA to use in relief efforts after disasters like hurricanes, tornadoes, floods, or terrorist acts in the United States. DLA's partnership with FEMA has grown strong over the years. Lessons learned during Hurricanes Katrina, Rita, and Wilma in 2005 shaped DLA's early support to FEMA, while more recent hurricanes and flooding have fine-tuned those efforts.

FEMA Assistant Administrator for Logistics Jeffrey Dorko (left) and DLA Logistics Operations Director Rear Adm. Vincent Griffith conclude an interagency agreement March 10th 2017 to facilitate DLA's continued support to FEMA during natural disasters.

LOE 5. ENHANCE ADAPTATION AND RESILIENCE THROUGH COLLABORATION

EGLIN AND MACDILL AIR FORCE BASE COLLABORATION

Eglin and MacDill Air Force Bases in Florida partnered with local groups to address persistent coastal erosion around their installations. The U.S. Fish and Wildlife Service and regional partners designed and implemented a 1.6-mile-long living shoreline project starting in 2004. This ongoing project helped to adapt to climate change by creating a natural shoreline stabilization system that will adjust to changes in sea level to control shoreline erosion from heavily trafficked shipping lanes in Tampa Bay, Florida. The shoreline comprises oyster reefs on man-made structures, fossilized shells, and coastal marsh plants.

These decrease wave energy, increase sediment accumulation, improve water quality through oyster filtration, enhance biodiversity, and provide habitats for several marine species. This project helps reduce risks to portions of remaining undeveloped shoreline in the Tampa Bay region. Six phases of work have been completed to date with several future phases planned to reduce risks for another half mile of shoreline.

Volunteers from 823rd Red Horse Squadron and Corvias base housing privatization team unload rocks from a boat for a "living shoreline" project Aug. 24, along the Eglin Air Force Base coastline. The goal of the project to build an artificial reef along 1,400 linear feet of Eglin shoreline is to protect erosion. Volunteers from base agencies have completed 450 feet using more than 60 tons of limestone rock. (U.S. Air Force photo courtesy Samuel King, Jr.)

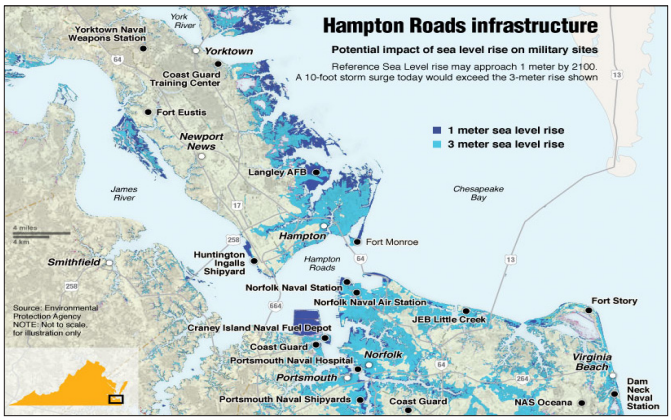
PATRICK AIR FORCE BASE COLLABORATION

Patrick Air Force Base imposes strict Florida Building Code hurricane requirements and finished floor elevations for all new construction based on flood plain and storm surge data. Base staff coordinate with state, county, and academic institutions to ensure these requirements are implemented.

Patrick Air Force Base.

Illustration depicting hurricane categorization.

GREATER HAMPTON ROADS COLLABORATION



Case Study: Addressing Sea Level Rise in Hampton Roads.

Navy Region Mid-Atlantic has several partnerships to increase understanding of current and future flooding risks to the greater Hampton Roads area in Virginia and to identify specific conditions including recurrent flooding, coastal storms, and erosion that have the potential to impact Navy operations. A 2018 addendum to the Joint Base Langley-Eustis's 2010 joint land use study with the City of Hampton outlined climate vulnerabilities and identified recommendations for actions to increase installation resilience. The City of Hampton purchased $14 million of high elevation land around Joint Base Langley-Eustis, Virginia, so that the city may provide land to the installation in the future if sea level rise requires retreat from the current installation fence line. Officials from 22 different cities, counties, and towns collaborated to produce the Hampton Roads Hazard Mitigation Plan, which focuses on a wide range of weather-related and other hazards that have the potential to threaten citizen safety, damage or destroy public and private property, and disrupt the local economy.

U.S. ARMY GARRISON HAWAII ENERGY RESILIENCY PROGRAM

U.S. Army Garrison Hawaii Energy Resiliency Program approach increased onsite energy resources from 31.8 MW to 85.5 MW, increased renewable energy output from 10.8 GWH to 45.8 GWH, and implemented efficiency measures that increased onsite energy capacity from 10 to 13 days for Wheeler Army Airfield, Schofield Barracks, and Field Station Kunia. The program also includes 51 MW of resources to help stabilize and restore the entire Oahu grid to increase resilience for 19 Army installations and all DOD installations to include Joint Base Pearl Harbor-Hickam that supports Army deployment. These achievements have institutionalized U.S. Army Garrison—Hawaii into Hawaii's Integrated Grid Planning process and influenced enactment of state law to facilitate microgrids. This program integrates application of renewable technologies, efficiency improvements, demand reduction, and utility scale strategies to both reduce costs and increase the level, duration, and breadth of energy and water resilience. The program balances firm and variable resources to ensure a net benefit to grid stability and applies demand and energy reduction measures to increase onsite energy reserves, reduce costs, and finance resilience measures.

The 50 MW Schofield Generating Station is sited above the tsunami inundation zone, behind the fence at U.S. Army Garrison Hawaii.

DYNAMO PROGRAM

Doppler radar deployed during the DYNAMO mission, with MJO-associated cumulus clouds growing over the Indian Ocean. (Credit: E. Maloney, Colorado State University).

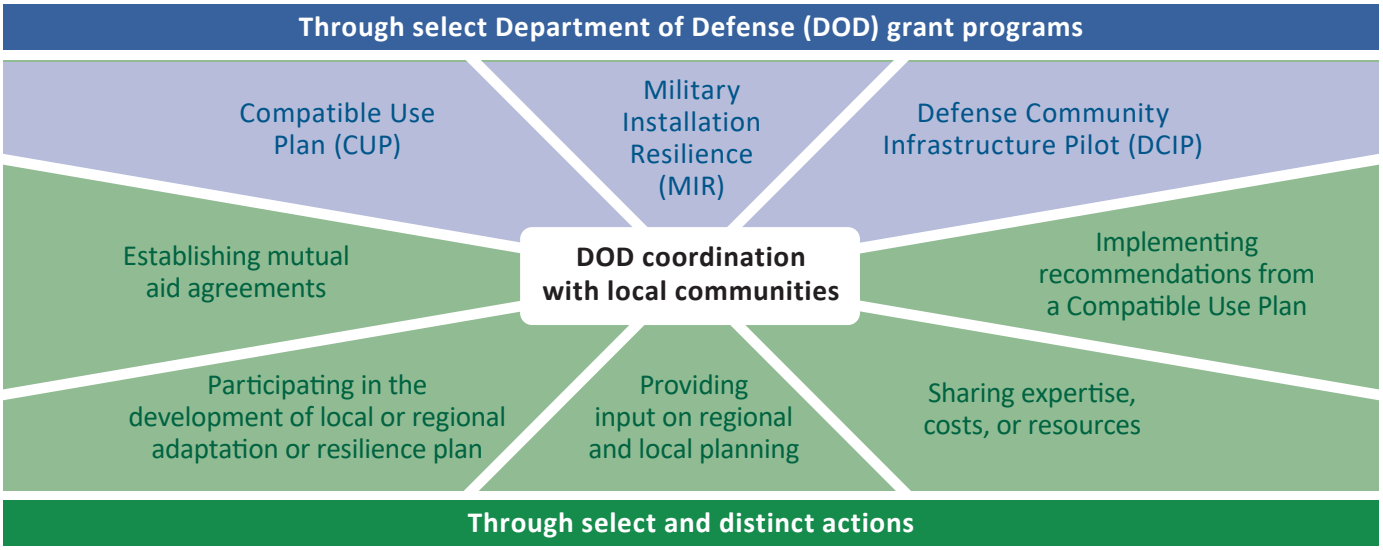
Predicting climate conditions anywhere from 2 weeks to a season in advance is critical for making informed decisions and safeguarding infrastructure across various sectors of the U.S. economy, including DOD operations and installations, water resources, energy supply, public safety, and agriculture, among many others.

The U.S. Global Change Research Program (USGCRP) agencies are supporting improved climate forecasts on these relatively short timescales through field campaigns coupled with model development and analysis efforts. Department of Energy, NASA, National Oceanic and Atmospheric Administration, National Science Foundation, and DOD's Office of Naval Research funded a campaign known as "DYNAMO" to conduct concentrated observations of the Madden Julian Oscillation (MJO)—an atmospheric phenomenon that exerts major influence on North American near-term climate, including extreme weather like hurricanes, heavy downpours, and tornadoes.

DOD COMMUNITY COLLABORATION

DOD installations also report taking a range of actions to coordinate with organizations (including public utilities, county governments, and state agencies) to limit installation exposure to the effects of climate change and extreme weather.

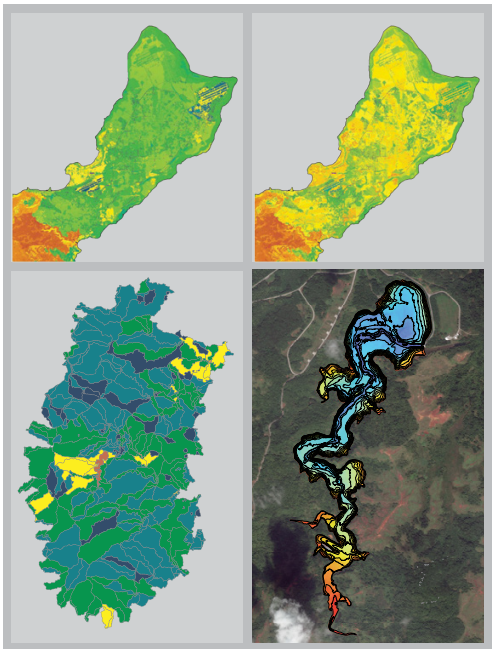
The DOD administers three grant programs that support community coordination with local installations on climate change and extreme weather—the longstanding Compatible Use Plan (CUP), and the Military Installation Resilience (MIR), and Defense Community Infrastructure Pilot (DCIP) Programs established in FY20. DOD and community officials emphasized the value of these grant programs as a means of facilitating and funding coordination with surrounding communities, including through joint land use studies and community infrastructure development. In FY20, approximately $67 million was awarded under the three grant programs.



Department of Defense's Climate Change and Extreme Weather Coordination Efforts with Communities through select grant programs.

WATER RESOURCES ON GUAM—POTENTIAL IMPACTS OF AND ADAPTIVE RESPONSE TO CLIMATE CHANGE (SERDP PROJECT 2340)

The goals of this joint collaborative USGS, University of Hawaii, University of Guam, University of Texas, and East-West Center study were to (1) provide basic understanding about water resources for U.S. Department of Defense installations on Guam and (2) assess the resulting effect of sea level rise and a changing climate on freshwater availability on the basis of historic information, sea level rise projections, and global-climate model temperature and rainfall projections. Downscaled regional climate models, informed by a multi-model ensemble of global climate models provided projections of future climate conditions for Guam. These projected climate conditions provided input to surface-water and groundwater models developed for Guam's hydrology. Guam's water resources in a future climate condition (2080–99) are projected to diminish relative to the recent climate condition.



Projections of future climate conditions for Guam, as reported by SERDP Project 2340.

DOD REPI PROGRAM

The Readiness and Environmental Protection Integration (REPI) Program preserves military missions by limiting or alleviating encroachment threats that could adversely affect DOD installations including incompatible development, endangered species restrictions, and climate change impacts. Authorized under 10 U.S.C. § 2684a, the REPI Program funds cost-sharing partnerships between the military services and state agencies, local governments, or private organizations to mitigate encroachment risks. These win-win partnerships acquire real property interests or other interests in land from willing sellers to promote compatible land uses, enhance military installation resilience, and preserve habitat to relieve existing or future restrictions on military activities.

Cover photo of the Readiness and Environmental Protection Integration (REPI) 15th Annual Report to Congress, 2021.

Table 1: Accomplishments by Service from the Enactment of 10 U.S.C. § 2684a through FY 2020

Military Service	Transactions	Acres Protected	REPI	Service	Partner	Total Expenditures
Army	990	420,754	$317,119,278	$323,310,208	$510,519,077	**$1,150,948,564**
Navy	717	132,115	$155,746,965	$36,818,177	$229,738,239	**$422,303,382**
Marine Corps	100	101,063	$116,745,679	$33,163,106	$135,711,346	**$285,620,131**
Air Force	449	103,365	$78,973,168	$21,765,455	$99,377,843	**$200,116,466**
Total[#]	**2,256**	**757,297**	**$668,585,090**	**$415,056,946**	**$975,346,506**	**$2,058,988,542**

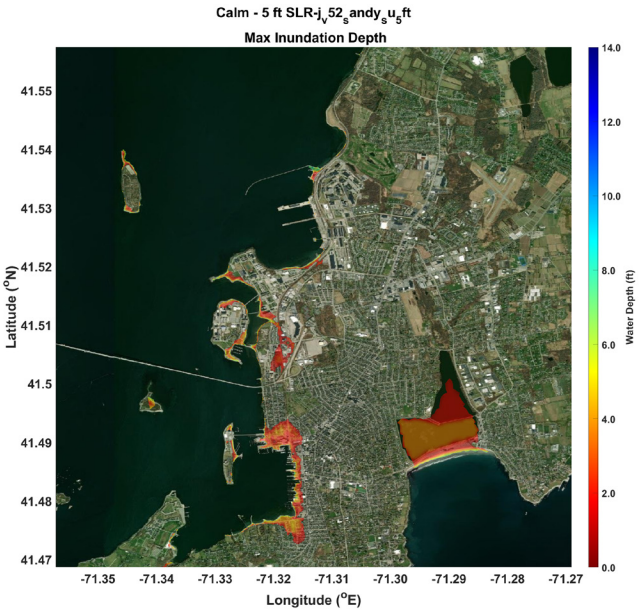
[#]Subtotals may not sum to combined totals due to rounding.
Select Service totals reported in Table 1 may vary slightly from Service totals reported in Tables 3 through 6 because of consolidation due to Joint Basing.

Accomplishments by Service from the Enactment of 10 USC § 2684a though FY2020.

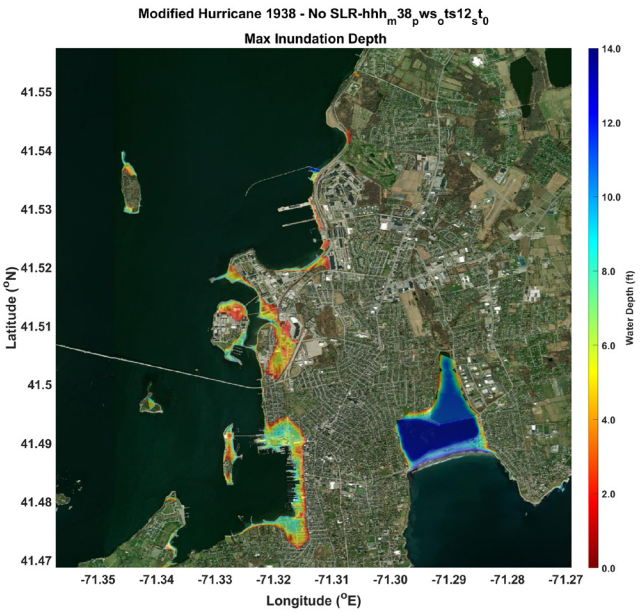
OFFICE OF LOCAL DEFENSE COMMUNITY COLLABORATION

Naval Air Station Newport: Modeling of Climate Impacts to Infrastructure to Support Improved Mitigation and Adaptation Response (MIR Grant)—Methodology piloted in a Department of Homeland Security project is being refined to include high-resolution storm modeling, collection, and integration of "consequence thresholds" for critical infrastructure—a scenario-based approach to stakeholder engagement and a framework for capabilities and responsibilities of key stakeholders to ensure infrastructure resilience. The project will utilize state-of-the-art hydrodynamic models, together with collection and integration of qualitative data, to illuminate threats, impacts, and consequences of storm events and sea level rise to infrastructure in the study area, allowing improved responses and continuity of operations.

Modified for today's hurricane conditions, reflects 2-9' of inundation at the base (area north of the bridge), and areas that support the base including Downtown Newport (lower areas).



Sea level rise will result in water depth of 2-5' of water depth in low lying areas in the base (upper left above the bridge), and areas that support the base, including Downtown Newport (lower left), and one of the municipal reservoirs (lower right).

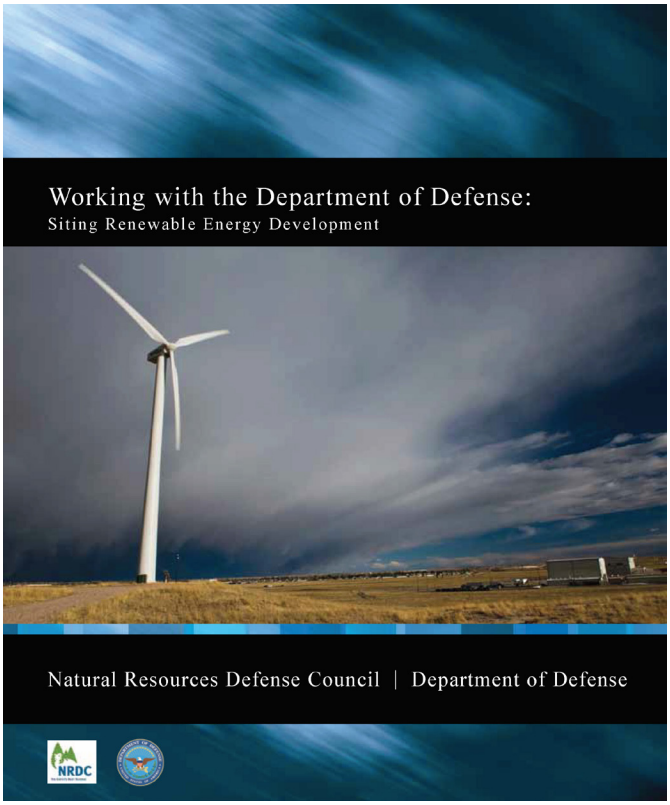


Modified for today's hurricane conditions, reflects 2-9' of inundation at the base (upper left above the bridge), and areas that support the base including Downtown Newport (lower left), and one of the municipal reservoirs (lower right).

Naval Weapons Station Earle: Protecting the Installation and Its Ordnance Loading Pier from Extreme Weather and Sea Level Rise (CUP and MIR grants)—Flooding and erosion have significantly impacted military operations at the base, and these impacts are projected to increase. This MIR project has resulted in strategic regional stormwater management planning across jurisdictional boundaries for effective solutions that are continuing to evolve. Local entities are implementing these plans with non-Office of Local Defense Community Cooperation (OLDCC) funding, including construction of artificial oyster reefs and berms, as well as through marshland restoration, reducing the risk of some climate change impacts affecting the installation.

Ordnance loading pier at Naval Weapons Station Earle.

Commonwealth of Virginia Military Installations: Protecting Military Training from Incompatible Renewable Energy Siting On- and Off-Shore (MIR Grant)—Virginia and the DOD's Energy Siting Clearinghouse partnered to produce a renewable energy mapping tool identifying areas encroaching on DOD's national security interests due to wind turbine development that can degrade radar and increase obstruction hazards. The tool will assist developers to concentrate efforts on sites that meet the Commonwealth's desire to increase renewable energy production, both on- and off-shore, while protecting key assets such as military training routes as well as areas off the coast of Norfolk Naval Base. The partnership also seeks to develop long-term strategies for continued support and updating the mapping tool, as well as possible legislative solutions to protect both military and renewable energy developer interests.



Cover photo of the NRDC/DOD siting primer, which showcases military readiness, healthy natural resources and the development of renewable energy essential to our national interests.

Naval Air Station Pensacola: Protect the Main Thoroughfare and Sanitary Sewer from Continued Coastal Erosion by Constructing Reef Breakwaters and Restoring Beach Habitat (DCIP)—OLDCC partnered with Escambia County, Florida and other organizations to construct 5,300 linear feet of emergent and submerged off-shore reef breakwaters and restore 20 acres of sandy beach habitat to mitigate continued beach erosion. The construction area, in Sherman Inlet adjacent to the installation, has reached a point of critical destabilization over the last 20 years, in part caused by storm damage which will likely continue to increase in severity due to climate change.

Aerial view of the Pensacola coastline; location of restored breakwaters and beach habitat.

PROJECT URLS

STRATEGIC FRAMEWORK
https://media.defense.gov/2021/Oct/07/2002869699/-1/-1/0/DEPARTMENT-OF-DEFENSE-CLIMATE-ADAPTATION-PLAN-2.PDF

2014 DOD CLIMATE CHANGE ADAPTATION ROADMAP
https://www.acq.osd.mil/eie/downloads/CCARprint_wForward_e.pdf

DOD REGIONALIZED SEA LEVEL (DRSL) DATABASE
https://drsl.serdp-estcp.org/

https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Infrastructure-Resiliency/Regional-Sea-Level-Scenarios-for-Coastal-Risk-Management

NAVFAC CLIMATE CHANGE INSTALLATION ADAPTATION AND RESILIENCE PLANNING HANDBOOK
https://www.fedcenter.gov/Documents/index.cfm?id=31041

DOD INTEGRATED NATURAL RESOURCE MANAGEMENT PLANS (INRMPS)
https://www.denix.osd.mil/nr/dodadaptationguide/

AIR FORCE CIVIL ENGINEER SEVERE WEATHER/CLIMATE HAZARD SCREENING AND RISK ASSESSMENT PLAYBOOK
https://cs2.eis.af.mil/sites/10041/CEPlaybooks/SevereWeather/Pages/default.aspx

ARMY CLIMATE ASSESSMENT TOOL AND ARMY CLIMATE RESILIENCE HANDBOOK
https://www.asaie.army.mil/Public/ES/doc/Army_Climate_Resilience_Handbook_Change_1.pdf

DOD CLIMATE ASSESSMENT TOOL (DCAT)
https://media.defense.gov/2021/Apr/20/2002624613/-1/-1/1/DOD-INSTALLATION-EXPOSURE-TO-CLIMATE-CHANGE-AT-HOME-AND-ABROAD.PDF

https://corpsmapr.usace.army.mil/cm_apex/f?p=118

UNIFIED FACILITIES CRITERIA (UFC) UPDATES
https://www.wbdg.org/ffc/DOD/unified-facilities-criteria-ufc

GEOGRAPHIC INFORMATION SUPPORTING MILITARY OPERATIONS (GISMO)
https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Cold-Regions-Ecology-and-Management/RC-2110

DEFENSE INSTALLATIONS SPATIAL DATA INFRASTRUCTURE (DISDI) PORTAL
https://rsgisias.crrel.usace.army.mil/disdiportal/f?p=166:5:

WEATHER EFFECTS ON THE LIFECYCLE OF DOD EQUIPMENT REPLACEMENT (WELDER) SERDP/ESTCP PROJECT
https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and- Resiliency/Infrastructure-Resiliency/Vulnerability-and-Impact-Assessment/ RC19-5264

https://www.sms.erdc.dren.mil/#portfolioModal7

SMART INFRASTRUCTURE FOR A CHANGING ARCTIC ENVIRONMENT USING DISTRIBUTED FIBER-OPTIC SENSING METHODS SERDP/ESTCP PROJECT

https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Cold-Regions-Ecology-and-Management/RC-2437

https://www.serdp-estcp.org/News-and-Events/Blog/SERDP-Moves-into-Cold-Regions-Research

GLOBAL HYDROLOGIC INTELLIGENCE MODEL

https://www.557weatherwing.af.mil/#

https://www.army.mil/article/238257/army_integrates_u_k_model_into_weather_forecasting_simulation_tool

PERMAFROST FOUNDATION DECISION SUPPORT SYSTEM (PFFDSS) SERDP/ESTCP PROJECT

https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Cold-Regions-Ecology-and-Management/RC-2436

FORT HUACHUCA REPI PROJECT

https://www.repi.mil/Portals/44/Documents/Buffer_Fact_Sheets/Army/FortHuachuca.pdf

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