Engineering With Nature®

Using Nature-Based Solutions to Support the Sustainability and Resilience of Department of the Navy Installations and Missions

MCAS Yuma Engineering With Nature Workshop, March 1- 3, 2022
Workshop Report

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Jacobs

Foreword

Using Nature-Based Solutions To Improve Resilience at Department of Defense Facilities

For more than 10 years, the Engineering With Nature® (EWN®) Program of the U.S. Army Corps of Engineers has worked to accelerate innovation and delivery of nature-based solutions (NBS) to solve critical engineering challenges and enhance resilience. These solutions also deliver multi-faceted economic, environmental, and community co-benefits. The progress achieved over the last decade has been the result of many projects, partnerships, technical advancements, and communication investments. EWN is continuing to evolve and develop new strategies to meet new challenges. This report highlights the unique challenges and opportunities for utilizing NBS at Department of Defense (DoD) installations in the Desert Southwest.

The proposed solutions highlighted in this report use NBS to harness the power of nature to support mission sustainment and resilience in the harsh, arid climate of the Desert Southwest. At the same time, these solutions provide considerable opportunities to explore the integrated nature and co-benefits of carbon sequestration, biodiversity, and water resources.

The examples here are only a glimpse of the much larger potential for use of NBS at DoD installations. They demonstrate a range of possible NBS that could be developed or envisioned for installations facing diverse natural hazards and challenges. The risks produced by combinations of natural hazards, climate change, and aging infrastructure systems are increasing; and the need and opportunity for innovation and action to create resilient systems continues to grow. Coordinated investment in built and natural infrastructure is needed to sustain readiness and mission resilience across DoD. We hope these examples will continue to encourage and inspire thought and conversation.

Developing and integrating the natural infrastructure associated with DoD's 25 million acres of land and water will reduce risks, build resilience, and support the well-being of DoD service members and civilians. Meeting these challenges will require us to continue finding new ways of addressing complex problems, exploring new solutions, and embracing change and adaptation.

The EWN Program looks forward to continuing to engage, collaborate, and partner with the DoD to develop NBS that support readiness and resilience for its missions.

Jeffrey K. King, Ph.D., P.E.
National Lead for Engineering With Nature
U.S. Army Corps of Engineers

Foreword

Climate change is reshaping geostrategic, operational, and tactical environments with significant implications for U.S. national security and defense. As conveyed in Department of the Navy (DON) Climate Action 2030, the Department is considering the effects of climate change at every level of the enterprise and building resilience accordingly.

The DON manages, trains, and operates on over 4.5 million acres that span the nation and the globe from coastal and island installations to forests, grasslands, and deserts. We leverage the power of nature in these ecosystems to train and test, to sustain our infrastructure and capabilities, and to preserve critical habitat for a wide range of species. Nature also provides important green spaces that benefit the physical and mental health of our forces, increasing personnel resilience as well as providing rest and relaxation opportunities for the entire base community, contributing to quality of life.

Navy and Marine Corps facilities across the Southwest are already experiencing the impacts of climate change. Drought, wildfires, dust, and extreme flooding events are impacting our infrastructure, water supplies, and training and testing events, as well as our people and defense communities. The Engineering With Nature team has engaged interdisciplinary teams that bring capabilities and expertise not normally resident at the installation level and, working closely with DON regional and installation experts, we are better able to tackle this complex problem set and develop meaningful, scaled solutions.

At the Desert Southwest workshop, hosted at Marine Corps Air Station Yuma, we brought together a wide range of subject matter experts and stakeholders to share their knowledge and weigh in on the difficult questions and opportunities facing DON installations in arid regions. We learned together, identified barriers and opportunities, and together began developing the relevant toolkit of nature-based solutions that will deliver enduring resilience.

The impacts climate change is having in the Desert Southwest represent some of the most challenging problem sets that we as a nation, as well as the rest of the world, will have to confront in learning how to thrive in this new era. Our collaboration with the Engineering With Nature Program has helped us build a strong foundation from which we will move forward in delivering resilience solutions in this critical region for the DON.

Deborah Loomis
Senior Advisor to the Secretary of the Navy (Climate Change)
Department of the Navy

Executive Summary

The Department of the Navy (DON) recognizes that climate threats will increasingly set the context for military installations and operations, with negative impacts on mission resilience and readiness. Failing to acknowledge the consequences of climate change can incur high costs in terms of budget, recovery, and detriment to mission capabilities.

To explore the regionally common climate shocks and stressors and potential nature-based solutions (NBS), Engineering With Nature (EWN®) and DON hosted a workshop at Marine Corps Air Station (MCAS) Yuma, Arizona, in March 2022. The workshop focused on critical climate change impacts and increasing natural disaster issues affecting the desert Southwest.

> *"Many global operational missions are accomplished and/or sustained from DoD installations. Changing climate provides an opportunity to reevaluate use of regional approaches that allow for flexibility to adjust to changing conditions while providing an appropriate level of standardization for resilience, efficiency, and costs."*
>
> *-- Line of Effort 3: Resilient Built and Natural Installation Infrastructure Climate Adaptation Plan 2030 Department of Defense*

Participants included subject matter experts who are actively addressing climate vulnerabilities in the desert Southwest region, including:

- Drought, heat, winds, wildfire, desertification, and earthquakes
- Water quantity and quality
- Groundwater recharge challenges
- Dangers of flash flooding and the need for erosion control
- Climate-related and anthropomorphic shocks and stressors to vegetation and habitat

The key findings and recommendations that arose from the workshop were divided into four categories (pilot projects, partnerships, programs and studies, and policy and funding) and sorted by short-, medium-, and long-term timelines.

The workshop explored the use of EWN solutions such as check dams to slow runoff, increase infiltration, encourage revegetation, enhance biodiversity, increase carbon sequestration, improve air quality, and reduce heat island effect. Soil improvements from composting and regenerative agriculture were also explored. Case study examples were provided where implementation and use of livestock on rangelands can result in better soil fertilization, increased water capture, expanded plant and animal biodiversity, carbon sequestration, and reduced erosion, dust, and desertification.

A detailed table summarizing the recommendations is provided in Appendix A.

Introduction

Military installations in the desert Southwest are grappling with the challenges posed by a range of natural hazards, such as drought, heat, winds, wildfire, desertification, earthquakes, sudden flooding, and soil erosion.

To explore the challenges and potential solutions, Engineering With Nature (EWN®) and the Department of the Navy (DON) hosted a workshop at Marine Corps Air Station (MCAS) Yuma, Arizona, in March 2022. The workshop focused on critical climate change impacts and increasing natural disaster issues affecting the desert Southwest. It featured subject matter experts who are actively addressing climate vulnerabilities in the region. Climate vulnerabilities were explored through a series of breakout group exercises that included identifying shocks and stressors, opportunities and constraints, and potential solutions to mitigate vulnerabilities and increase mission assurance and resilience.

Representatives from the U.S. Navy, the U.S. Marine Corps (USMC), U.S. Army Corps of Engineers (USACE), Engineering Research and Development Center (ERDC), academia, and the private sector met to consider and identify opportunities for using NBS to support the sustainability and resilience of installations and missions. The workshop was conducted and facilitated by the USACE's EWN Program in partnership with Jacobs, a global engineering and solutions company. Workshop participants included installation personnel, resource managers, scientists, engineers, landscape architects, resilience planners, and stakeholders.

NOTEWORTHY DEFINITIONS

In his introduction to the DON's Climate Action 2030 report, Carlos Del Toro, Secretary of the Navy, emphasized the importance of the DON's role, saying:

> *"…the Department of the Navy will take on the urgency of the climate crisis and harness our power to make change – as an environmental leader and a market driver."*

The report went on to provide definitions of several important concepts and terms, including the following:

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. *Source: DoD Directive 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. *Source: DoD Climate Adaptation Plan and U.S. Global Change Research Program*

Natural Infrastructure: Naturally occurring landscape features and/or nature-based solutions that promote, use, restore, or emulate natural ecological processes. *Source: Environmental Defense Fund*

Resilience: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. *Source: Office of the Chairman of the Joint Chiefs of Staff, DoD Dictionary of Military and Associated Terms*

The full text of the Climate Action 2030 strategy document can be found here. *Source: Department of the Navy, Office of the Assistant Secretary of the Navy for Energy, Installations, and Environment. May 2022. Department of the Navy Climate Action 2030. Washington, DC.*

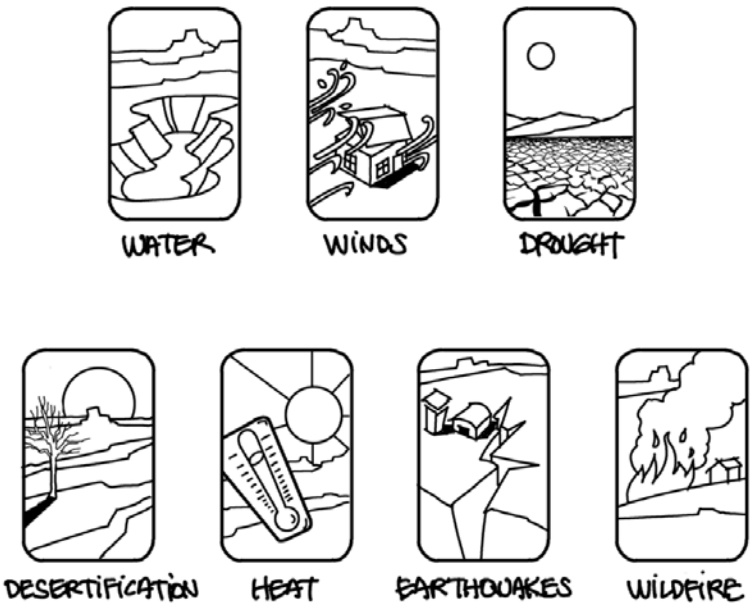
The goal of the workshop was to provide awareness-building exercises and group discussions to identify potential large-scale EWN solutions that could be implemented on DON installations or executed with the assistance of stakeholders in the larger community. Workshop outcomes and products will be used to identify opportunities for follow-on efforts.

This report is intended to capture and summarize the insights and findings of the workshop and to lay the groundwork for prioritizing next steps and an action plan.

NATURAL HAZARDS FOR U.S. MILITARY INSTALLATIONS IN THE DESERT SOUTHWEST

Natural hazards that are being faced by communities and installations in the desert Southwest include:

- drought/limited water supply,
- intense heat,
- desertification,
- high winds,
- wildfire,
- sudden flooding and erosion, and
- earthquakes.



RESILIENCE FOR MILITARY INSTALLATIONS

A 2019 report evaluated the risk and vulnerability of 79 installations to climate change and extreme weather.* Of the installations reviewed, 43 are at risk from drought, 36 are at risk from wildfires, and 18 installations were Navy. Drought and wildfire are presenting increasing threats to western U.S. military installations and mission readiness. These and other climate-related hazards demand that we take a systems approach to EWN solutions.

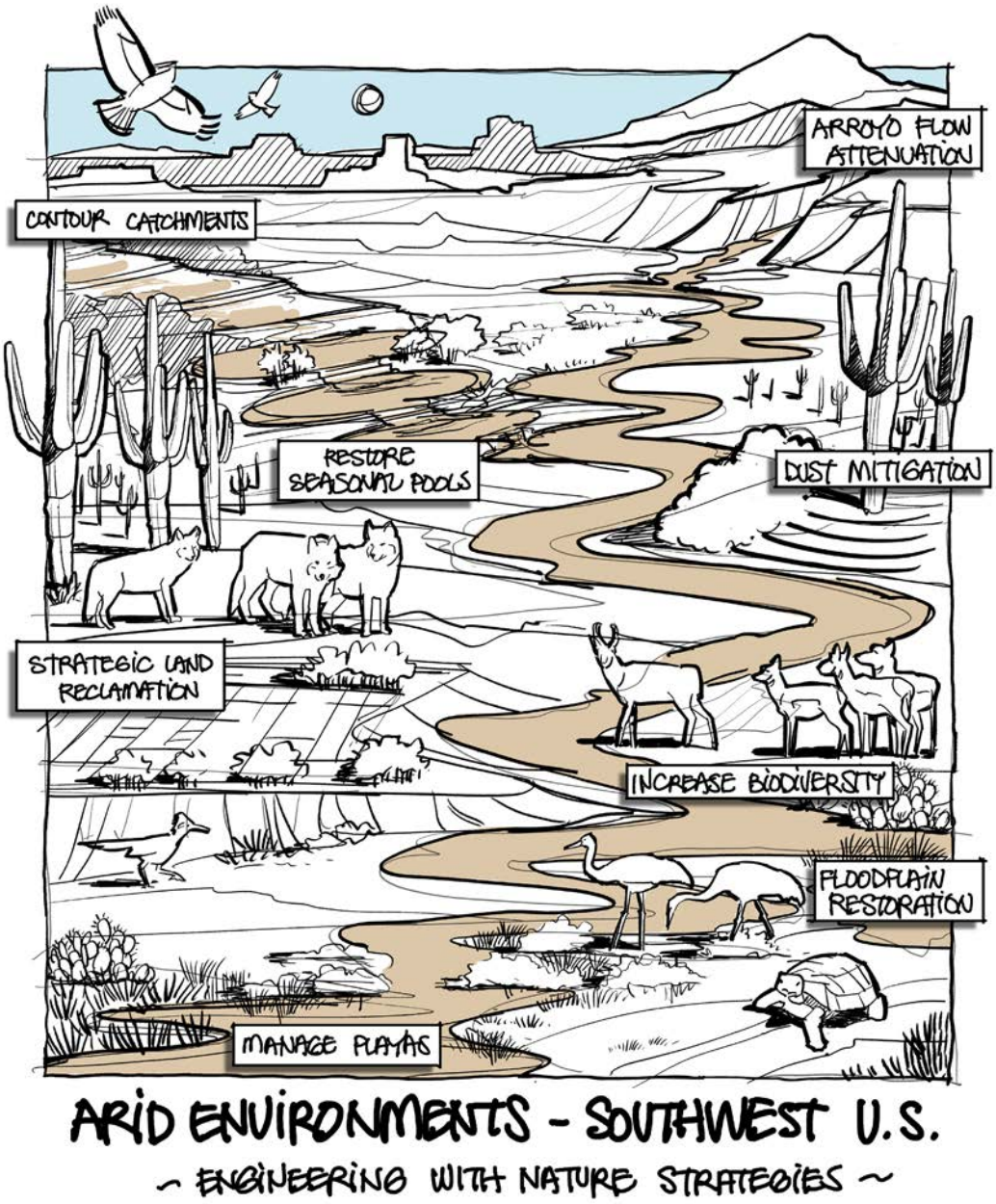
NBS can lead to increased, broad-based resilience on military installations. Some of the benefits of using NBS are:

Scalable, which reduces cost and allows for adaptation over time as environmental conditions continue to evolve

Self-healing following storm events or other environmental hazards, which means mitigating or avoiding costly maintenance and repairs that conventional infrastructure can incur

Healthy and therapeutic, enhancing personal well-being of the people who work, train, and live at DoD facilities through environmental and social benefits.

** Citation: Office of the Under Secretary of Defense for Acquisition and Sustainment. 2019. Report on Effects of a Changing Climate to the Department of Defense (Washington, DC). https://media.defense.gov/2019/Jan/29/2002084200/-1/-1/1/CLIMATE-CHANGE-REPORT-2019.PDF*



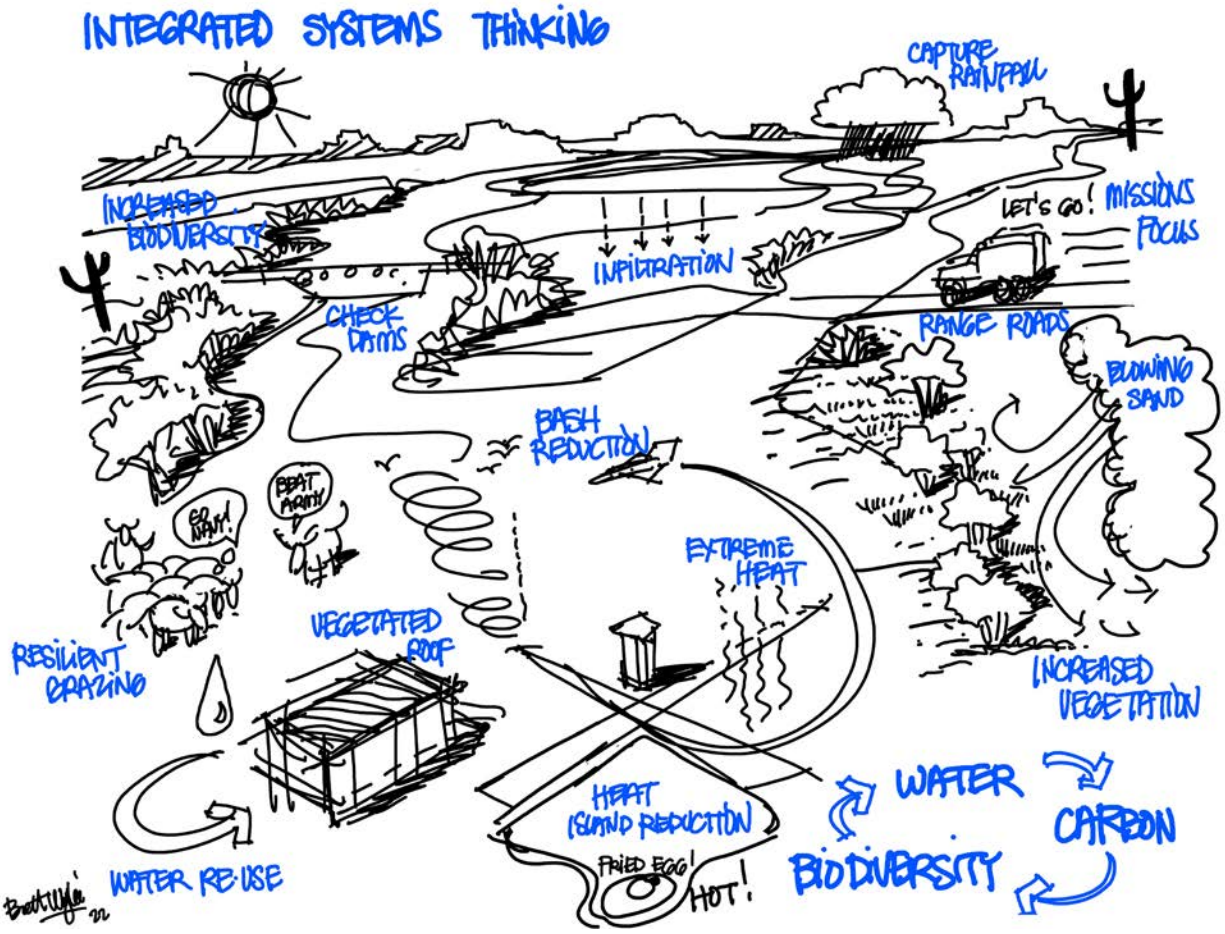
EWN CRITICAL ELEMENTS

EWN's purpose is to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through an integrated land management approach.

With recent advances in the fields of engineering and ecology, there is an opportunity to combine engineering and natural systems into a single collaborative and cost-effective approach for infrastructure functions and responsible environmental management. Triple-win outcomes are achieved by systematically integrating social, environmental, and economic considerations at every phase of an EWN project. The results are innovative and resilient solutions that are more socially acceptable, viable and equitable, and, ultimately, more sustainable.

EWN has defined four critical elements of its mission as:

- Mission Assurance
- Using Natural Processes
- Broadening Benefits (triple bottom line and co-benefits)
- Promoting Collaboration (stakeholders, funding, and community)



Desert Southwest factors, climate challenges, and solutions explored during the workshop.

ADVANCING THE USE OF NBS

NBS can effectively address some of the environmental and climate-related challenges and opportunities facing the DoD in the 21st century.

Different definitions of NBS or EWN approaches and related terms (e.g., natural infrastructure, ecosystem-based approaches, and green infrastructure) have been used by organizations engaged in these activities. The common element among these definitions is the focus on conservation, restoration, and engineered replication of nature for the benefit of mission assurance, people, and ecosystem services.

To promote awareness of NBS and their practical applications, the EWN Program published Engineering With Nature: An Atlas (2018) and Engineering With Nature: An Atlas (Volume 2) (2021). Both volumes are available for download at ewn.erdc.dren.mil.

In October 2021, the EWN Program published Engineering With Nature: Supporting Mission Resilience and Infrastructure Value at Department of Defense Installations, in conjunction with Jacobs, with a focus specifically on how EWN approaches have been successfully applied to mitigate shocks and stressors that threaten mission readiness on DoD installations.

Additional EWN publications to advance understanding and use of NBS in the United States and around the world are forthcoming. These and other resources provide tangible examples of NBS that can be used alone and in combination with conventional engineering solutions to address human-made natural hazards to diversify the benefits achieved through infrastructure on DoD installations.

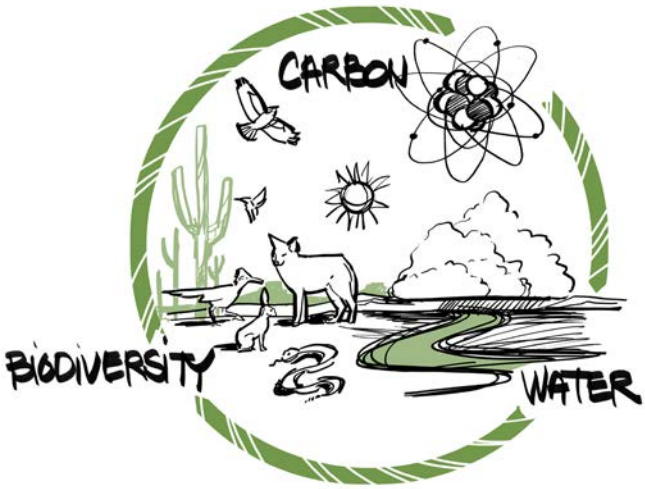
Workshop Objectives

Objectives of the workshop included:

- sharing and reviewing information about proven natural hazards and vulnerabilities that DON western installations are experiencing now or are likely to experience in the future;
- sharing knowledge and information about NBS currently being used to support the resilience and sustainability of installation missions;
- using facilitated dialogue, applicable project examples, and a series of exercises to demonstrate use of NBS strategies and placement of NBS to reduce vulnerabilities;
- collaboratively identifying challenges and prioritizing an initial set of concepts, technical approaches, and potential NBS; and
- documenting workshop proceedings and outputs for follow-on consideration and potential future actions.

On the first day of the workshop, the meeting was convened with a welcome and opening remarks from Col. Charles Dudik, Commanding Officer, MCAS Yuma; Deb Loomis, Senior Advisor to the Secretary of the Navy (Climate Change); and DON staff. A workshop introduction was provided by Dr. Todd Bridges, National Lead, EWN.

Representatives from each installation provided an installation overview. Installations included MCAS Yuma, Naval Air Weapons Station China Lake, Naval Air Station Fallon, and Marine Corps Air Ground Combat Center Twentynine Palms. Two featured presentations provided insights on rangeland management and addressing wildfire consequences. Hollie Schmidt, Director of Resilience and Sustainability Business Advisory for Jacobs, presented an overview of climate shocks and stressors, and attendees participated in breakout groups for a facilitated discussion of Department of Defense (DoD) installation resilience challenges and vulnerabilities to climate-related risks.



THREE KEY INTEGRATED COMPONENTS OF CLIMATE RESILIENCE

The workshop focused on the need to address the integrated nature of carbon sequestration, biodiversity, and water resources as part of mission sustainment and resilience in the desert Southwest and other arid regions. Efforts to encourage EWN projects that support natural vegetation and biodiversity will lead to better groundwater recharge, address erosion during flash flooding, and create opportunities for carbon sequestration.

The second day of the workshop featured presentations on solutions for recharging groundwater; transforming deserts into thriving landscapes; and regreening the desert through rangeland and agricultural regeneration techniques for managing land, soil, and water. A facilitated breakout session was held to explore current and future opportunities for using NBS and conventional solutions. Additionally, the workshop attendees conducted a site visit to an MCAS Yuma flight training area, followed by a plenary discussion led by Dr. Todd Bridges on observations from the site visit and potential uses of NBS. The day concluded with a presentation on managing soil, land, and water.

The final day of the workshop included a featured presentation on how composting can be used to create better soil conditions and regeneration, contribute to biodiversity, reduce waste, and enhance the potential for carbon sequestration. Participants engaged in a facilitated breakout session to discuss installation-specific opportunities for NBS demonstration or implementation projects. The workshop closed with a review of overall findings, actions items, and next steps.

Featured presenters included:

- Dr. Chris Haring, Research Engineer U.S. Army ERDC (Managing Wildfire Consequences),
- Becca Muenich, Assistant Professor, Environmental Engineering School of Sustainable Engineering and the Built Environment, Arizona State University (Managed Aquifer Recharge),
- Dr. Laura Norman, USGS, Supervisory Research Physical Scientist, USGS, Western Geographic Science Center (Natural Infrastructure in Arid Settings),
- Dr. Ryan Busby, Research Ecologist, U.S. Army ERDC (Compost for Climate Resilience),
- Ricardo Aguirre, P.E., CFM, AP, Director of Land Management and Water Security Executive Director of Drylands Alliance Addressing Water Needs (DAAWN) West Consultants, Inc. (Land Management and Water Security),
- Cole Bush, Regenerative Agriculture Advocate, Educator, and member of the California Board of Forestry and Fire Protection Range Management Advisory Committee (Shepherding Landscapes),
- Gabe Brown and Alejandro Carrillo, Understanding Ag, (Understanding Ag and Bringing a Ranch Back to Life)

Additional workshop presentations and discussions were led by:

- Colonel Charles Dudik, Commanding Officer, MCAS Yuma
- Commander Gareth Montgomery, Director of Installation & Logistics, MCAS Yuma
- Deb Loomis, Senior Advisor to the Secretary of the Navy (Climate Change)
- Dr. Todd Bridges, National Lead, EWN Program, USACE, ERDC
- Jacque Rice, Natural Resources Program Lead, Headquarters, USMC
- Jennifer Oelke Farley, Environmental Planning and Conservation Office of the Deputy Assistant Secretary of the Navy (Environment and Mission Readiness)
- Randy English, Conservation Manager, MCAS Yuma
- Christy Wolf, Conservation Program Manager, Naval Weapons Station Fallbrook
- Vanessa Shoblock, Natural Resource Specialist, NAVFAC Southwest, EV
- Brian Hennan, Supervising Environmental Protection Specialist, Marine Corps Air Ground Combat Center Twentynine Palms
- Hollie Schmidt, Director, Resilience + Sustainability, Business Advisory, Jacobs

A site visit to the F-35 Auxiliary Landing Field was led by William Sellars, Yuma Range Director; Randy English, Conservation Manager; Jeremy Pennell, Staff Biologist; and Blake Hash, Outdoor Recreation Planner.

See Appendix B for the workshop agenda and handouts and Appendix C for speaker presentations.

EWN Concepts

This section presents the potential EWN design concepts that were identified during the workshop. Several of these strategies are interrelated and have synergies that need to be assessed and implemented with the systems approach that is the guiding framework of EWN.

Water Capture

- Implement **check dams**/flow control in streams that are known to damage assets; address in a large systemic/watershed approach
- Restore **natural storm flow**, reduce incision of desert washes, and increase spreading of flow to increase percolation
- Repair and **restore riparian habitat**
- Combine **gabion structures** within impact areas to contain water and increase infiltration; construct **leaky dams** of rocks and mud structures that leak water and slow flows
- **Divert seasonal flow** to catch basins to increase percolation
- Promote **water infiltration** to recharge aquifer
- Enhance **groundwater recharge** at local/small scale (beneficial reuse)

BENEFITS OF CHECK DAMS AND RETENTION STRUCTURES

Use of check dams to slow the flow of water after rapid rainfall decreases sheet flow and increases infiltration into the ground. Revegetation will result in better habitat and increased biodiversity and ultimately carbon sequestration.

Water

- Slow water and reduce floods
- Support surface water and restore perennial flow
- Increase infiltration and recharge aquifers

Soils

- Stabilize soil and reduce erosion
- Reduce nonpoint source pollution, capture ordnance
- Carbon sequestration

Vegetation

- Encourage plant growth
- Create habitat for animals

Excerpted from Dr. Laura Norman, Natural Infrastructure in Arid Settings, Presentation for the U.S. Department of Defense, February 22, 2022.

Photo courtesy of Dr. Laura Norman, U.S. Geological Survey

- **Harvest water (including use of recycled or greywater, dew condensation)** on the installation to grow food instead of food inputs off installation (on-base community gardens)
- Maximize **capture of cantonment stormwater** for increased percolation
- Expand capacity of water sources to ensure water availability to wildlife during droughts
- Create long-term **water security plan**

Design Measures for Water/Carbon Storage

- Implement desert design features such as **permeable pavement**
- **Re-engineer range roads** to reduce incisions and erosion
- Design **infiltration basins and contour catchments**
- Utilize **nature-based structural design** to reflect the heat (e.g., Saguaro cactus)
- Use **smart hardscapes** (high Solar Reflectance Index value) to reduce heat capture
- Retrofit roof drainage for beneficial use of rain on roof surface and design **green roofs** with native species

Water Conservation

- Reduce **irrigation and use efficient irrigation methods** by changing zoning permits, discouraging lawn sprinkler systems, and restricting sprinkling of transportation routes to grey water only
- Reduce **evaporation** by implementing cover story (shade) of vegetation along irrigation canals
- Enhance **leak detection systems**
- **Maximize beneficial water reuse**
- Use regionally **native plants** and **xeriscaping** to eliminate supplemental watering needs
- Assess **water supply**, **water quality**, and **soil impacts** of agricultural land leases

POLICY ADVANCES IN NBS

Recent actions from the federal government have placed a spotlight on and accelerated awareness of NBS. In January 2021, President Joe Biden issued Executive Order (EO) 14008, "Tackling the Climate Crisis at Home and Abroad." This EO paved the way for the development of the DoD's Climate Risk Analysis and the DoN's Climate Action 2030 guidebook.

The EWN Program, and NBS in general, also received major support with the issuance of EO 14072, "Strengthening the Nation's Forests, Communities, and Local Economies," on April 22, 2022. Additionally, the White House issued an NBS Roadmap and NBS Resources Guide in October 2022.

The EWN supports the DoD and DoN in implementing their visions for future climate resilience and mission readiness, as laid out in these publications.

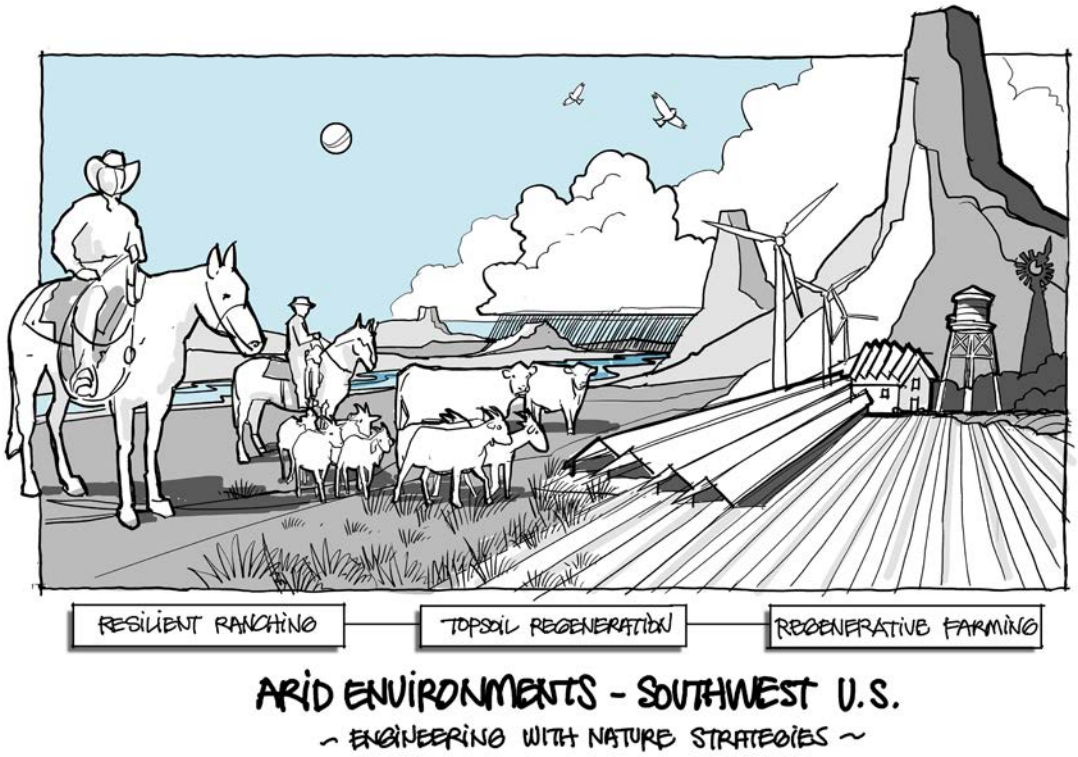
Department of Defense, Office of the Undersecretary for Policy (Strategy, Plans, and Capabilities). 2021. Department of Defense Climate Risk Analysis. Report Submitted to National Security Council.

Department of the Navy, Office of the Assistant Secretary of the Navy for Energy, Installations, and Environment. May 2022. Department of the Navy Climate Action 2030. Washington, DC.

White House Council on Environmental Quality, White House Office of Science and Technology Policy, White House Domestic Climate Policy Office. 2022. Opportunities for Accelerating Nature-Based Solutions: A Roadmap for Climate Progress, Thriving Nature, Equity, and Prosperity. Report to the National Climate Task Force. Washington, DC.

Vegetation Biodiversity/Carbon Storage

- **Revegetate** "hot spots" in the watershed to reduce dust
- Use **crop dusting irrigation** to stabilize inoculum and foster seed germination
- **Map vegetation** to identify maximum potential for post-disaster recovery strategy
- **Reclaim degraded land** through holistic land management and amendments
- Implement **regenerative grazing management** (cattle/sheep/goats); conduct a browse preference study, research needs, review published management strategies, address scaling and logistical concerns, and implement herd health and tracking confirmation
- Use non-mechanical treatment of **fuel breaks**
- Incentivize **use of agriculture for carbon storage**
- Implement **composting program** to capture food waste with on-base restaurants, grocery stores, municipal start-up recycling green waste services, beginning with local municipality
- Combine compost with highly managed grazing rotation for **soil improvement and regeneration**
- Control and **manage invasive species** through integrated natural resource management plans
- Use **umbrella species** whose conservation is expected to provide protection to many naturally co-occurring species

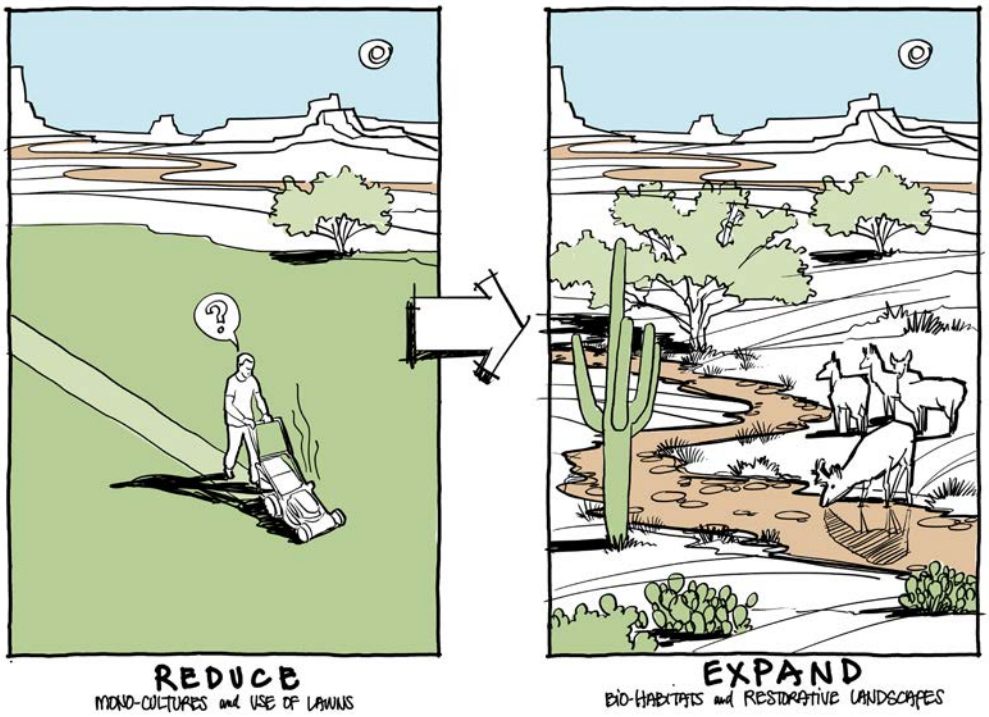


An example of sustainable ranching and agriculture.

- Reduce and eliminate **chemical and biocide** use
- Promote **no-till and low-till** practices, contour plowing, and keyline plowing
- Anticipate future ecologies and **use adaptive management practices** to design intervention for future scenarios; develop ecosystems-based resilience strategies
- **Convert grass/greenspace** to functional ecosystems

Soil Improvement, Dust, and Fire Control

- Apply **biological soil** amendments
- Create **water capturing zone** with fill, compost, and amendments using pavement and vegetation
- Reduce **soil compaction** by addressing the root causes
- Look at U.S. Department of Agriculture agricultural soil classifications for **restoration potential**
- Restore the **cryptogenic crust**
- Use **bio-cementation** to stabilize soils and add organic matter
- Enhance understanding of **soil health**, living soil layers, and hyperbolic zone and the value for and impacts on the mission
- Consider use of streams as potential **fire breaks** where appropriate



Key Findings and Recommendations

The following table summarizes the top-tier short-, medium-, and long-term recommendations that emerged during workshop collaboration. These recommendations do not reflect agency positions or actions. Proposed solutions by benefit category and additional detailed findings and recommendations are provided in Appendix A.

	Short-Term Implementation (0 – 3 Years)	Medium-Term Implementation (3 – 5 Years)	Long-Term Implementation (5+ Years)
Pilot Projects	• Align in-progress projects to the EWN framework • Implement best practices for erosion reduction (e.g., modify drainage and install check dams)	• Develop desert Southwest Playbook with toolbox, checklist of EWN applications • Deploy NBS Innovation Hubs at selected installations	• Sustain partner engagements on NBS • Develop NBS Analysis Tool to quantify benefits
Partnerships	• Identify existing partnerships and potential new partnerships to create comprehensive stakeholder pool • Create a stakeholder management strategy • Identify and communicate appropriate funding sources for NBS implementation	• Leverage regional partnerships to develop, implement and fund NBS initiatives (e.g., Western Regional Partnership) • Collaborate with other agencies to elevate existing efforts regarding restoring fire/burn areas and implementing water conservation, dust control and agricultural practices	• Explore grazing/regenerative agriculture partnership opportunities • Coordinate with Tribal governments on restoring fire/burn areas and integrating Traditional Ecological Knowledge • Identify opportunities for composting with local municipality and creating community gardens

Programs & Studies	• Explore carbon sequestration for arid environments with resilience benefits through NBS • Utilize resilience war game at installation level to inform Program Objectives Memorandum funding priorities • Measure carbon sequestration key performance indicators based on biomass, photosynthesis, endangered species, infiltration rates, soil temperature, plant diversity, soil microbiology, and water quality • Study alternatives for circular economy of water, including water recycling for wastewater and greywater, as well as beneficial use of rainfall (blue roofs and ground-level decentralized storage)	• Conduct check dam and wetland restoration demonstration study • Initiate on-base composting program; send to off-base agriculture demonstration study • Develop enterprise-wide mechanism for capturing and communicating progress	• Implement large-scale regenerative landscape project • Train veterans to be holistic land managers to implement large-scale grazing
Policy & Funding	• Leverage the current Unified Facilities Criteria (UFC) language regarding resilience • Enforce resilience planning in required master plans • Incorporate resilience components into development of all Department of Defense 1391s • Issue installation or regional specific memos to design for climate shocks and stressors for water, biodiversity, and carbon • Identify opportunities to streamline National Environmental Policy Act consultations and permitting for resilience projects	• Revise UFC and other required planning studies • Prioritize ranking for projects with resilience measures • Create guidance on cross-functional integration for master planning, facilities, environmental, natural resources, and public works	• Consider opportunities for innovative financing to incentivize resilience investment • Establish international agreements on climate resilience (e.g., to adjudicate geoengineering, cloud seeding for drought response)

Next Steps

The next steps for the DON/EWN effort include virtual meetings to develop and refine potential projects in the Southwest. Through facilitated breakout sessions, installation personnel will work with EWN experts to identify NBS for highlighted shocks and stressors, potential benefits and co-benefits, partnerships, timelines for implementation, and funding opportunities. Installations will be encouraged to identify pilot projects or ongoing projects that can be broadened to further support mission assurance.

Appendix A.
Matrix of Workshop Comments

MCAS Yuma, EWN Workshop, March 1-3, 2022
Summary of Themes

Projects:

Desert Southwest Playbook	Create a "Toolbox" or "Playbook" or "Checklist" of EWN applications for desert Southwest
Database of installation ecology	Create a database of DoD installation ecosystem and geography
DoD Summit on NBS	Conduct a DoD summit on NBS
NBS analysis tool	Create modeling and benefit analysis tool for NBS
Native plant seed bank	Create a native plant seed bank
Biomimicry	Conduct a biomimicry process evaluation in Southwest region and arid environments
Mapping refugia	Map climate refugia at species and community levels
Xeriscaping	Create a xeriscaping strategy playbook for installations in the desert Southwest

Studies:

Proof-of-concept studies	Historical context - hypothesis testing/proof of concept studies; historical context plus adaptation studies
Soil improvements/carbon sequestration	Soil carbon sequestration study at massive scale through check dams and wetland restoration
Soil mapping	Advanced aerial mapping of soil mineralogy for optimal NBS placement
Groundwater	Study methods to reduce groundwater use
Stormwater	Study and methods of stormwater capture; demonstrate proof of concept
Vegetation mapping	Forest/vegetation mapping to identify maximum potential, post-disaster strategy recovery
Grazing study	Cattle/sheep/goat grazing management study to address browse preferences and research needs; review published management strategies; address scaling and logistical concerns; confirm methodologies for herd health and tracking.

Programs:

Resilience wargame	Use resilience wargame at installation level to identify good ideas for funding; develop Program Objectives Memorandum
Innovation hubs	Create NBS innovation hubs at select installations or regions
Program communication	Develop enterprise-wide mechanism for capturing and communicating progress
Measure NBS Success	Identify key performance indicators and measure carbon sequestration; measure results based on biomass, photosynthesis, endangered species, infiltration rates, soil temperature, plant diversity, soil microbiology, and water quality
Regenerative landscape	Develop ecosystem-based resilience; implement regenerative landscape and communicate non-monetary benefits
Bird/aircraft management	Work with Airfield Management regarding bird/wildlife aircraft strike hazard
Veteran training/grazing operations	Train veterans to be holistic land managers to implement large-scale grazing operations in approved areas
Composting	Implement base-wide composting program for food and green waste
Solid waste/recycling	Integrate solid waste recycling and morale/welfare/recreation activities with natural resource programs

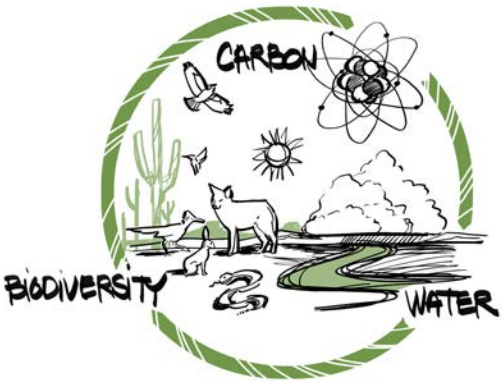
Partnerships:

Partners outside the fence	Wastewater reuse may need to include partners outside the fence
Adjacent landowners	Build partnerships with DoD-adjacent property owners
Surrounding agriculture agencies	Work with surrounding agriculture to reduce their water use
City of Yuma	Create compost alliance with the City of Yuma
School outreach	Work with school districts to kickstart neighborhood efforts and community gardening, vermiculture, dung beetle farms, etc.
Tribal coordination	Integrate Traditional Ecological Knowledge in general; work with Tribal partners on restoration of burned areas with native plants on ranges
Regional partnership	Build regional partnership for dust and fire management
Other agencies	Combine with other agencies' restoration efforts
EWN Alliance	Implement EWN Alliance for desert Southwest
Partnerships within DoD and USACE	Build agency-level partnerships across DoD and USACE
BLM	Work with BLM regarding grazing management

Policies:

Carbon sequestration	Develop installation specific strategies for carbon sequestration
Funding change	Insert good ideas for funding in DON's funding list, change funding scheme at higher level, create scheme that gives bonus points/higher weighting for climate resilience projects that support mission
Funds for climate adaptation plans	Identify funds specifically for the projects in the context of climate adaptation plans (need to be woven into existing plans)
Taxes	Create carbon tax or water use tax; give homeowners rebates for savings
Incentives	Change incentives to favor NBS
Remove roadblocks	Identify the existing policy process, outline the steps, and identify roadblocks that can be removed to accelerate EWN projects. Look for ways to deconflict (e.g., U.S. Department of Agriculture example). Congress and National Defense Authorization Act sets funding and policy, administration issues Executive Orders, Federal and State agencies (partners) carry out regulations. Agencies carry out regulations that address clean water, historic preservation, and biological and air emissions (greenhouse gases).
Integration across disciplines	Create guidance on cross functional integration for master planning, facilities, environmental, natural resources, and public works
DON's design and construction process	Need climate resilience requirements and threat assessments in design and construction requirements process, planning, National Environmental Policy Act (NEPA), as well as operations and maintenance
NEPA streamlining	Streamline NEPA; pursue programmatic approach
NEPA Categorical Exclusion	Utilize Categorical Exclusions for natural resources for resilience projects
Integrated Natural Resource Management Plans	Provide guidance to Natural Resource Managers; integrated natural resource management plans don't stop at developed facilities
UFC	Update the UFC on natural infrastructure resilience
Drought response	Consider opportunities for innovative financing to incentivize resilience investment Establish international agreements on climate resilience (e.g., to adjudicate geoengineering, cloud seeding for drought response)
Range clearing mitigation	Mitigate costs of clearing operational ranges

The integrated nature of carbon sequestration, biodiversity, and water resources can be harnessed with NBS and can serve to support mission sustainment and provide resilience in the desert Southwest region. The following table provides some solutions that highlight resilience targets related to the water, carbon, and biodiversity.



Resilience Target	Themes	Resilience Solutions
Water	Check dams at watershed scale	Check dams/flow control in streams that are known to damage assets at a large systemic/watershed scale
	Crop dusting irrigation	Crop dusting irrigation to stabilize inoculum and foster seed germination
	Dew condensation	Harness dew condensation
	Dust hot spots	Revegetation or other management of dust "hot spots" in watershed
	Irrigation	Stop engineering nature: change zoning permits, outlaw sprinkler systems for lawns and along transportation routes, especially if not using grey water
	Irrigation	Reduce irrigation and use efficient irrigation methods
	Irrigation	Address evaporation and cover story (shade) of vegetation along irrigation channels
	Leak detection	Create a leak detection system in water conveyance
	Leaky dams	Rock wood mud structure that leaks water
	Range roads	Re-engineer range roads to reduce incision due to erosion
	Stormwater	Combine gabion structures within impact areas to keep ordnance from going down stream
	Stormwater	Maximize capture of stormwater for increased percolation and promote groundwater recharge by using solutions such as infiltration basins and permeable pavements
	Stormwater	Restore natural storm flow patterns: "Slow the flow," increase spreading of flow (reduce incision of desert washes)
	Stormwater	Contour catchments
	Water	Maximize reuse of treated water
	Water	Harvest water to grow food instead of food inputs from outside installations

Resilience Target	Themes	Resilience Solutions
Carbon	Agriculture for carbon storage	Incentivize carbon storage in agriculture
	Carbon sink	Increase sediment water carbon sink
	Biomimetic design	Use biomimetic structural design to reflect the heat (similar to Saguaro cactus)
	Electric vehicles	Shift culture to increase electric vehicle use on installation
	Emissions -generators	Increase efficiencies to reduce generator emissions
	Emissions -vehicles	Reduce civilian vehicle use on installation
	Food waste	Implement organic waste collection
	Fuel break treatment	Utilize non-mechanical treatment of fuel breaks
	High Solar Reflectance Index	Use High Solar Reflectance Index materials to reduce heat capture
Biodiversity	Invasive species	Control and manage invasive species
	Species management	Use umbrella species and productive communities
Water, Carbon	Composting soil	Add compost to soil with highly managed rotation
	Plowing	Promote contour plowing and keyline plowing
	Soils	Promote no-till and low-till practices
Water, Biodiversity	Agriculture	Reduce and eliminate chemical and biocide use

Resilience Target	Themes	Resilience Solutions
Water, Carbon, Biodiversity	Adaptive management practices	Anticipate future ecologies and use adaptive management practices to design intervention for future scenarios
	Floodplain restoration	Restoration of seasonal floodplains and riparian habitat
	Grazing	Use adaptive grazing
	Green roofs	Use green roofs with native species
	Green space	Convert lawns to functional ecosystems
	Infrastructure/ roads	Change infrastructure instead of roads (MCAS Yuma)
	Land management	Reclaim degraded land through holistic land management and amendments
	Revegetation	Revegetate disturbed areas (infiltration and dust control)
	Shade	Plant local and appropriate trees to provide shade over water surfaces to reduce water loss
	Soil amendment	Apply biological soil amendments; mine waste streams of base restaurants and grocery stores for compostable material to amend soil (and avoid solid waste disposal fees)
	Soil and water	Amend soil to increase water absorption capacity
	Soil compaction	Address the root causes of compaction
	Soil restoration	Review restoration potential based on USDA soil classification system
	Soils	Restore cryptogamic crust
	Soils	Use biocementation to stabilize soils and add organic matter
	Standardize and deploy land management practices	Deploy large-scale and standardized land management practices that are repeatable across installations
	Streams as firebreaks	Use streams as fire breaks, where appropriate

Appendix B. Workshop Agenda

Agenda for F2F Natural Infrastructure Workshop

FEBRUARY 28, 2022: Travel to Marine Corps Air Station (MCAS) Yuma
MARCH 1, 2022: DAY 1 (All times listed are Mountain Standard Time)

Time	Action	Lead or Speaker
0800 - 0830	**Arrive MCAS Yuma** The Club / Bldg #1200	
0830 - 0900	**Welcome and Opening Remarks**	**Col. Charles Dudik**, *Commanding Officer, MCAS Yuma or CDR Gareth Montgomery, Director of Installation & Logistics, MCAS Yuma* **Ms. Deb Loomis**, *Senior Advisor to the Secretary of the Navy (Climate Change)* **Ms. Jacque Rice**, *Natural Resources Program Lead Headquarters, U.S. Marine Corps* **Ms. Jennifer Oelke Farley**, *Environmental Planning and Conservation Office of Deputy Assistant Secretary of the Navy (Environment and Mission Readiness)*
0900 - 0920	**Introduction and Workshop Orientation**	**Dr. Todd Bridges**, *National Lead Engineering With Nature® Program, US Army Corps of Engineers and Senior Research Scientist (ST), Environmental Science, US Army Engineer Research and Development Center*
0920 – 1000	**Overview of Installations** (10 min presentation using provided slide template / 10 min Q&A) 1. MCAS Yuma Intro Slides 2. Naval Air Weapons Station China Lake, California	**Mr. Randy English**, *Conservation Manager, MCAS Yuma* **Ms. Christy Wolf**, *Conservation Program Manager, Naval Weapons Station, Fallbrook*
1000 – 1020	**Break**	
1020 - 1100	**Overview of Installations (Continued)** (10 min presentation using provided slide template / 10 min Q&A) 3. NAS Fallon and Fallon Range Training Complex (FRTC) 4. Marine Air Ground Force Training Command Marine Corps Air Ground Combat Center	**Ms. Vanessa Shoblock**, *Natural Resource Specialist, NAVFAC SW, EV* **Mr. Brian Hennan**, *Supervising Env. Protection Specialist, Environmental Affairs, MAG TFTC ISD*
1100 – 1115	**Natural Infrastructure Talk #1: Shepherding Landscapes** (10 Minute Talk / 5 Minute Q&A)	**Ms. Cole Bush**, *Shepherdess, Regenerative Agriculture Advocate, Entrepreneur, and Educator*
1115 – 1130	**Introduction to Breakout Sessions** (Please see Section "Instructions for Breakout Groups and Group Assignments" for more details and Group Assignments)	**Ms. Hollie Schmidt**, *Director, Resilience + Sustainability Business Advisory P+PS Americas, Jacobs*
1130 – 1300	**Lunch**	
1300 – 1430	**Facilitated Breakout Session 1: Installation Resilience Challenges and Vulnerabilities**	

1430 – 1445	**Break**	
1445 – 1600	**Breakout Group Report Outs for Session 1** (10 Minutes for Reporting and 10 Minutes for Q&A)	
1600 - 1615	**Natural Infrastructure Talk #2: Managing Wildfire Consequences** (10 Minute Talk / 5 Minute Q&A)	**Dr. Chris Haring**, *Research Engineer, U.S. Army Engineer Research and Development Center*
1615 – 1630	**Day 1 Recap**	
1630	**Adjourn**	

MARCH 2, 2022: (All times listed are Mountain Standard Time)

Time	Action	Lead or Speaker
0800 – 0830	**Arrive MCAS Yuma** The Club / Bldg #1200	
0830 - 0900	**Reflections about Day 1 / Activities for Day 2**	**Dr. Todd Bridges**
0900 – 0915	**Natural Infrastructure Talk #3: Managed Aquifer Recharge** (10 Minute Talk / 5 Minute Q&A)	**Dr. Becca Muenich**, *Assistant Professor, Environmental Engineering, School of Sustainable Engineering and the Built Environment*
0915 - 1045	**Facilitated Breakout Session 2: Current and future opportunities for using conventional and natural infrastructure** (Please refer to Worksheets for Additional Details)	
1045 – 1130	**Breakout Group Report Outs for Session 2** (10 Minutes for Reporting and 10 Minutes for Q&A) • Group 1 • Group 2	
1130 – 1300 1200 – 1300	**Lunch** **Talk #4: Understanding Ag**	**Mr. Gabe Brown and Mr. Alejandro Carrillo**, *Understanding Ag*
1300 - 1320	**Breakout Group Report Outs for Session 2** (10 Minutes for Reporting and 10 Minutes for Q&A) • Group 3 • Group 4	
1320 - 1345	**Break and Transfer to Vehicles for Site Visit**	
1345 - 1530	**MCAS YUMA** Site Visit(s) with Return to Bldg 1200_	
1530 - 1545	**Break**	
1545 – 1600	**Plenary Discussion Specific to Site Visit and Natural Infrastructure**	**Dr. Todd Bridges**
1600 - 1615	**Natural Infrastructure Talk #5: Land Management and Water Security** (10 Minute Talk / 5 Minute Q&A)	**Mr. Ricardo Aguirre**, *P.E., CFM, AP, Director of Land Management and Water Security, Executive Director of Drylands Alliance Addressing Water Needs (DAAWN), WEST Consultants, Inc.*
1615 – 1630	**Close Out of Day 2**	**Dr. Todd Bridges**
1630	Adjourn	

MARCH 3, 2022: (All times listed are Mountain Standard Time)

Time	Action	Lead or Speaker
0800 – 0830	**Arrive MCAS Yuma** The Club / Bldg #1200	
0830 - 0845	**Reflections about Day 2 / Activities for Day 3**	**Dr. Todd Bridges**
0845 – 0900	**Natural Infrastructure Talk #6:** **Compost for Climate Resilience** (10 Minute Talk / 5 Minute Q&A)	**Dr. Ryan Busby**, *Research Ecologist, US Army Engineer Research and Development Center*
0900 - 1000	**Facilitated Breakout Session 3: Installation specific follow-on NI demonstration/implementation project opportunities** (Please refer to Workbook for Additional Details)	
1000 – 1010	**Break**	
1010 – 1130	**Breakout Group Report Outs for Session 3** (10 Minutes for Reporting and 10 Minutes for Q&A) • Group 1 • Group 2 • Group 3 • Group 4	
1130 – 1200	**Review of Workshop Findings, Action Items and Next Steps**	**Dr. Todd Bridges**
1200	**Adjourn**	

Breakout Session #1

Installation Shocks and Stressors that Create Vulnerability at our Installation

What are the largest sources of uncertainty concerning Nature-Based Solutions (NBS), performance, and management (including Operations & Maintenance)? How might an increased understanding of ecosystem services provided by NBS be used in decision-making in desert communities (for example, understanding performance of different features)? Please provide your rationale, succinctly. Given these levels of uncertainty, what specific physical, ecological, or social processes/science should be targeted and considered in order to advance the use and integration of NBS into desert infrastructure strategies?

Please provide your rationale, succinctly below and turn in your completed workshop to your facilitator by the end of the workshop.

Attendee Name:		**Agency:**		**Small Group #:**	

What are the largest sources of installation Shocks and Stressors?	
Earthquakes	
Wildfire	
Flooding	
Other	

How might an increased understanding of ecosystem services provided by EWN be used in decision-making in desert communities? (with rationale):

Given uncertainty, what specific physical, ecological or social processes/science should be targeted to promote use of EWN?	
Physical	
Ecological	
Social	

Engineering With Nature®

Sustaining and Diversifying the Infrastructure Value of DoD Facilities

Breakout Session #2

Opportunities and Challenges for Nature-Based Solutions

What types of challenges to you encounter when trying to execute infrastructure projects?
What technical, policy, organizational, cultural, procedural challenges/obstacles are holding back progress toward resilient/sustainable installations?
How could pursuit and application of nature-based solutions be undertaken to address these challenges/obstacles?

Please provide your rationale, succinctly below and turn in your completed workshop to your facilitator by the end of the workshop.

Attendee Name:		**Agency:**		**Small Group #:**	

What types of nature-based solution projects is your organization currently conducting? Please provide name of effort, location, description and entities involved.

What types of challenges do you encounter when you execute infrastructure projects?

Technical:		**Operational:**	
Funding:		**Innovation:**	
Policy:		**Approvals:**	
Cultural:		**UFC:**	

What types of nature-based solution projects present the best opportunities for DON and its stakeholders and partners (considering research priorities, policy, planning, permitting issues, construction, operations, etc.)?

Breakout Session #3

Priority Nature-Based Solutions Collaborative Projects

What future Nature-Based Solution (NBS) projects would you prioritize for collaboration by USACE and DON?
Existing projects that can be leveraged should also be included.
What do you consider to be the key aspects or elements of these collaboration projects?
When considering your priority project(s), what key next steps should be taken to advance the collaborative efforts?

Please provide your rationale, succinctly below and turn in your completed workshop to your facilitator by the end of the workshop.

Attendee Name:		Agency:		Small Group #:	

What future Nature-Based Solutions projects would you prioritize for collaboration by USACE and DON, other partners and stakeholders?				
Name of Effort:		**Existing?**	**Yes:** _____	**No:** _____
Location(s):				
Collaborators Involved:				
Description of Key Aspects:				
Next Step(s):				

Name of Effort:		**Existing?**	**Yes:** _____	**No:** _____
Location(s):				
Collaborators Involved:				
Description of Key Aspects:				
Next Step(s):				

Name of Effort:		**Existing?**	**Yes:** _____	**No:** _____
Location(s):				
Collaborators Involved:				
Description of Key Aspects:				
Next Step(s):				

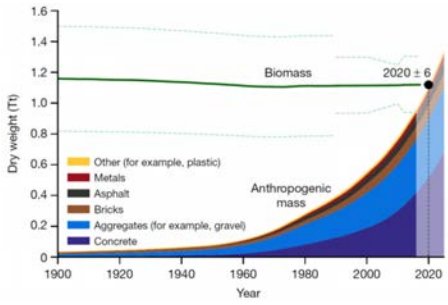
Appendix C. Workshop Presentations

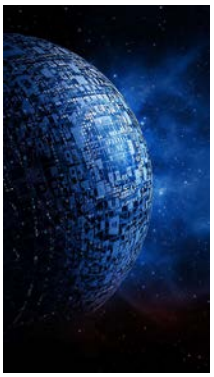
Pre-Workshop Presentations

Dr. Todd Bridges: Engineering With Nature®, Pursuing a New Arrangement with Nature

1900-2000: The Century of Infrastructure (US)

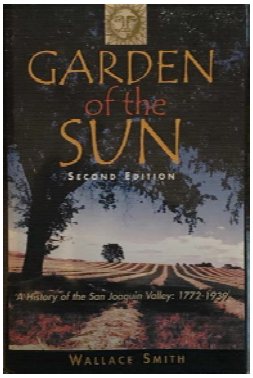
- 4,071,000 miles of roadway
  - 47,182 miles in the Interstate system
- 149,136 miles of mainline rail
- 640,000 miles of high-voltage transmission lines
- 614,387 bridges
- 90,580 dams
- >30,000 miles of flood levee
- 155,000 public drinking water systems
- ~5,000 military installations
- 926 ports, 25,000 miles of navigation channel



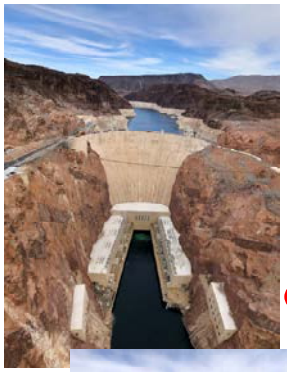


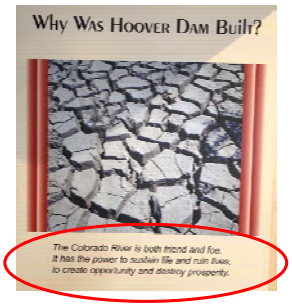
Elhacham et al. 2020. Global human-made mass exceeds all living biomass. Nature 588:442-444

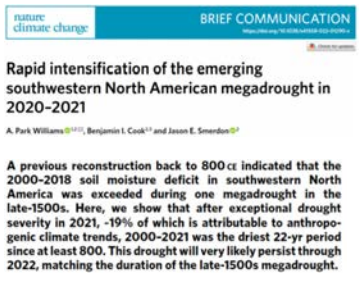
The San Joaquin Valley, California

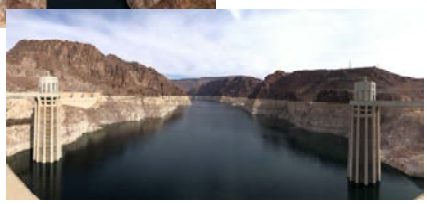


The West's Climate Change Conundrum









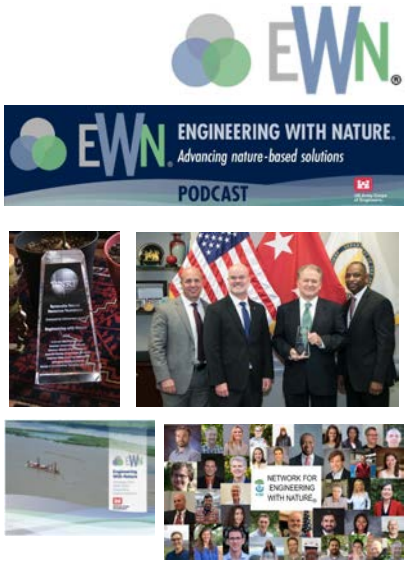
US Army Corps of Engineers • Engineer Research and Development Center

Engineering With Nature®

…the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaboration.

Key Elements:

- Science and engineering that produces operational efficiencies
- Using natural process to maximum benefit
- Increase and diversify infrastructure value
- Science-based collaboration to organize and focus interests, stakeholders, and partners



"The mission of US Army Corps of Engineers is to deliver vital public and military engineering services; partnering in peace and war to strengthen our nation's security, energize the economy and reduce risks from disasters. Engineering With Nature supports this mission which is why it will always be an important initiative for the Corps." LTG Scott A. Spellman, 55th Chief of Engineers, Commanding General, USACE

US Army Corps of Engineers • Engineer Research and Development Center

Engineering With Nature: *USACE Proving Grounds*

- Galveston District
- Buffalo District
- Philadelphia District
- Mobile District
- San Francisco District
- St. Louis District
- South Pacific Division



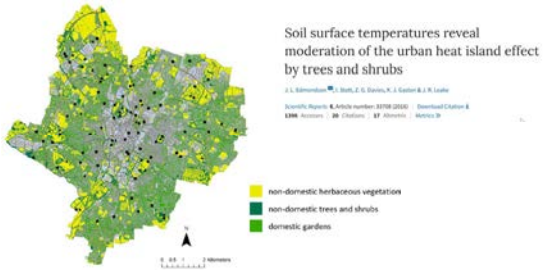



Nature-Based Solutions:

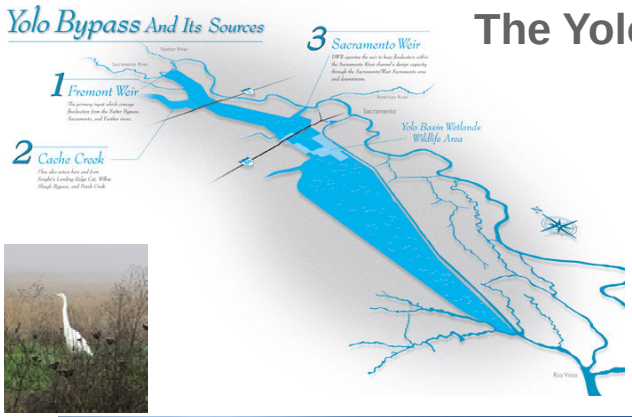
Conserving, restoring, and engineering nature for the benefit of people and nature

An Example: Trees as Infrastructure!

- Shaded surfaces can be 20-45°F cooler
- Evapotranspiration plus shading can reduce peak summer temperatures by 2-9°F
- Reducing wind speed and winter heat loss from buildings by 10-50%
- Improve local air quality
- Increase water infiltration, reducing surface water run-off



The Yolo Bypass, California (1911)




Yolo Bypass Wildlife Area

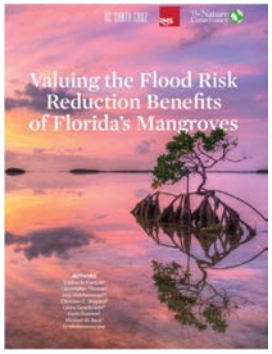

Sacramento Weir


Yolo Bypass, 2017

Leveraging Nature for Engineering Value: *Mangroves*

Florida Mangroves Study:

- Used an insurance industry catastrophe model to quantify the flood reduction benefits of mangroves across Florida
- During Hurricane Irma:
  - Mangroves averted $1.5 billion dollars in flood damages to properties
    - 25% savings in counties with mangroves
  - >600,000 people living behind mangrove forests saw reduced flooding across Florida



Menendez et al., 2020. *The Global Flood Protection Benefits of Mangroves.* https://www.nature.com/articles/s41598-020-61136-6

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Horseshoe Bend Island, Atchafalaya River, Louisiana, USA






Quantifying Wildlife and Navigation Benefits of a Dredging Beneficial-Use Project in the Lower Atchafalaya River: A Demonstration of Engineering with Nature

Project Awards:

- 2015 Western Dredging Association Award for Environmental Excellence
- 2017 Western Dredging Association Award for Climate Change Adaption
- 2017 Dredging and Port Construction Award for Engineering with Nature
- 2020 USACE Green Innovation Award

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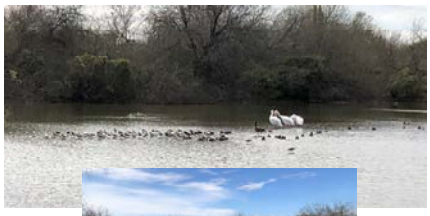
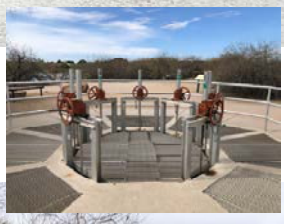
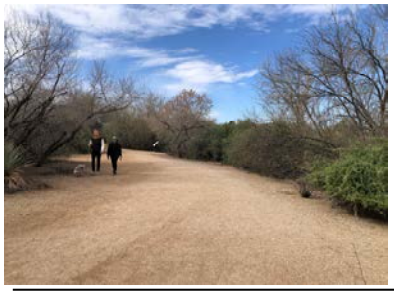
Groundwater Recharge: *Gilbert Riparian Preserve*

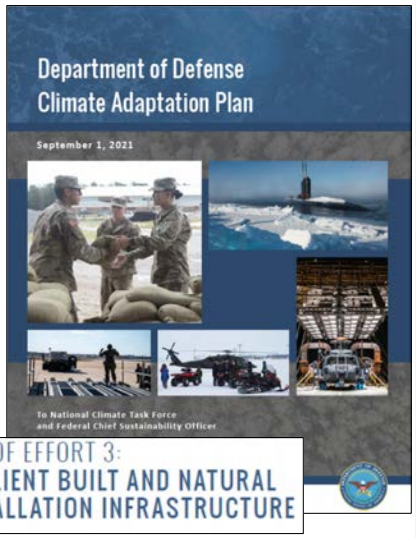



Military Installation Resilience: Built + Natural Infrastructure

"Built and natural infrastructure are both necessary for successful mission preparedness and readiness"."

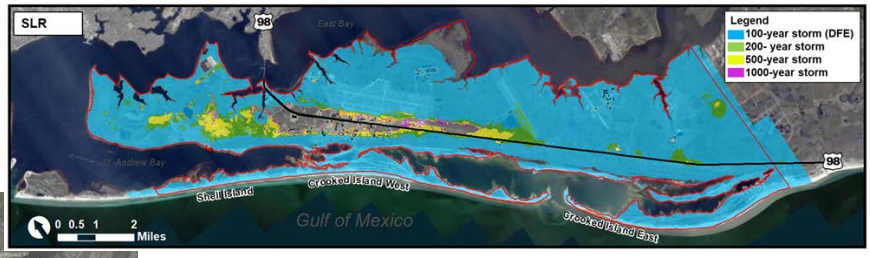
www.engineeringwithnature.org » About

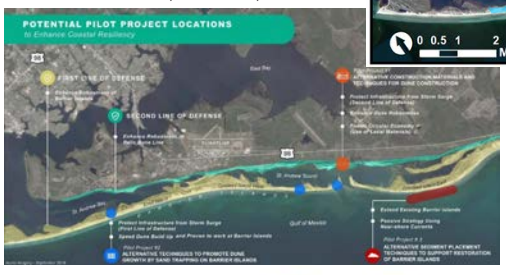


LINE OF EFFORT 3:
RESILIENT BUILT AND NATURAL INSTALLATION INFRASTRUCTURE

EWN® Applied to Tyndall Air Force Base for Coastal Resilience

Hurricane Michael, 10-11 OCT, 2018





Tyndallcoastalresilience.com

- EWN Podcast Season 1, Episode 3: BG Melancon
- *Winner*: 2021 UK Environment Agency Flood & Coast International Excellence Award

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"Revolutionizing" Practice Through Nature-Based Solutions

- Policy development
  - Engagement with policymakers
  - Policy/procedure "modernization"
- Engagement, partnering, and teaming
  - Within USACE, e.g., EWN Proving Grounds
  - With other organizations inside and outside government
- Innovation
  - Creating a vision of the future
  - Establishing goals, targets and conditions
  - New science and engineering and tools for delivery
- On-the-ground projects and demos
  - Across the spectrum of applications and project development (i.e., from planning to operations)
  - Scaling up nature-based solutions
- Strategic communications
  - Individual research papers
  - Communication tools, e.g., EWN Atlas Vol 1 and 2
  - Education, e.g., academic curricula, training

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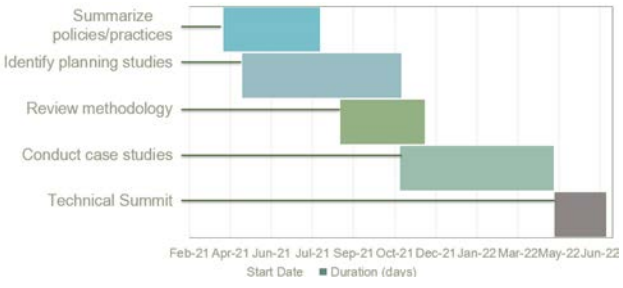
EWN BCA Policy Research: Overview

Current federal alternative evaluation process does not comprehensively value economic, environmental, and social benefits. These constraints screen out or exclude Nature-Based Solutions (NBS) and could lead to outcomes inconsistent with the Administration's priorities around community resilience and equity.

Approach:

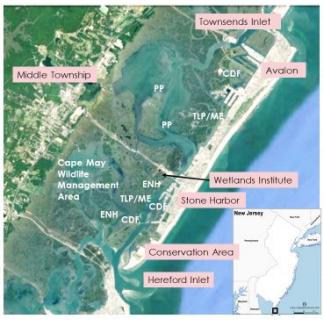
- **Summarize** historical and current alternative evaluation policies and practices
- **Identify** 6 historical planning studies that considered NBS alternatives suitable for case study analysis
- **Review** updated valuation methods and planning frameworks that incorporate environmental and social benefits
- **Analyze** case studies using updated methods and exploratory analysis to look beyond current policy constraints



The Power of Co-Development and Demonstration

Seven Mile Island Innovation Laboratory

- Collaboration and partnership that is building first-of-their-kind NBS projects in coastal New Jersey
  - Began in conversation
  - Accelerated by a storm (Sandy)
  - Progressed through piloting
  - Now in full-scale implementation



US Army Corps of Engineers

The Nature Conservancy

Fish and Wildlife

Wetlands Institute

The Network for Engineering With Nature (N-EWN)

- Multi-sector network supporting innovation
  - Types of partners: public and private sector
  - Research – gov't, academic, private
  - Industry practitioners
  - Project owners
- Aligning research with the needs of practice
- Grounding approach in real projects
- EWN education: curricula and training
- Experiential learning for students – systems thinking, cross-disciplinary training
- Freely flowing communication and knowledge sharing
- Accelerate implementation

N-EWN

US Army Corps of Engineers

Institute for Resilient Infrastructure Systems UNIVERSITY OF GEORGIA

NYC Mayor's Office of Climate Resiliency

TRIBAL NATIONS TECHNICAL CENTER OF EXPERTISE

THE WATER INSTITUTE OF THE GULF

The UNIVERSITY of OKLAHOMA

Arizona State University

GEORGIA Department of Natural Resources Coastal Resources Division

NCCOS National Centers for Coastal Ocean Science

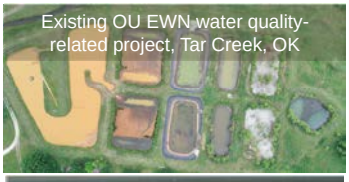
UF University of Florida Center for Coastal Solutions

www.engineeringwithnature.org; https://n-ewn.org/

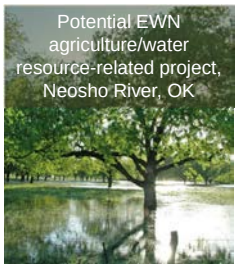
UNCLASSIFIED

EWN Solutions for the Heartland

- Establish collaborative EWN enterprise
- Pursue EWN field demonstrations
- Launch EWN communications platform


Existing OU EWN water quality-related project, Tar Creek, OK


Port of Catoosa, Kerr-McClellan Arkansas River Navigation System


Potential EWN agriculture/water resource-related project, Neosho River, OK

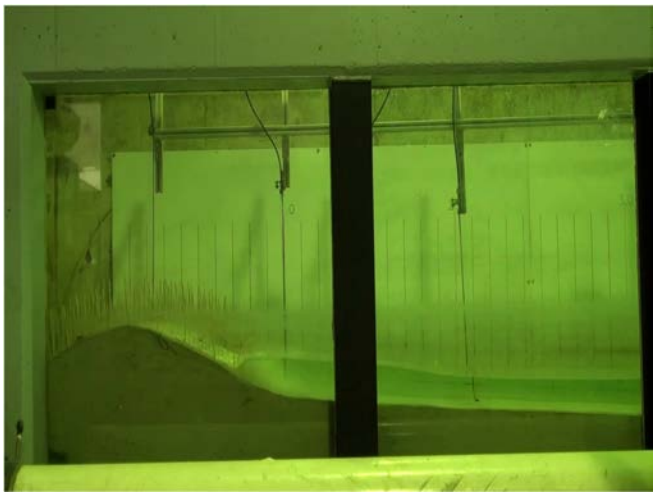
- **Research focus areas**
  - EWN opportunities inventory
  - Agricultural applications
  - Water resource (river/reservoirs) uses
  - Water quality role
  - Extreme weather/climate variability effects
  - Energy-water nexus possibilities
- **Collaborative R&D enterprise tasks**
  - Public/private partnership development
  - Incorporation of social sciences
  - EWN curricula/graduate certificate
  - Continuing education opportunities
  - Workshops, symposia, seminars
  - Webinars, videos, publications
  - Documentary film

UNCLASSIFIED

EWN Science, Engineering, Technology: Capability Targets

- **Fundamental processes**
  - Sediment transport through and around coastal NNBF
  - Long-term performance of features
  - Quantifying multi-purpose benefits of nature-based solutions
  - Processes contributing to system-scale resilience
- **Physical and numerical modeling**
  - Planners, stakeholders and decision-makers
  - Engineering design
  - Operations and maintenance
- **Reliable, cost-efficient monitoring technologies**
  - Measuring system evolution
  - Infrastructure/feature performance
  - Informing system adaptation
- **Guidance development**
  - Across applications: navigation, water supply, flood, drought, etc.
  - For planning, design, construction, O&M
- **Demonstration/pilot projects to innovate/learn**
  - Learn by doing
  - Collaboration to evolve organizational culture and practice
  - Produce evidence at field scale
  - Fuel the "power of the story"

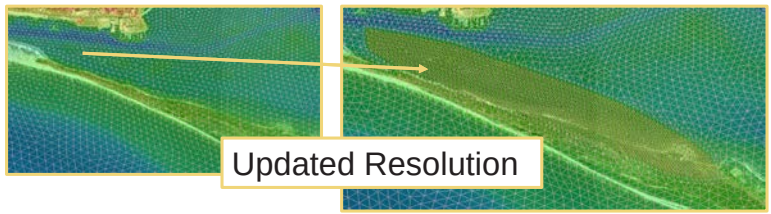
Performance of Coastal Dunes: *The Value of Dune Vegetation*

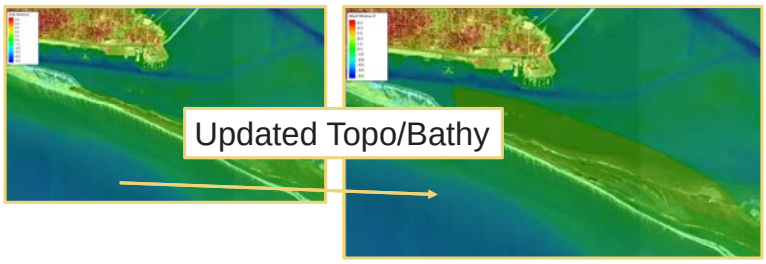


Tyndall AFB

The EWN® Toolkit for: Coastal Storm (CSTORM) Modeling System

- Toolkit allows for rapid representation of EWN features within a coastal and fluvial numerical model background.
- The user will have a geospatially rectified background image (i.e. from satellite or similar) to reference while working in the mesh editing environment.
- A simple set of tools for creating polygons, and layers of polygons, in which to represent EWN features will be available.
- Each EWN feature will come with an options tab or drop down menu to adjust various parameters for that feature (i.e. density of vegetation, Manning's n values, and bathymetry) that will be stored in a look up table.





CSTORM-MS COASTAL STORM MODELING SYSTEM

International Guidelines on Natural and Nature-Based Features for Flood Risk Management

www.engineeringwithnature.org

NNBF Guidelines Table of Contents

- Chapter 1. Introduction
- Chapter 2. Principles, Frameworks, and Outcomes
- Chapter 3. Community Engagement
- Chapter 4. Systems Approach
- Chapter 5. Performance
- Chapter 6. Benefits and Costs of NNBF
- Chapter 7. Adaptive Management
- Chapter 8. Introduction to Coastal Systems
- Chapter 9. Beaches and Dunes
- Chapter 10. Coastal Wetlands and Intertidal Areas
- Chapter 11. Islands
- Chapter 12. Reefs
- Chapter 13. Plant Systems
- Chapter 14. Environmental Enhancements
- Chapter 15. Introduction to Fluvial Systems
- Chapter 16. Fluvial Systems and Flood Risk Management
- Chapter 17. Benefits and Challenges of NNBF in Fluvial Systems
- Chapter 18. Fluvial NNBF
- Chapter 19. Fluvial NNBF Case Studies
- Chapter 20. The Way Forward

https://ewn.erdc.dren.mil/?page_id=4351

NNBF Guidelines

- >1,000 pages, 5-year effort
- >70 multi-sector organizations
- >170 authors and contributors

"The guidelines do not contain or represent the policy commitments or policy positions of the organizations that participated in their development. Policy development is the sole purview of each organization and the laws and procedures that govern their activities." Pages xi-xii.

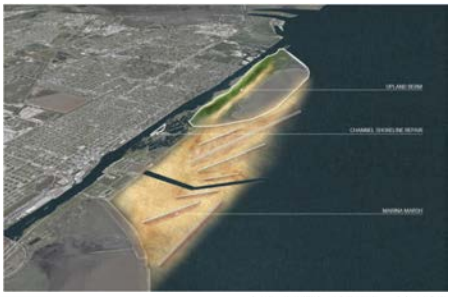
23

NNBF for FRM: Overarching Observations

- **Natural features and landscapes have always contributed to flood resilience.**
- **The function and success of FRM measures and systems are related to scale.**
- **Sustainable FRM systems will include combinations of conventional, natural, and nature-based elements.**
- **The flexibility and adaptability of NNBF are useful for achieving flood resilience.**
- **NNBF can increase and diversify the value provided by infrastructure.**
- **Innovation in practice will be key to addressing future problems and opportunities.**
- **Policies need to be developed to guide and expand the use of NNBF.**
- **Coordination, collaboration, and partnership will fuel successful implementation of NNBF.**

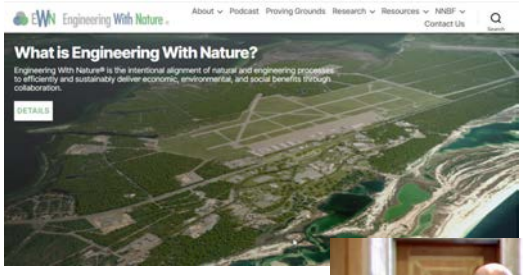
24

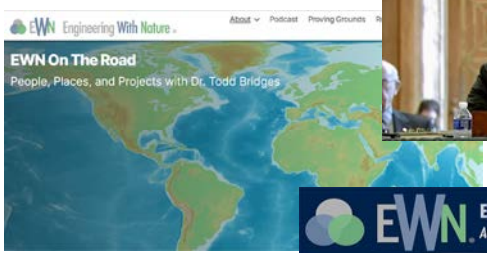
Designing for EWN: Sabine to Galveston, TX



https://ewn.el.erdc.dren.mil/designs.html

Communicating Nature-Based Solutions



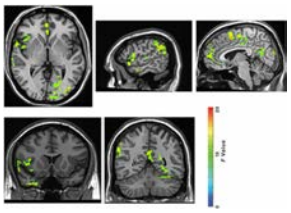


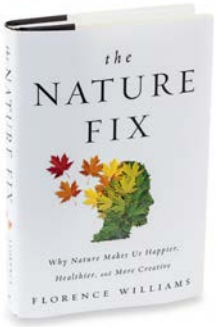
https://ewn.erdc.dren.mil/?p=3586

www.engineeringwithnature.org

Nature and Human Well-Being

- Science supports positive health effects of engagement with nature:
  - Physical health
    - Blood pressure
    - Healing
    - Immunity
    - Etc.
  - Mental health
    - Cognitive function
    - Anxiety
    - Depression
    - Socialization
    - Etc.





Nature experience reduces rumination and subgenual prefrontal cortex activation

Gregory N. Bratman, J. Paul Hamilton, Kevin S. Hahn, Gretchen C. Daily, and James J. Gross
PNAS July 14, 2015 112 (28) 8567-8572; first published June 29, 2015 https://doi.org/10.1073/pnas.1510459112

"It is a scientific fact that the occasional contemplation of natural scenes... is favorable to the health and vigor of men…"

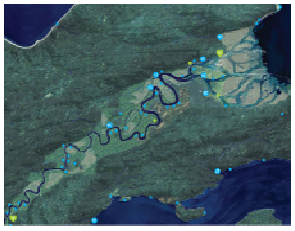
Frederick Law Olmsted (1822-1903)

Some Practical Aspects of "Revolutionizing" Practice Through EWN and Nature-Based Solutions

- NBS are relevant across multiple hazards and infrastructure contexts
- Co-develop a shared vision of the solution with communities from the BEGINNING
  - Shape and support vision THROUGHOUT
  - Landscape architects to help communicate vision
  - Engage and communicate with others!
- Diversify benefits to make solutions palatable for communities.
  - Communities live with the solution for 99% of time when the project is NOT under a storm load
  - USACE must expand benefits evaluation procedures, per James' memo (5 Jan 2021) and beyond
- Partner with industry, other agencies to iteratively develop engineering guidance, where needed
- "Hang-ups" to be overcome: Must NOT…
  - Think either/or (structural v. natural), but AND
  - Consider nature as a "frill" on an economic plan
  - Use uncertainty to excuse systematic/procedural bias

The Spectrum

"Wild and Free-Flowing Nature" — *"Tamed and Conquered Nature"*



Duwamish River, WA 1800s

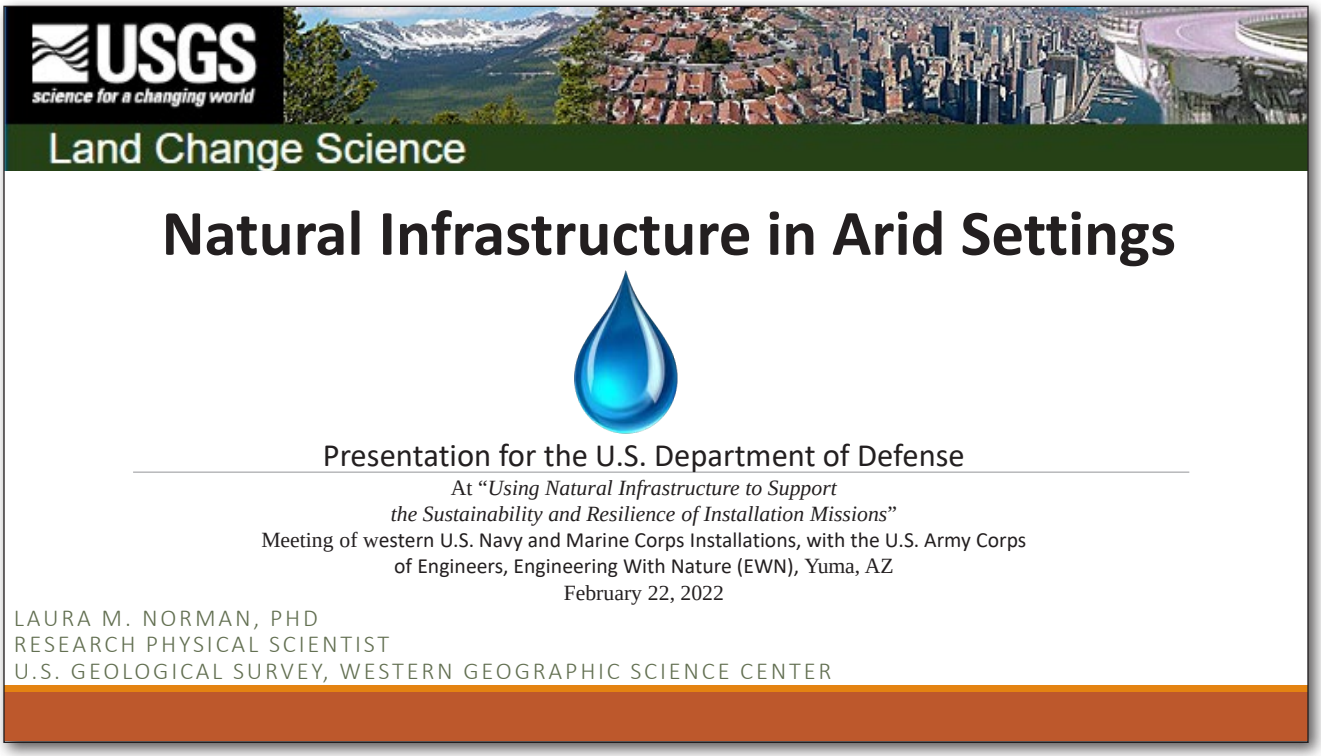
San Joaquin Valley, CA 1800s

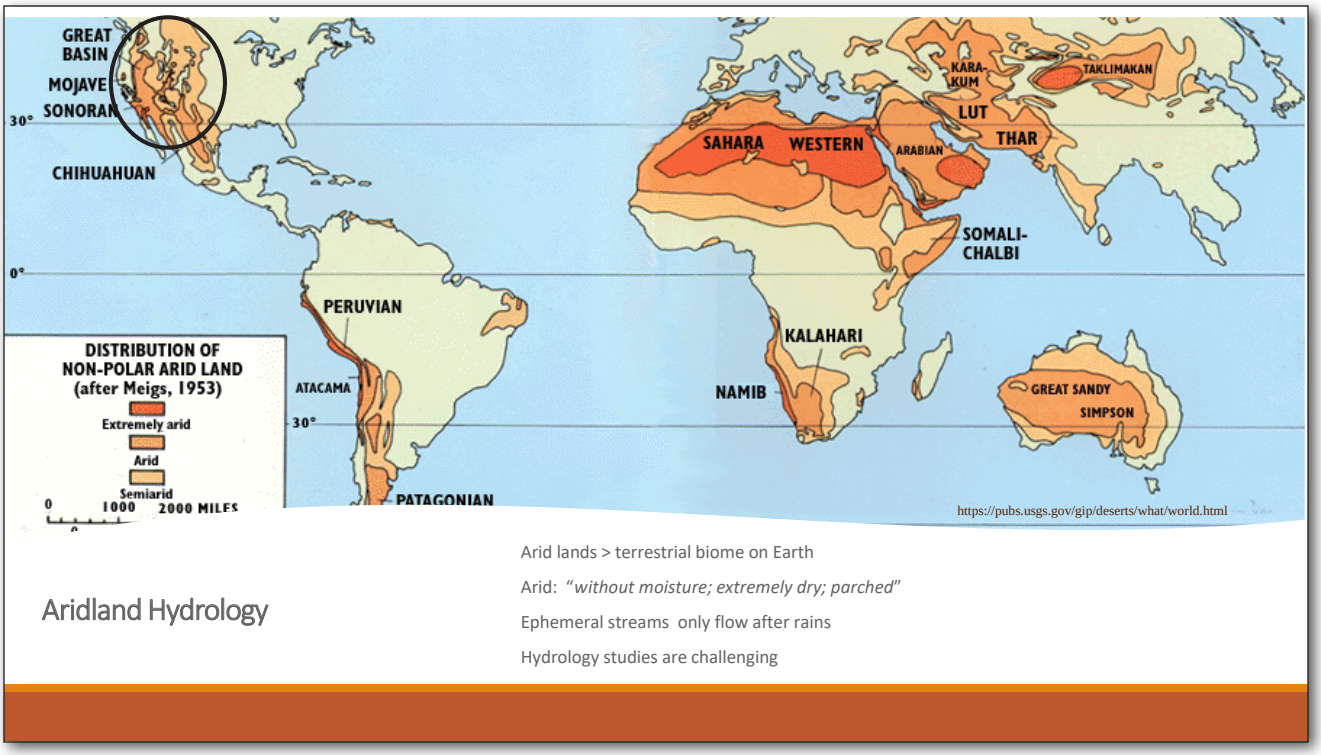
Achieving Nature-Engineering Balance

- Vision for sustainable systems
- Community needs and values
- Collaboration across boundaries
- Communication with others
- Innovation in engineering
- Enabling policy

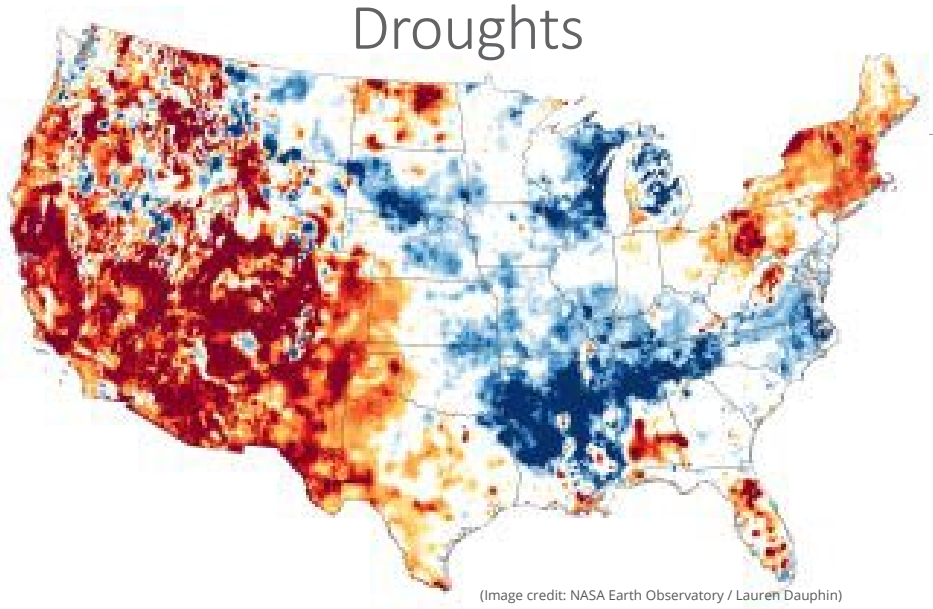
Duwamish River, WA today

San Joaquin Valley, CA today


USGS
science for a changing world
Land Change Science
Natural Infrastructure in Arid Settings
Presentation for the U.S. Department of Defense
At "Using Natural Infrastructure to Support
the Sustainability and Resilience of Installation Missions"
Meeting of western U.S. Navy and Marine Corps Installations, with the U.S. Army Corps
of Engineers, Engineering With Nature (EWN), Yuma, AZ
February 22, 2022
LAURA M. NORMAN, PHD
RESEARCH PHYSICAL SCIENTIST
U.S. GEOLOGICAL SURVEY, WESTERN GEOGRAPHIC SCIENCE CENTER


GREAT BASIN
MOJAVE
SONORAN
CHIHUAHUAN
PERUVIAN
ATACAMA
PATAGONIAN
SAHARA
WESTERN
ARABIAN
KARA-KUM
TAKLIMAKAN
LUT
THAR
SOMALI-CHALBI
KALAHARI
NAMIB
GREAT SANDY
SIMPSON
30°
0°
30°
DISTRIBUTION OF NON-POLAR ARID LAND (after Meigs, 1953)
Extremely arid
Arid
Semiarid
0 1000 2000 MILES
https://pubs.usgs.gov/gip/deserts/what/world.html
Aridland Hydrology
Arid lands > terrestrial biome on Earth
Arid: "without moisture; extremely dry; parched"
Ephemeral streams only flow after rains
Hydrology studies are challenging

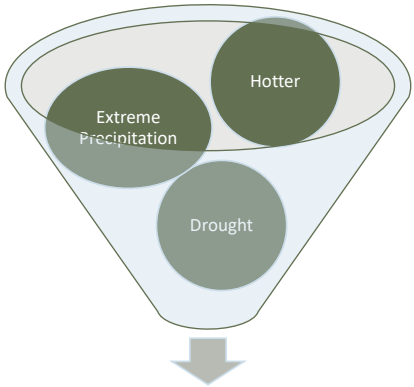
Droughts



(Image credit: NASA Earth Observatory / Lauren Dauphin)

Flood Hazards

Climate Change :: Aridification



This **increased risk of flooding** during periods of extreme precipitation and **megadrought condition** creates the need (& opportunity!) for ***climate resilience***!

Climate Adaptation vs. Mitigation

ADAPTATION: respond to a changing environment

https://conxpros.com/out-with-the-old-in-with-the-new-how-are-you-adapting-to-succeed-in-2021-and-beyond/

MITIGATION: efforts are made to reduce greenhouse gas (GHG) emissions

https://www.outsourcing-pharma.com/Article/2017/11/13/Quality-by-design-How-to-mitigate-risk-in-drug-development

NATURAL INFRASTRUCTURE IN DRYLAND STREAMS

Photographs where blue arrows portray direction of flow:

a) *leaky weirs (photo by Josiah Austin);*
b) *gabion (Photo by Andrea Prichard (Norman et al., 2010b);*
c) *check dams (photo by Jeremiah Liebowitz);*
d) *one-rock dams (Photo by Deborah Tosline (Tosline et al., 2020a));*
e) *trincheras (Photo by Valer Clark); and*
f) *a beaver dam!*

Norman, L.M., Lal, R., Wohl, E., Fairfax, E., Gellis, A.C., Pollock, M.M., 2022 *In Prep*. Natural Infrastructure in Dryland Streams Create Regenerative Wetland Sinks that Mitigate Climate Risk. Journal of Science of the Total Environment.

The Original Engineers

BEAVER DAM

AMERICAN BEAVER (CASTOR CANADENSIS)

https://www.eldoradotu.org/conservation/news/salmon-habitat-enhancement-through-beaver-reintroduction

Airborne Beavers Fight Floods

OUT in Idaho, the Department of Fish and Game is teaching eager beavers to yell "Geronimo!" These busy little creatures are being dropped by parachute to terrain where they can do their bit in the conservation battle.

Idaho state caretakers trap unwanted beavers which may be a nuisance in certain areas, round them up at central points and pack them in pairs in specially constructed wooden crates. After they are dropped, the boxes remain closed as long as there's some tension on the parachute shrouds but pull open as soon as the chute collapses on the ground. Then, out crawl Mama and Papa beaver, ready to start work.

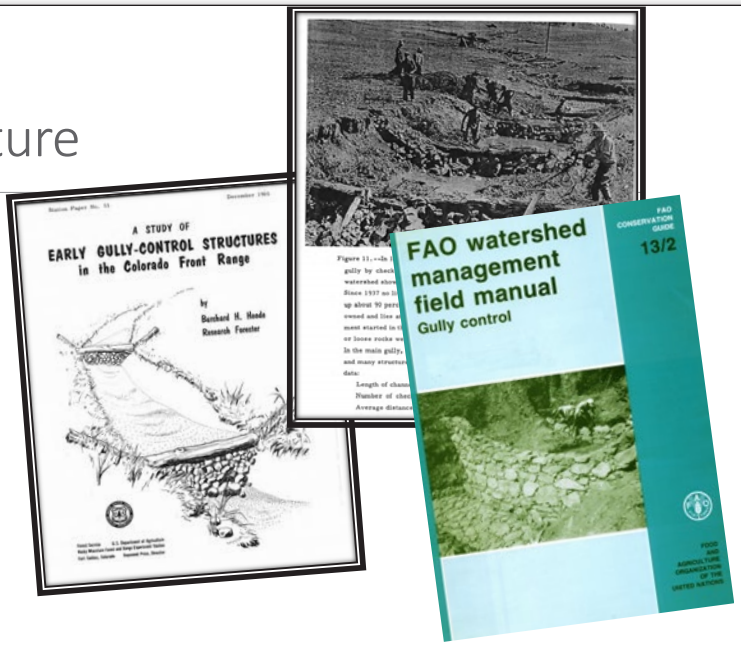
After they're settled, the 40-pound, web-footed rodents multiply and become outpost agents of flood control and soil conservation. Fur supervisor John Smith reports that in carefully observed early operations, the beavers headed straight for water and started building a new dam within a couple of days.

However, one problem still remains to be solved—a question of ethics more than conservation. *Are these eager beavers bona fide members of the Caterpillar Club?* •

1. Boxed for travel, this beaver is placed in a crate designed by Scotty Slater, left. 2. Rubber bands pull the box apart when the chute hits the ground, freeing the animals. 3. Heading for water, the airborne beavers start working like beavers on their new dam.

Human-made Natural Infrastructure

CHECK DAMS AND GABIONS



Heede, B. H. (1960). *A Study of early Gully-Control Structures in the Colorado Front Range* (Station Paper No. 55) (p. 45). Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Retrieved from http://www.fs.fed.us/rm/pubs_exp_forests/manitou/rmrs_1960_heede_b001.pdf

Geyik, M. P. (1986). Gully Control. In *Watershed Management Field Manual* (Vol. 2). Rome: Food and Agricultural Organization of the United Nations. Retrieved from http://www.fao.org/docrep/006/ad082e/ad082e00.htm

USGS science for a changing world

Land Change Science

Aridlands Water Harvesting Project

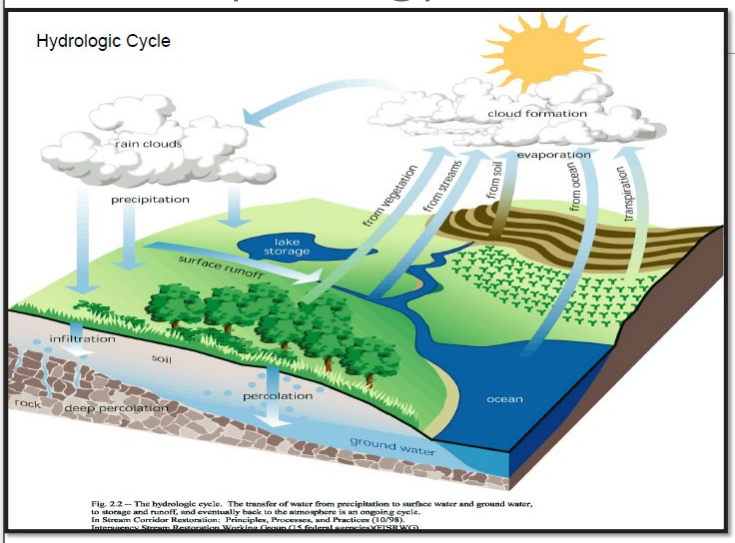
Determine efficacy of various Rock Detention Structures (RDS)

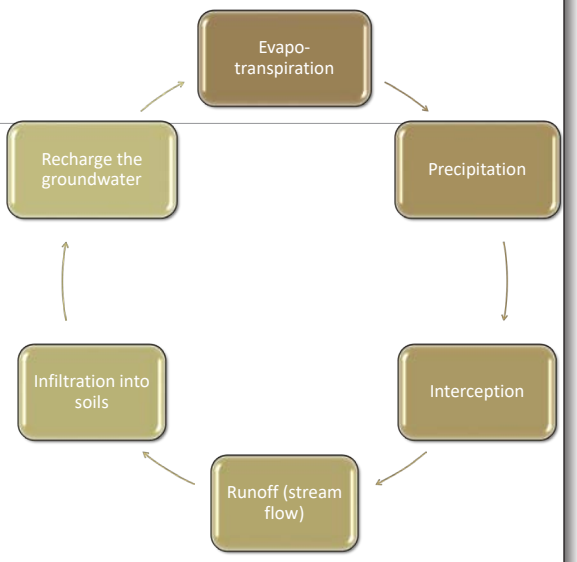
Water
- Slow water & reduce floods
- Support surface water & restore perennial flow
- Increase infiltration & recharge the aquifer

Soils
- Stabilize the soil & reduce erosion
- Reduce nonpoint source pollution
- Carbon sequestration

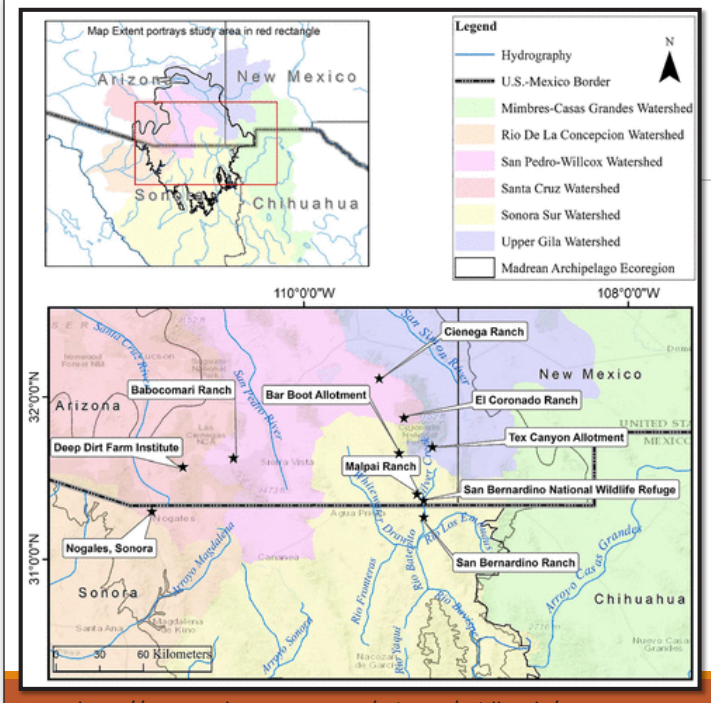
Vegetation
- Encourage plant growth
- Create habitat for animals

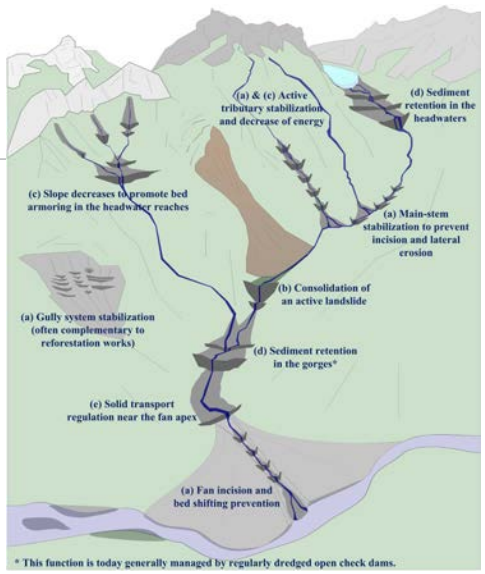
Ecohydrology





Zalewski, M. (2011). Ecohydrology. In J. Gliński, J. Horabik, & J. Lipiec (Eds.), *Encyclopedia of Agrophysics* (pp. 235–237). Dordrecht: Springer Netherlands. Retrieved from https://doi.org/10.1007/978-90-481-3585-1_46





https://onlinelibrary.wiley.com/doi/pdf/10.1002/esp.3967

http://geography.wr.usgs.gov/science/aridlands/

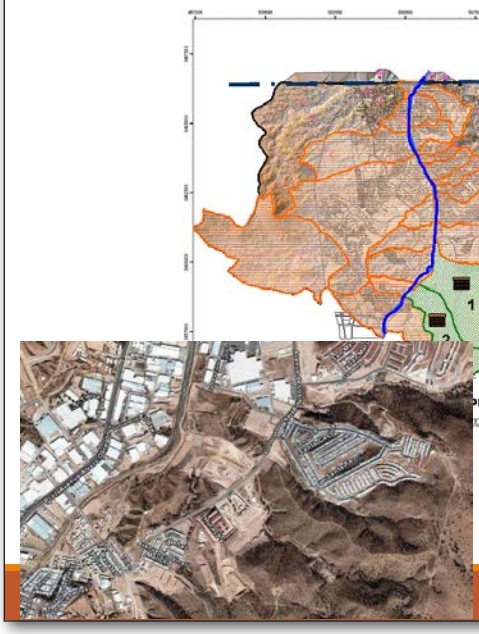
USGS science for a changing world

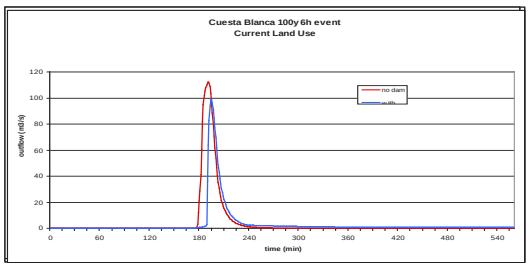
Land Change Science

2.) Work with partners to determine where new structures should be…..

- For flood prevention?
- For vegetation and habitat improvement?
- To "heal" the land?
- For groundwater recharge?
- For erosion control?
- For increasing water quality & quantity?
- To armor landscapes?
- For climate regulation?

Sky Island Restoration Cooperative



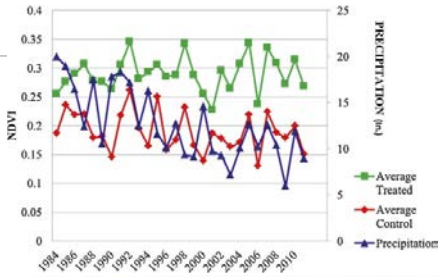


Sediment yield (kg), 25 year, 6 hour event		
Channel Impacts	Cuesta Blanca	Capulines
w/out feature	8,518,604	9,268,617
w/ feature	2,964,995	3,869,279
Difference	5,553,609	5,399,338

Norman, L.M., Levick, L., Guertin, D.P., Callegary, J., Quintanar Guadarrama, J., Zulema Gil Anaya, C., Prichard, A., Gray, F., Castellanos, E., Tepezano, E., Huth, H., Vandervoet, P., Rodriguez, S., Nunez, J., Atwood, D., Patricio Olivero Granillo, G., and Octavio Gastelum Ceballos, F., 2010, **Nogales flood detention study**: U.S. Geological Survey Open-File Report 2010-1262, 141 p.

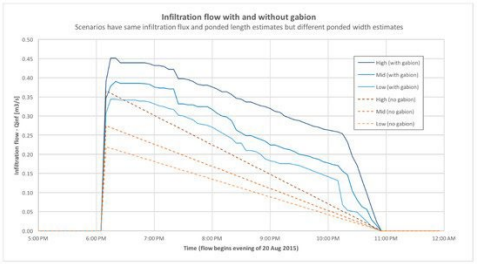
Wetland Restoration: Increased Vegetation

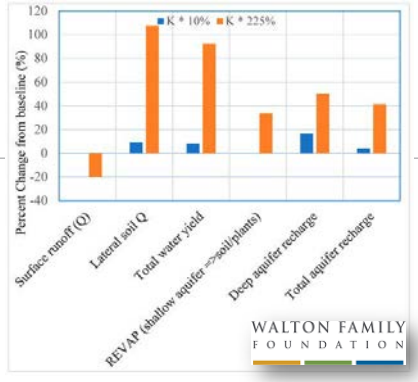
- Over a 27-year time period, we documented that vegetation is maintained and improved at structures, despite drought conditions, *and*
- This was evidenced extending up to 5km downstream and 1 km upstream!

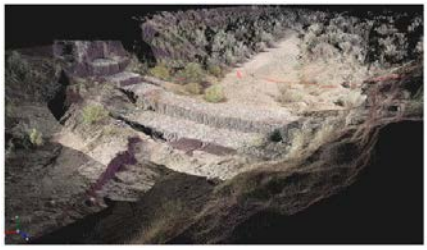


- Norman, L. M., Villarreal, M. L., Pulliam, H. R., Minckley, R., Gass, L., Tolle, C., & Coe, M. (2014). Remote sensing analysis of riparian vegetation response to desert marsh restoration in the Mexican Highlands. Ecological Engineering, 70C, 241–254. https://doi.org/10.1016/j.ecoleng.2014.05.012
- Wilson, N. R., & Norman, L. M. (2018). Analysis of vegetation recovery surrounding a restored wetland using the normalized difference infrared index (NDII) and normalized difference vegetation index (NDVI). International Journal of Remote Sensing, 39(10), 3243–3274. https://doi.org/10.1080/01431161.2018.1437297

Aquifer Recharge







Norman, L., Callegary, J., Lacher, L., Wilson, N., Fandel, C., Forbes, B., & Swetnam, T. (2019). Modeling Riparian Restoration Impacts on the Hydrologic Cycle at the Babacomari Ranch, SE Arizona, USA. Water, 11(2), 381. https://doi.org/10.3390/w11020381

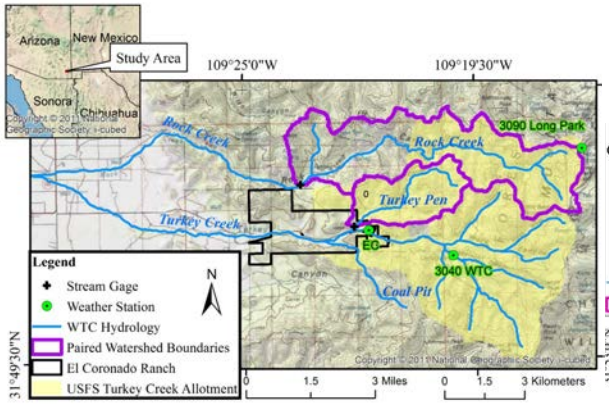
Phoenix, AZ→ Climate Regulation

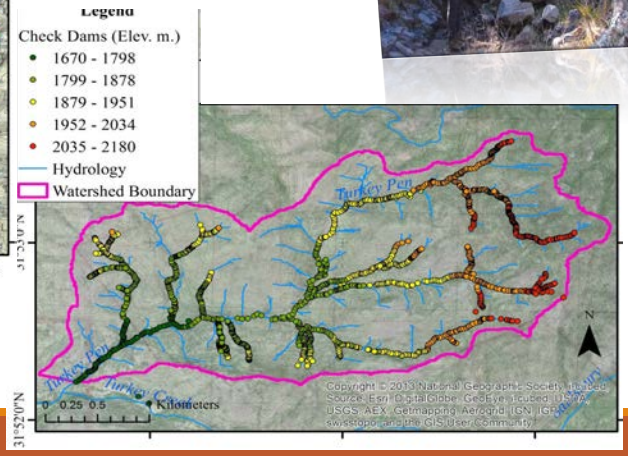
Deborah Tosline RG
Hydrogeologist
Bureau of Reclamation

Tosline, Deborah, Norman, L. M., Greimann, B. P., Cederberg, J., Huang, V., & Ruddell, B. L. (2020). *Impacts of Grade Control Structure Installations on Hydrology and Sediment Transport as an Adaptive Management Strategy* (Science and Technology Program Research and Development Office ST-2017-1751-01). Bureau of Reclamation. https://data.usbr.gov/catalog/4414/item/6298
Norman, L.M., Ruddell, B.L., Tosline, D.J., Fell, M.K., Greimann, B.P., Cederberg, J.R., 2021. Developing Climate Resilience in Aridlands Using Rock Detention Structures as Green Infrastructure. Sustainability 13, 11268. https://doi.org/10.3390/su132011268

Monitoring Streamflow

Hydrology of Streams Restored with Check Dams





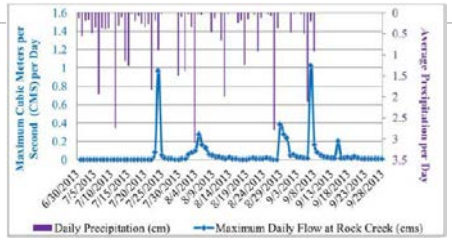
Norman, L. M., Brinkerhoff, F., Gwilliam, E., Guertin, D. P., Callegary, J., Goodrich, D. C., Nagler, P.L., and Gray, F. (2016). Hydrologic Response of Streams Restored with Check Dams in the Chiricahua Mountains, Arizona. *River Research and Applications*, http://doi.org/10.1002/rra.2895

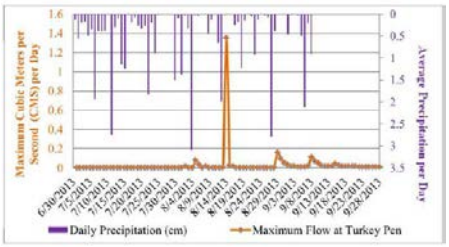
Monitoring Streamflow - Results

Fletcher Brinkerhoff,
Hydrologic Technician
Arizona Water Science Center

Evan Gwilliam
Ecologist
National Park Service

	Untreated/Control (RC)		
	Q Volume (Total Cubic Meters)	Precipitation (Monthly total * Watershed Size, in Cubic Meters)	% Runoff
July	12,959	3,878,490	0.33
August	58,139	3,468,960	1.68
September	34,264	1,011,780	3.39
October	1,720	0	0
	Treated (TP)		
	Q Volume (Total Cubic Meters)	Precipitation (Monthly total * Watershed Size, in Cubic Meters)	% Runoff
July	0	1,238,090	0
August	18,561	1,107,360	1.68
September	27,560	322,980	8.53
October	855	0	0

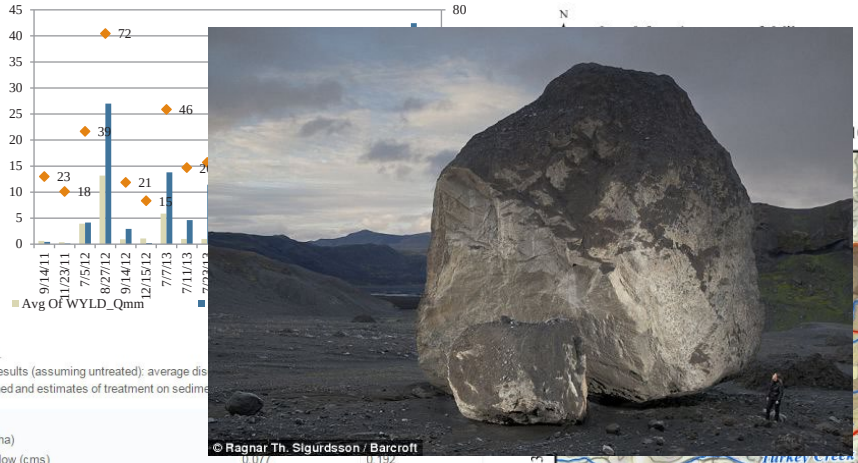




Norman, L. M., Brinkerhoff, F., Gwilliam, E., Guertin, D. P., Callegary, J., Goodrich, D. C., Nagler, P.L., and Gray, F. (2016). Hydrologic Response of Streams Restored with Check Dams in the Chiricahua Mountains, Arizona. *River Research and Applications*, http://doi.org/10.1002/rra.2895

Hydrologic Models – Soil and Water Assessment Tool (SWAT)

Erosion Control→ Water Purification



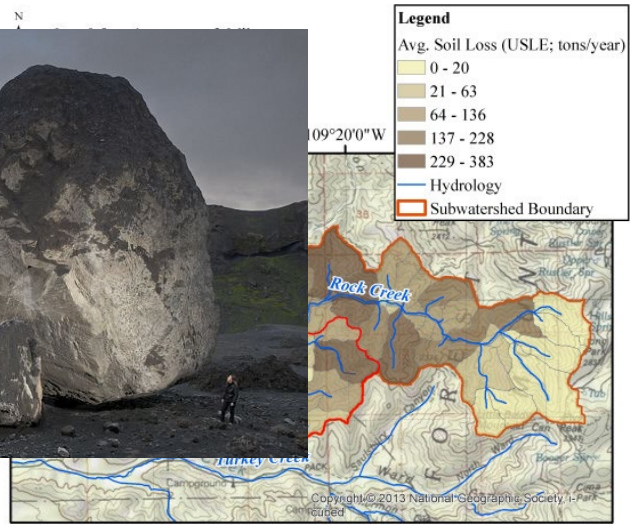


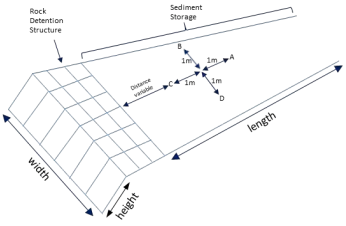
Table 2.
Model results (assuming untreated): average dis
watershed and estimates of treatment on sedime

Size (ha)		
Avg. flow (cms)	0.077	0.192
Average soil loss (USLE; tons/year)	792	3174
Avg. sediment yield (SDR = 0.45–0.61; tons/year)	356–483	1428–1936
Avg. sediment yield IF check dams (ton/year)	178–242	714–968

Norman, L. M., & Niraula, R. (2016). Model analysis of check dam impacts on long-term sediment and water budgets in Southeast Arizona, USA. *Ecohydrology & Hydrobiology*. http://doi.org/10.1016/j.ecohyd.2015.12.001

Analyzing Soil Samples

- Sampled Stable isotope ratios of carbon and nitrogen (δ ^{13}C and δ ^{15}N)



Callegary, J. B., Norman, L. M., Eastoe, C. J., Sankey, J. B., & Youberg, A. (2021). Post-Wildfire Carbon and Nitrogen Sequestration Potential in Entisols of Forest Ecosystems of Southwest USA. *Air, Soil and Water Research, 13*. https://doi.org/10.1177/11786221201001768

Carbon Sequestration and Storage

We conservatively estimated the potential mean annual capture of Soil Organic Carbon by check dams in the Turkey Pen Watershed (recall ~>2000 check dams/769 ha) to be ~200-250 metric tons/ha.

… Equivalent to what is stored in ***wetlands***

Callegary, J. B., Norman, L. M., Eastoe, C. J., Sankey, J. B., & Youberg, A. (2021). Post-Wildfire Carbon and Nitrogen Sequestration Potential in Entisols of Forest Ecosystems of Southwest USA. *Air, Soil and Water Research*, *13*. https://doi.org/10.1177/11786221201001768

*Arid*lands :: *Wet*lands

These are freshwater wetlands (*cienegas*)

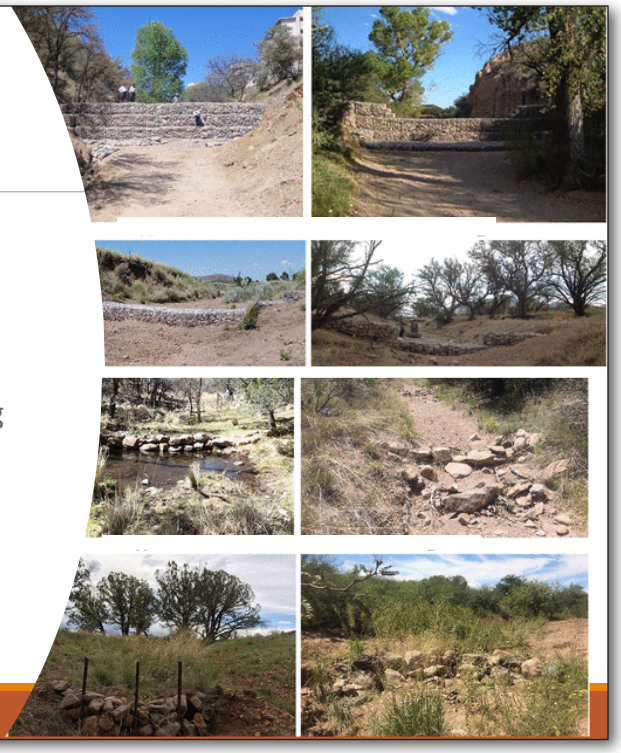
distinct ecosystems, flooded by water

Video by Kate Tirion

USGS science for a changing world

Climate Related Ecosystem Services of Rock Detention Structures

- ✓Flood regulation
- ✓Erosion regulation
- ✓Habitat Provisioning
- ✓Water regulation, purification, and provisioning
- ✓Carbon sequestration and storage
- ✓Social value
- ✓Climate regulation



Norman, L. M. (2020). Ecosystem Services of Riparian Restoration: A Review of Rock Detention Structures in the Madrean Archipelago Ecoregion. Air, Soil and Water Research, 13, 117862212094633.

Ver esta publicación en español

Norman, L. M. (2020). Servicios de ecosistemas de restauración ribereña: revisión de estructuras de detención de rocas en la ecorregión del archipiélago Madrense. *Air, Soil and Water Research*, *13*, 117862212094633. https://doi.org/10.25384/SAGE.12780900.v1

Natural Infrastructure in Dryland Streams Create *Regenerative* Wetland Sinks

a.k.a. Soil Water Carbon Sinks

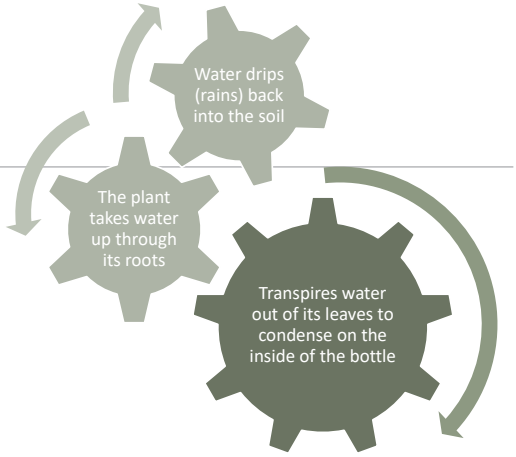
More Water Availability
- Increased water volume
- Increase water quality
- Increase infiltration
- Extended seasonal runoff

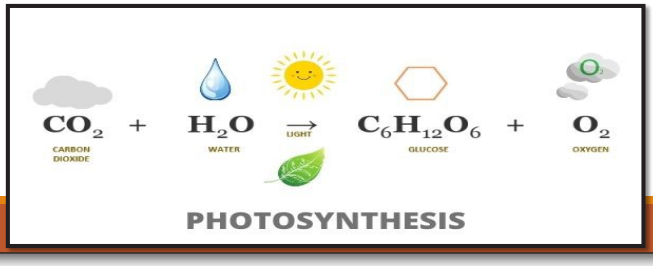
More Healthy Vegetation
- Extended growing season
- More Photosynthesis
- Deeper and more plentiful **Root**s

More sediment trapped
- More soil productivity
- More water storage
- More carbon storage
- Less NPS pollutants downstream (clearer water)

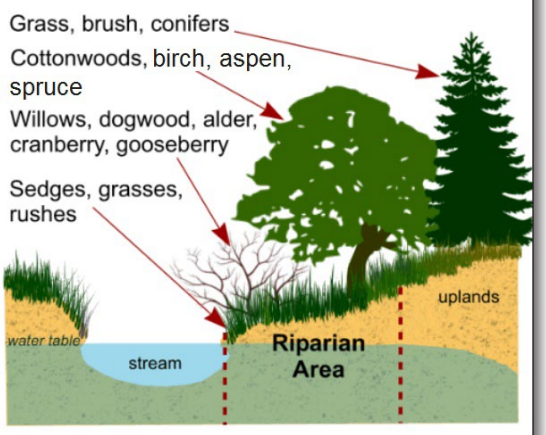
Norman, L.M., Lal, R., Wohl, E., Fairfax, E., Gellis, A.C., Pollock, M.M., 2022 *In Prep*. Natural Infrastructure in Dryland Streams Create Regenerative Wetland Sinks that Mitigate Climate Risk. Journal of Science of the Total Environment.

https://www.inspiremore.com/david-latimer-bottle-garden/

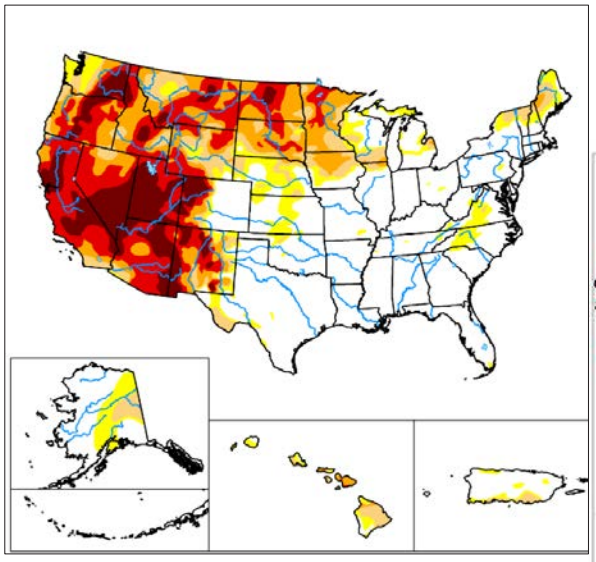




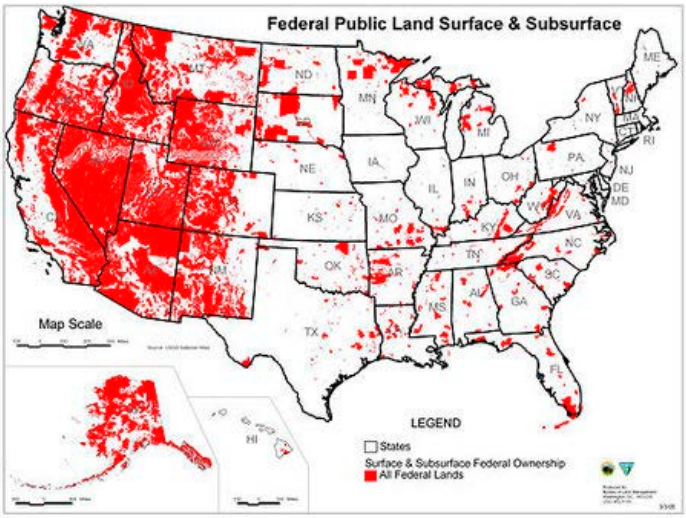
Nature-based Solutions:
Regenerating Riparian Areas



Norman, L.M., 2022. Invited Commentary: Dryland Watershed Restoration with Rock Detention Structures: A Nature-based Solution to Mitigate Drought, Erosion, Flooding, and Atmospheric Carbon. Front. Environ. Sci. 9.



July 20, 2021: Drought Monitor



Federal and Tribal riparian areas in Arizona

COSTS*

33,182 ha X ~$2,210 per ha = **$73M**

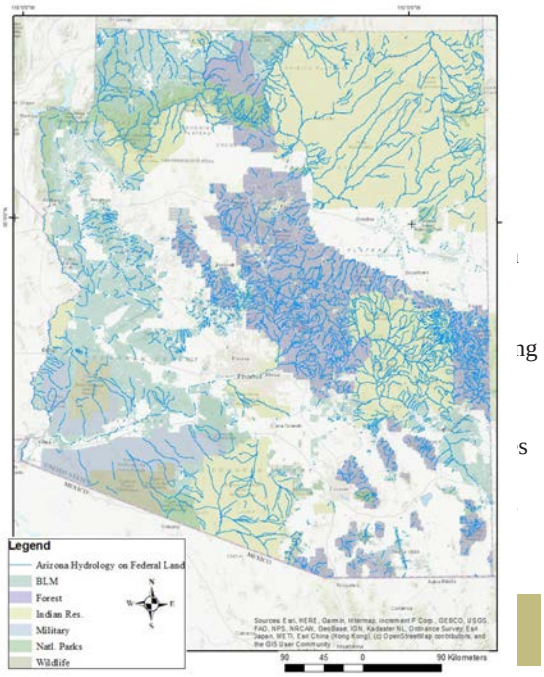
33,182 ha / 2.6 check dams/ha = >**86K check dams**

For comparison, climate-related disasters in Arizona spurred Legislation of **$100M** for recovery and support efforts to help deal with damages related to post-fire flooding **in 2021** (Office of the Governor, 2021).

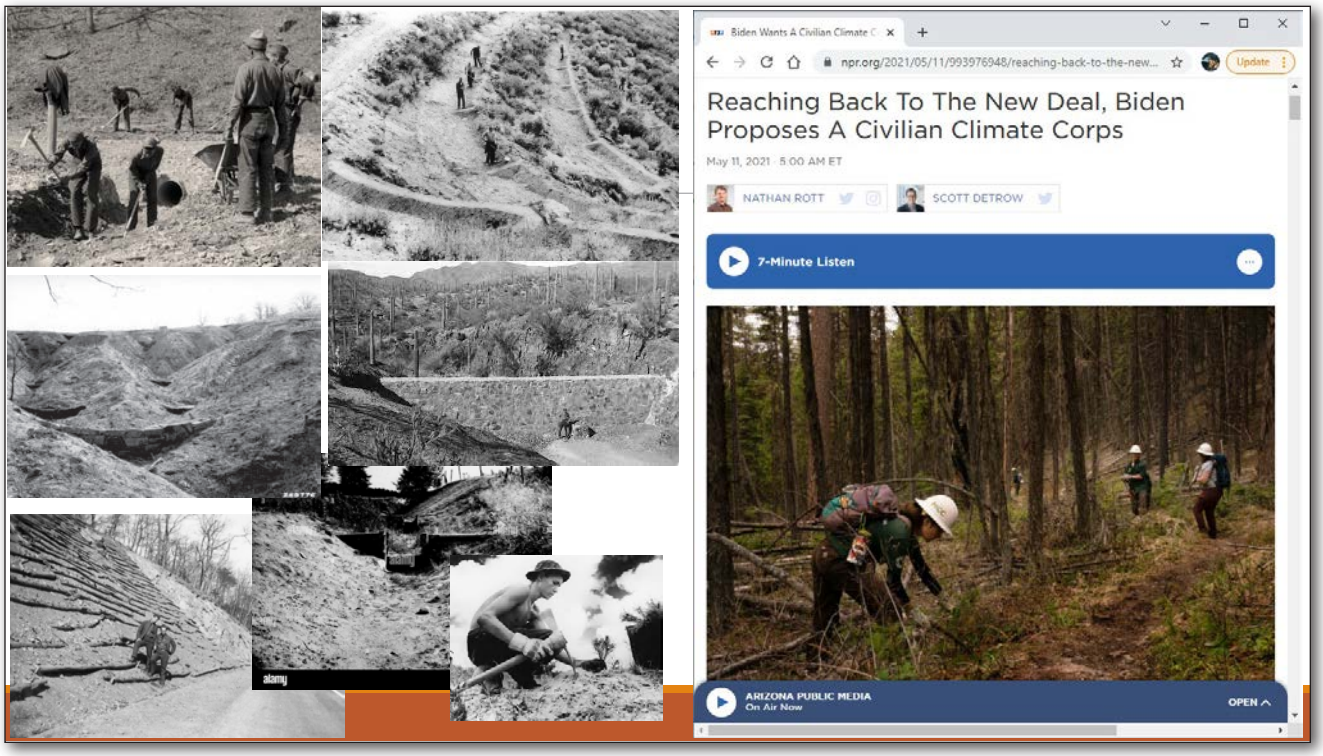
**all calculations are approximated based on previous research*

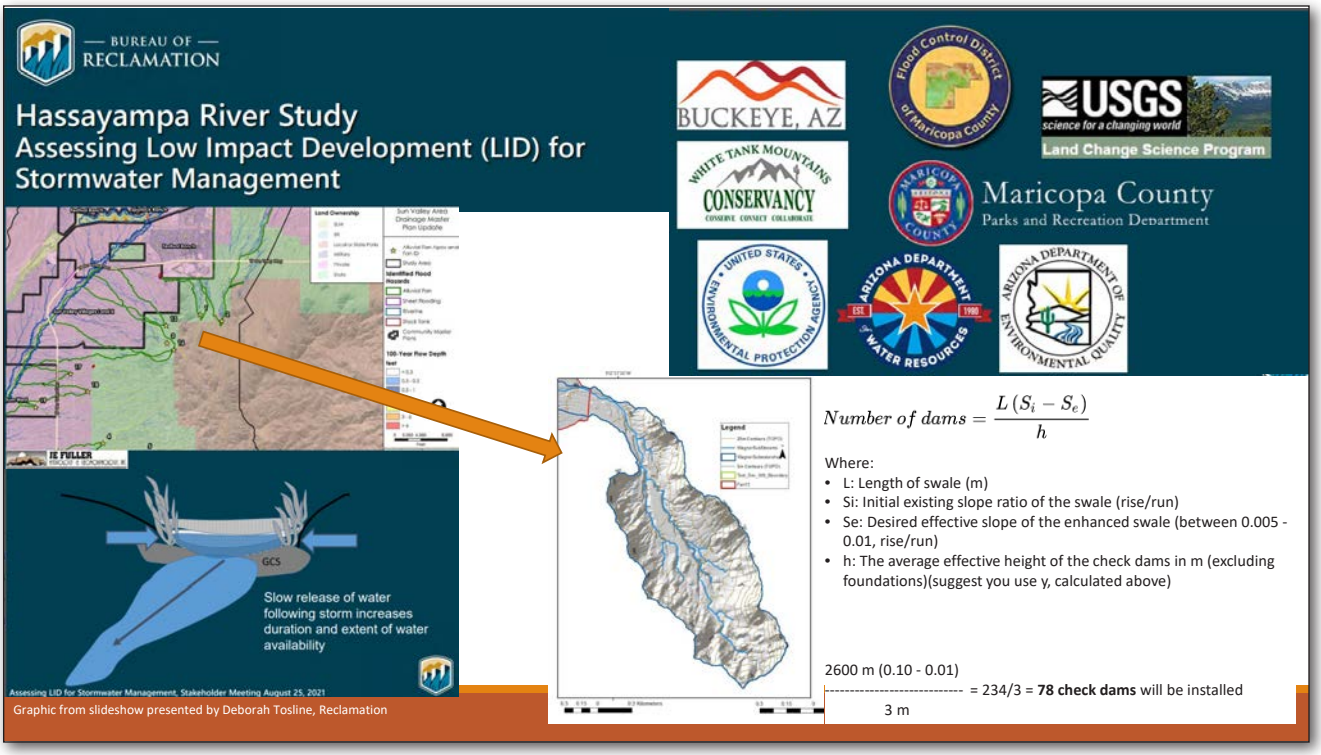
BENE

- ✓ sequester the soil st
- ✓ maintain growing s C sequest
- ✓ extend ep
- ✓ mitigate f
- ✓ promote l
- ✓ control er quality ar
- ✓ reduce an
- ✓ >1000 jo regional,



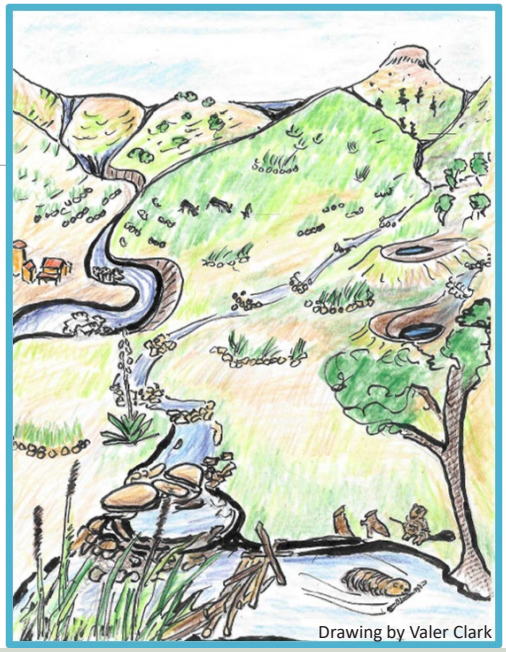
Norman, L.M., 2022. Invited Commentary: Dryland Watershed Restoration with Rock Detention Structures: A Nature-based Solution to Mitigate Drought, Erosion, Flooding, and Atmospheric Carbon. Front. Environ. Sci. 9.


Biden Wants A Civilian Climate C
npr.org/2021/05/11/993976948/reaching-back-to-the-new...
Update
Reaching Back To The New Deal, Biden Proposes A Civilian Climate Corps
May 11, 2021 · 5:00 AM ET
NATHAN ROTT
SCOTT DETROW
7-Minute Listen
ARIZONA PUBLIC MEDIA
On Air Now
OPEN


BUREAU OF RECLAMATION
Hassayampa River Study
Assessing Low Impact Development (LID) for Stormwater Management
BUCKEYE, AZ
Flood Control District of Maricopa County
USGS
science for a changing world
Land Change Science Program
WHITE TANK MOUNTAINS CONSERVANCY
Maricopa County
Parks and Recreation Department
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ARIZONA DEPARTMENT OF WATER RESOURCES
ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY
GCS
Slow release of water following storm increases duration and extent of water availability
Assessing LID for Stormwater Management, Stakeholder Meeting August 25, 2021
$$Number\ of\ dams = \frac{L\,(S_i - S_e)}{h}$$
Where:
• L: Length of swale (m)
• Si: Initial existing slope ratio of the swale (rise/run)
• Se: Desired effective slope of the enhanced swale (between 0.005 - 0.01, rise/run)
• h: The average effective height of the check dams in m (excluding foundations)(suggest you use y, calculated above)
2600 m (0.10 - 0.01)
---------- = 234/3 = 78 check dams will be installed
3 m
Graphic from slideshow presented by Deborah Tosline, Reclamation

Watershed Restoration

- Long-term maintenance and re-tooling
- Combination of structures, depending on conditions
- Lots and lots of structures (thousands
- Installed by people trained in restoration
- Based on prioritized needs (erosion control, recharge, habitat provisioning, flood detention, etc..)


Drawing by Valer Clark

Norman, L.M., Girard, M.M., Pulliam, H.R., Villarreal, M.L., Clark, V., Flesch, A.D., Petrakis, R.E., Leibowitz, J., Tosline, D.J., Vaughn, K., Wagner, T., Weaver, C., Hare, T., Perez, J.M., Lopez Bujanda, O.E., Austin, J.T., Campbell, C.F., Callegary, J.B., Wilson, N.R., Conn, J.A., Sisk, T., Nabhan, G.P., 2022. A shared vision for enhancing ecological resilience in the U.S. - Mexico borderlands: The Sky Island Restoration Collaborative. Society magazine (SERNews).

USGS science for a changing world

Land Change Science Program

Norman, L.M., Lal, R., Wohl, E., Fairfax, E., Gellis, A.C., Pollock, M.M., 2022 *In Prep*. Natural Infrastructure in Dryland Streams Create Regenerative Wetland Sinks that Mitigate Climate Risk. Journal of Science of the Total Environment.

USGS science for a changing world

Land Change Science Program

Want to learn more about the science and access publications?

https://usgs.gov/WGSC/Aridlands

Thank you!

Want to learn more about partnerships and practices on the US-Mexico border? USGS Public Lecture in March, posted online: https://www.usgs.gov/media/videos/pubtalk-32021-a-jaguars-field-dreams

Want to contact me?

Laura M. Norman, lnorman@usgs.gov

https://www.usgs.gov/staff-profiles/laura-m-norman

Hollie Schmidt: Defining the Installation of the Future After a Natural Disaster Using Nature Based Solutions at Tyndall Air Force Base

HOLLIE SCHMIDT
Director,
Resilience & Sustainability
Business Advisory,
Americas

JACOBS

INTRODUCTION

Task Lead for the Tyndall Air Force Base Rebuild Program

In this role, Hollie facilitated stakeholder engagement and outreach, served as the on-site coordinator, and led a large multi-disciplinary technical team while championing nature-based resiliency solutions. She led the infrastructure strategy, updates to the Installation Facilities Standards and the integrated land management approach for the reconstruction of Tyndall AFB.

Hollie Schmidt is the Director of the Resilience & Sustainability Business Advisory for the Americas with the Advance Planning Group at Jacobs. She is a landscape architect and master planner with 27 years' experience specializing in strategic planning and executive level decision facilitation for private and public sector clients. She leads large-scale, complex mega-projects facilitating diverse teams of planners, urban designers, landscape architects and the full spectrum of technical and engineering experts.


Jacobs
Ongoing Work with
USACE ERDC EWN


Jacobs
USACE ERDC EWN & JACOBS RELATIONSHIP
Engineering With Nature
Supporting Mission Resilience and Infrastructure Value at Department of Defense Installations
Nature-based Coastal Resilience Typologies
Numerous nature-based coastal resilience strategies and techniques are being implemented across the United States, exploring the emerging technologies of using nature's systems. Further analysis and study will ultimately determine appropriate recommendations for Tyndall AFB.
Jacobs Wins Department of Defense Facilities Contract
1
Tyndall Air Force Base Rebuild
Integrated EWN design solutions for the natural and built environment
2
Co-Published EWN Atlas
Supporting Mission Resilience and Infrastructure Value at Department of Defense Installations
3
Tyndall Coastal Resilience Strategy
Definition of Pilot Projects, Stakeholder Engagement, Funding Strategy, Implementation Plan
4
EWN DoD Facility Adaptation Planning
3-Year Contract for vulnerability assessments at DoD Installations that can be mitigated with EWN solutions

Jacobs

TYNDALL AIR FORCE BASE: HURRICANE MICHAEL IMPACTS

In October 2018, Tyndall Air Force Base was hit with a **category five hurricane** which resulted in **damage to 100% of its assets**.

The goal of this project was to rebuild the base to be more **resilient, sustainable**, and **smart** to be an **Installation of the Future**.

155 MPH
Sustained Winds

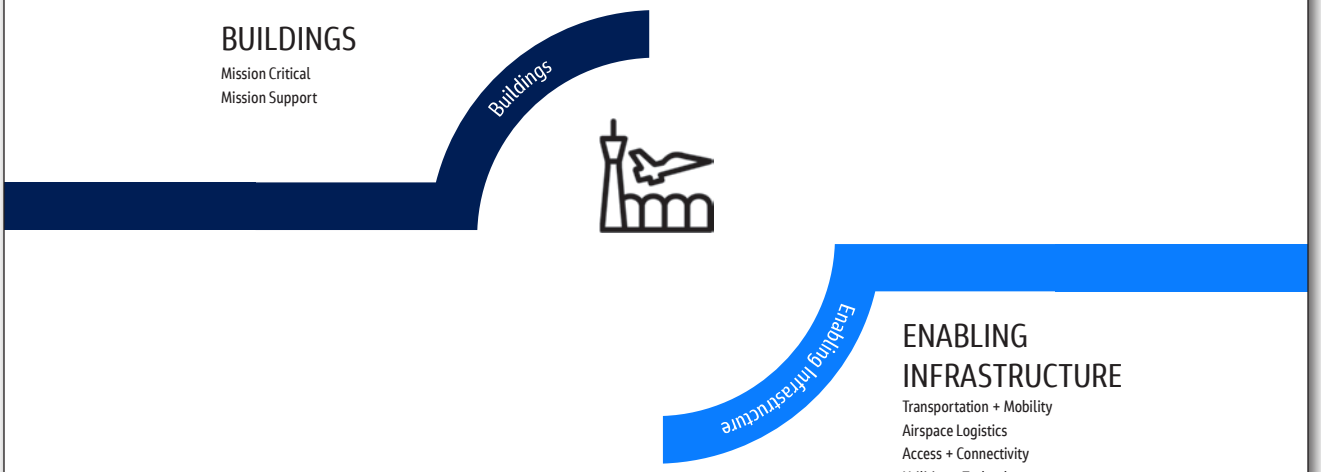
~14'
Storm Surge

What. Components and Aspirations.

Components of an Installation of the Past

BUILDINGS

Mission Critical
Mission Support



ENABLING INFRASTRUCTURE

Transportation + Mobility
Airspace Logistics
Access + Connectivity
Utilities + Technology
Public Works

7

What. Components and Aspirations.

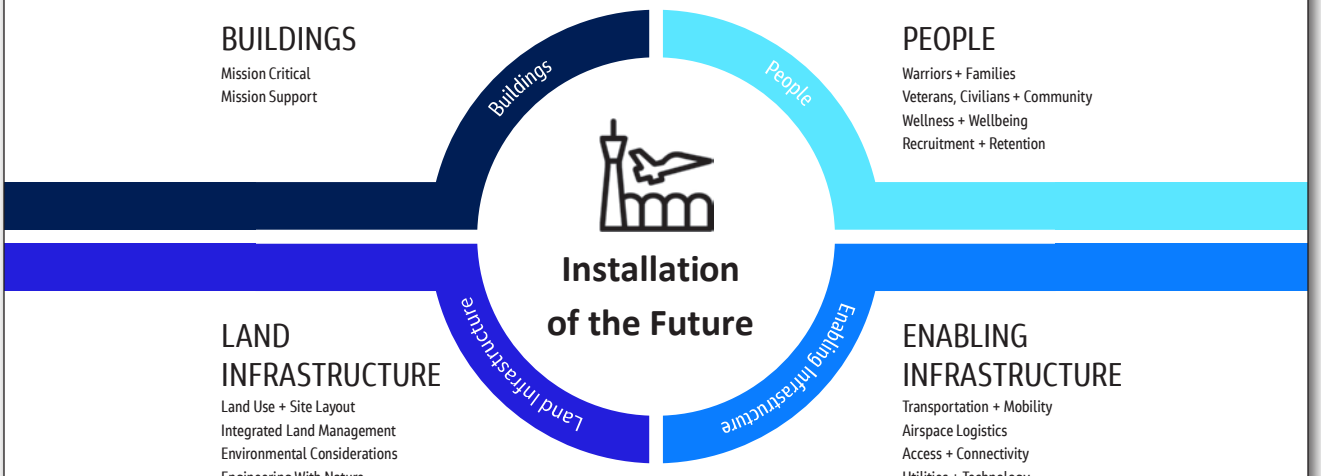
Components of an Installation of the Future

BUILDINGS

Mission Critical
Mission Support

PEOPLE

Warriors + Families
Veterans, Civilians + Community
Wellness + Wellbeing
Recruitment + Retention



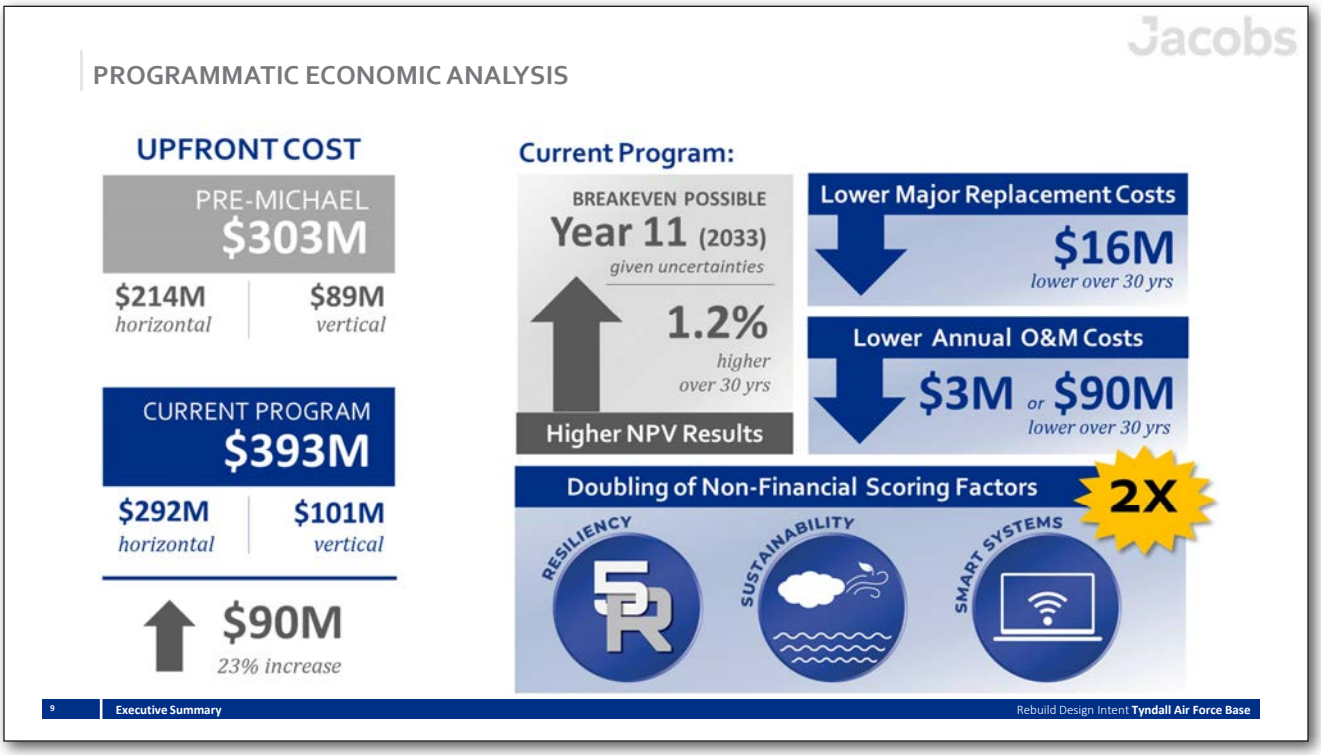
LAND INFRASTRUCTURE

Land Use + Site Layout
Integrated Land Management
Environmental Considerations
Engineering With Nature
Natural Capital

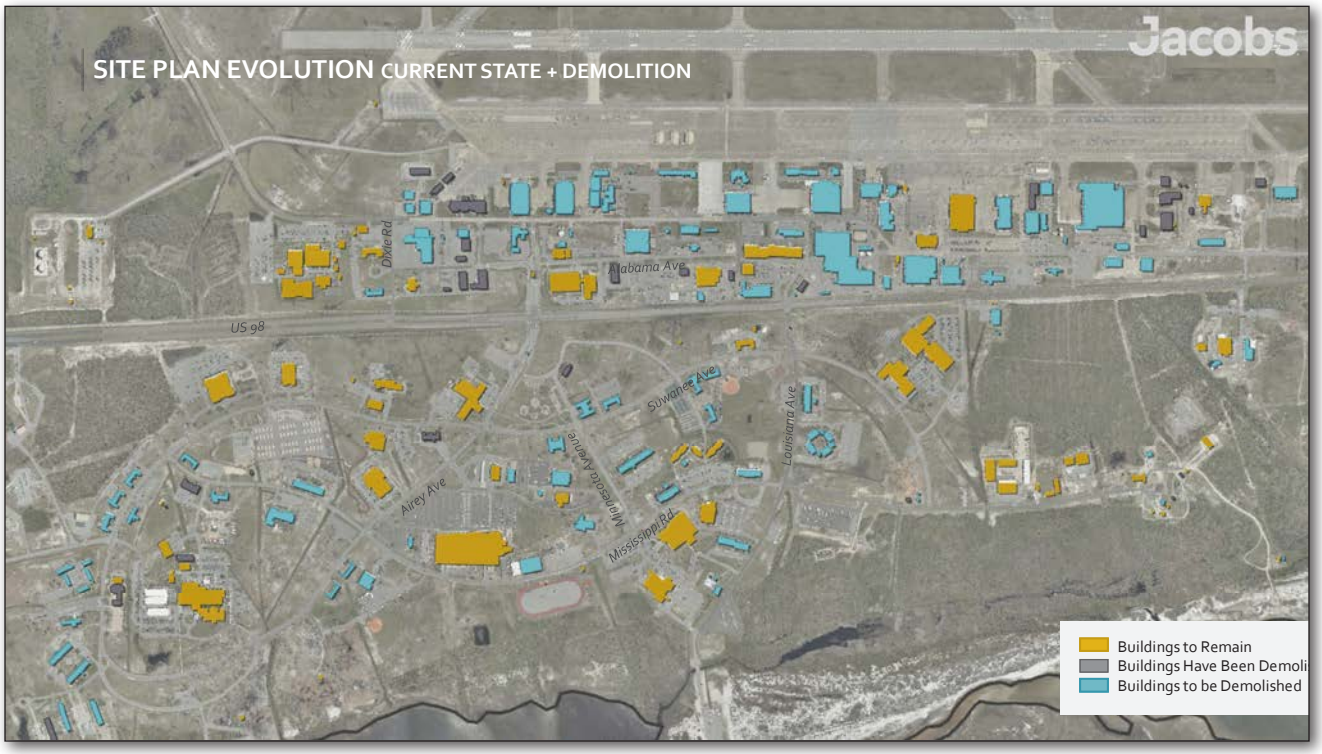
ENABLING INFRASTRUCTURE

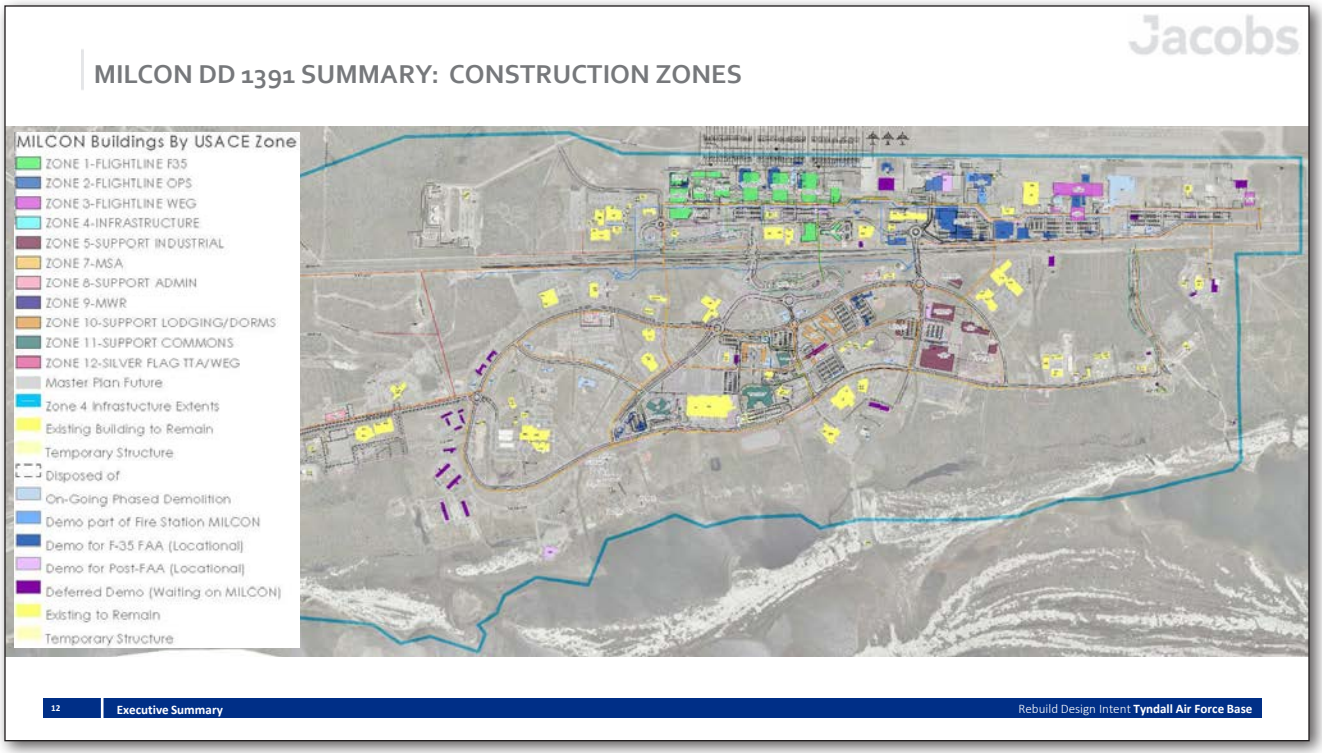
Transportation + Mobility
Airspace Logistics
Access + Connectivity
Utilities + Technology
Public Works

8


Jacobs
PROGRAMMATIC ECONOMIC ANALYSIS
UPFRONT COST
PRE-MICHAEL
$303M
$214M
horizontal
$89M
vertical
CURRENT PROGRAM
$393M
$292M
horizontal
$101M
vertical
$90M
23% increase
Current Program:
BREAKEVEN POSSIBLE
Year 11 (2033)
given uncertainties
1.2%
higher
over 30 yrs
Higher NPV Results
Lower Major Replacement Costs
$16M
lower over 30 yrs
Lower Annual O&M Costs
$3M or $90M
lower over 30 yrs
Doubling of Non-Financial Scoring Factors
2X
RESILIENCY
SUSTAINABILITY
SMART SYSTEMS
9
Executive Summary
Rebuild Design Intent Tyndall Air Force Base


Jacobs
REBUILD PROGRAM


Jacobs
SITE PLAN EVOLUTION CURRENT STATE + DEMOLITION
US 98
Dixie Rd
Alabama Ave
Suwanee Ave
Louisiana Ave
Airey Ave
Mississippi Rd
Buildings to Remain
Buildings Have Been Demoli
Buildings to be Demolished


Jacobs
MILCON DD 1391 SUMMARY: CONSTRUCTION ZONES
MILCON Buildings By USACE Zone
ZONE 1-FLIGHTLINE F35
ZONE 2-FLIGHTLINE OPS
ZONE 3-FLIGHTLINE WEG
ZONE 4-INFRASTRUCTURE
ZONE 5-SUPPORT INDUSTRIAL
ZONE 7-MSA
ZONE 8-SUPPORT ADMIN
ZONE 9-MWR
ZONE 10-SUPPORT LODGING/DORMS
ZONE 11-SUPPORT COMMONS
ZONE 12-SILVER FLAG TTA/WEG
Master Plan Future
Zone 4 Infrastucture Extents
Existing Building to Remain
Temporary Structure
Disposed of
On-Going Phased Demolition
Demo part of Fire Station MILCON
Demo for F-35 FAA (Locational)
Demo for Post-FAA (Locational)
Deferred Demo (Waiting on MILCON)
Existing to Remain
Temporary Structure
12
Executive Summary
Rebuild Design Intent Tyndall Air Force Base

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INSTALLATION FACILITIES STANDARDS: PERFORMANCE STANDARDS

Design Wind Speeds & Building Envelope Protection Memo

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, DC

MEMORANDUM FOR AFCEC/CL

FROM: HQ USAF/A4C
1260 Air Force Pentagon
Washington, DC 20330-1260

SUBJECT: Tyndall AFB Design Wind Speeds and Building Envelope Protection

Based upon our AF Structural SME recommendations and in alignment with the SecAF directed Severe Weather Readiness Assessment recommendations, the Tyndall PMO will use the draft 2019 UFC and the following Tyndall design wind speeds based upon Risk Categories III-V:

	RC I (mph)	RC II (mph)	RC III (mph)	RC IV (mph)	RC V (mph)
Tyndall Design Wind Speeds	Not Permitted	Not Permitted	165	170	203

DESIGN WIND SPEED
Risk Category III 165mph
Risk Category IV 170mph
Risk Category V 203mph

Design Flood Elevation (DFE) Memo

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, DC

05 June 2019

MEMORANDUM FOR AFCEC/CL (Mr. Terry G. Edwards)

FROM: HQ USAF/A4C
1260 Air Force Pentagon
Washington, DC 20330-1260

SUBJECT: Tyndall AFB Design Flood Elevation (DFE)

Design Flood Elevation is defined as the minimum elevation to design assets considering not just the Base Flood Elevation (BFE), but other factors such as historic storm surge data, sea level change, regulatory mandates, state or local requirements, building code requirements, and an asset owner's risk tolerance. This memorandum established two DFE values for the Tyndall AFB design effort:

a. For the Gulf side (generally southwesterly of Highway 98) the DFE is 19' above today's mean sea-level (MSL); and

b. For the East Bay side, generally northeasterly of Highway 98, the DFE is 14' above MSL.

MINIMUM
DESIGN FLOOD ELEVATION
19' Support District (S of HW 98)
14' Flightline District (N of HW 98)

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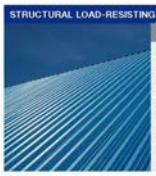
INSTALLATION FACILITIES STANDARDS: PERFORMANCE STANDARDS

STRUCTURAL LOAD-RESISTING SYSTEMS AND RELATED ENVELOPE ELEMENTS



Performance Standard	Source
Apply the 2019 UFC 3-301-01 design wind speeds based on Risk Categories II-IV and apply additional design guidance on opening protection and exterior envelope materials by integrating best practices from the Florida Building Code High-Velocity Hurricane Zone.	Design Wind Speed and Building Envelope Protection Memorandum issued by HQ USAF/A4C (27 Aug 2019) Installation Facilities Standards Const. Zone 35% RTA RFP Packages
Exterior architectural envelope elements are impact-resistant and meet Miami-Dade County Product Approval Notice of Acceptance provisions to reduce risk of envelope failure and building loss.	
Exterior site furnishings and light poles are designed to withstand a 170 mph wind speed.	

ARCHITECTURAL SYSTEMS

Performance Standard	Source
Incorporate Tyndall AFB's new architecture, image, and character base-wide. Create a cohesive, complementary array of facilities that reflect an image consistent with the history and regional character of the base. Apply design elements that not only are decorative but functional, such as roof awnings, canopies, and overhangs that are proactively built into designs which provide protection from weather for three or more people at a time.	Installation Facilities Standards Const. Zone 35% RTA RFP Packages

NATURE BASED SOLUTIONS

REVEGETATION AND INTEGRATED LAND MANAGEMENT

Performance Standard	Source
Provide streetscape landscaping for reduction on heat island effect.	Installation Facilities Standards Landscape Master Plan DD Form 1391/RD Const. Zone 35% RTA RFP Packages
Revegetate common spaces and overall reduction on maintenance base-wide.	Installation Facilities Standards Landscape Master Plan DD Form 1391/RD Const. Zone 35% RTA RFP Packages
Install permeable paving in overflow parking spaces.	Installation Facilities Standards Landscape Master Plan DD Form 1391/RD Const. Zone 35% RTA RFP Packages
Install bioswales and drainage swales plantings to reduce curb, gutter, inlets, and piping.	Installation Facilities Standards Landscape Master Plan DD Form 1391/RD Const. Zone 35% RTA RFP Packages

COASTAL RESILIENCE

Performance Standard	Source
Construct nature-based coastal measures (dunes, beaches, sea marshes, maritime forest, shrub communities, and barrier island restoration) to protect shoreline integrity and minimize facility risks, where feasible and cost efficient.	Coastal Resiliency OTA Pilot Project Installation Facilities Standards Landscape Master Plan
Create opportunities for innovative hybrid solutions that integrate nature-based and engineered solutions, such as reconstructed wetlands, restored coastal areas, and aquatic ecosystems.	Coastal Resiliency OTA Pilot Project Installation Facilities Standards Landscape Master Plan
Establish a coastal resilience adaptive management plan that adjusts to sea level rise.	Coastal Resiliency OTA Pilot Project

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INSTALLATION FACILITIES STANDARDS

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IFS UPDATE

1. IFS REBUILD APPENDIX
2. IFS PARENT UPDATE
3. LANDSCAPE MASTER PLAN

1.

2.

3.

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NATURE BASED INFRASTRUCTURE (NBI)

NBI Myth Busting

MILCON will not pay for landscape, it will never get installed

Landscape is "nice to have" and should not be installed at sacrifice to the mission, it has no value

The base will not maintain NBI solutions

Nature Based Infrastructure costs more and requires more maintenance

Landscaped areas attract snakes, bears and mosquitoes

Landscaped areas are a security concern

Proposed solutions will restrict or constrain future development and pose a threat to mission

LANDSCAPE MASTER PLAN

Utilities

20

LANDSCAPE MASTER PLAN

Stormwater Management

LANDSCAPE MASTER PLAN

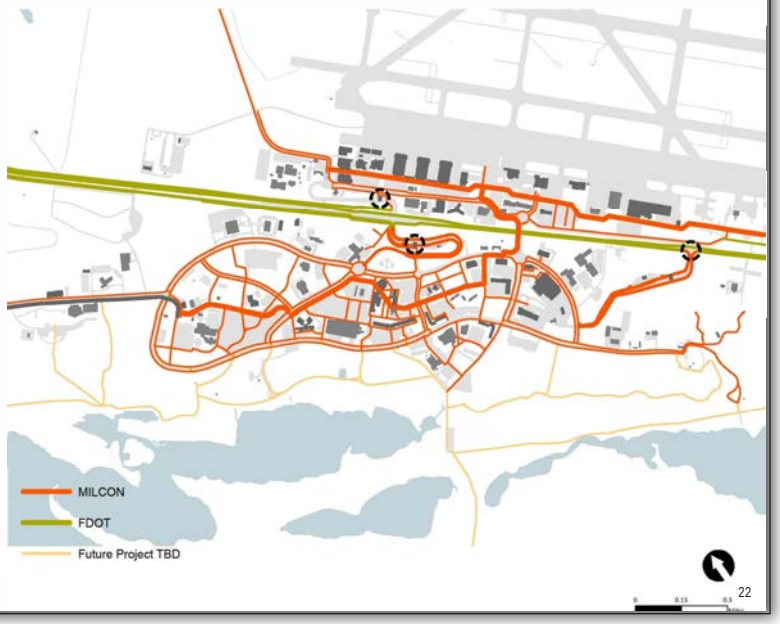
Integrated Mobility Framework

Prioritization and Implementation
The map on this page illustrates the mobility system considered part of the MILCON reconstruction, as well as long range mobility investments to position Tyndall as an installation of the future.

The renderings below show how the initial investment from MILCON can be enhanced in concert with mission growth and increased investment in alternative mobility options.

Multi-Modal Spine, Initial MILCON Phase

Multi-Modal Spine, Future Full Build-out



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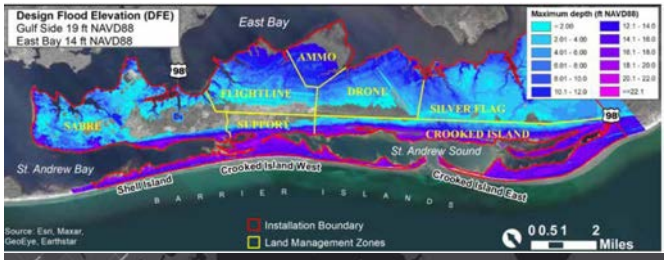
LANDSCAPE MASTER PLAN

Coastal Zone Site Furnishings

- Use interpretive signage to include educational and directional information, such as cultural & historical content, coastal & environmental conservation, wildlife habitat & dune restoration, installation of the future reconstruction.
- Minimize disturbance by limiting the use of lighting, using turtle friendly lighting, elevating boardwalk to allow wildlife, water and air pass through.
- Revegetated dunes help to reduce flood and erosion risk, provide wildlife habitat.

COASTAL RESILIENCE OTHER TRANSACTIONAL AUTHORITY (OTA)



Pilot 1: Constructed Defenses Construction Project – Gulf Side

- **Dune Construction.** Dune construction trial, located in Zone 4 along St. Andrew Bay just south of the support district, with onshore sand source.
- **Additional Measures.** The potential also exists to pilot the construction of either a living breakwater or oyster reef adjacent to Buck Beach in St. Andrew Sound to reduce coastal erosion. These alternatives would be subject to Air Force and regulatory approvals, further technical feasibility studies, stakeholder buy-in, and funding availability.

Pilot 2: Sand Trapping Construction Project – Gulf Side

- **Sand Fencing.** Trial sand fencing on relic dunes on Crooked Island West. This could be an ideal volunteer event.
- **Vegetation Planting.** Trial plantings on relic dunes on Crooked Island West. This could be an ideal stakeholder engagement event.
- **Woody Debris.** Trial woody debris placement on relic dunes on Crooked Island West.

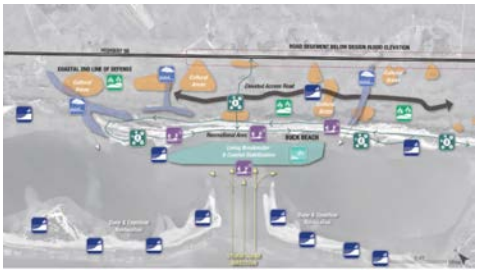
Pilot 3: Back Bay Feasibility Study – East Bay & Gulf Side

- Evaluation the strategic placement of subtidal sediments in the East Bay and sand placement off the Gulf Coast to enhance natural environments.

Pilot 4: Back Bay Feasibility Study – East Bay

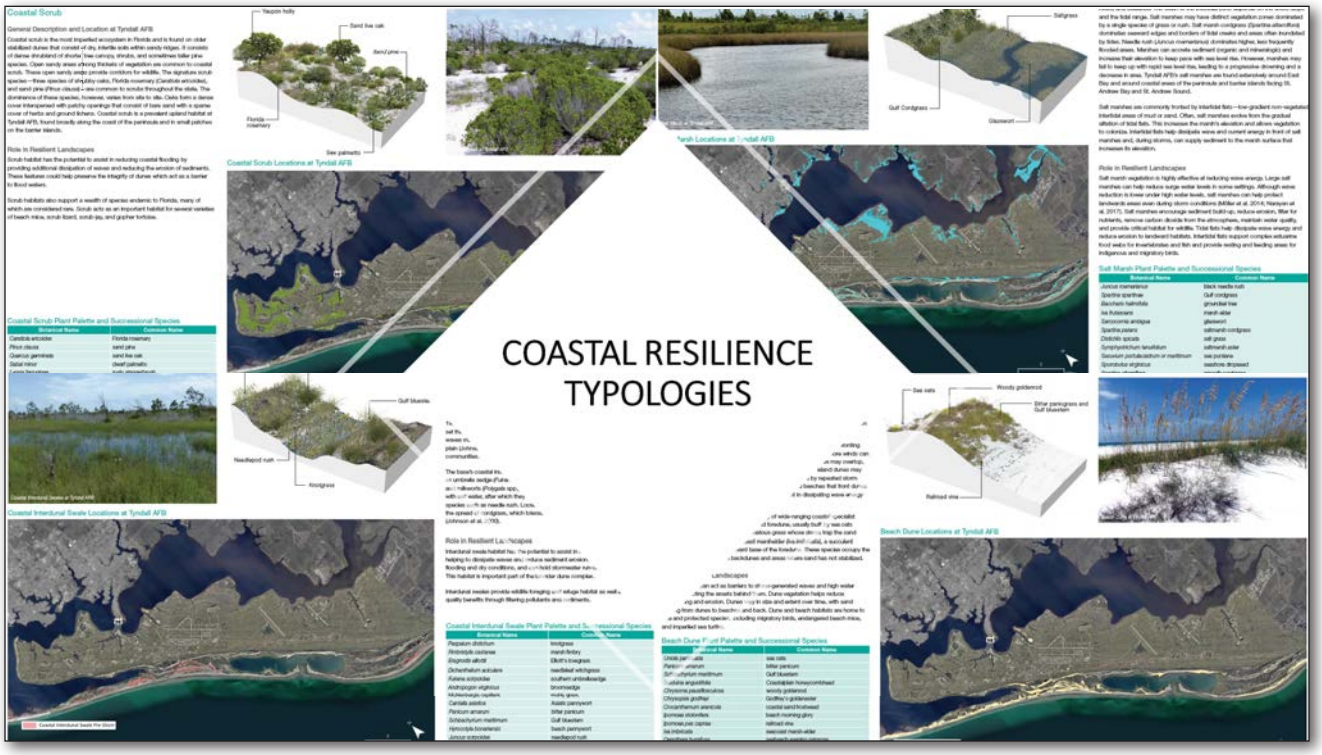
- Evaluation of marsh enhancement, horizontal levees and other potential nature based coastal defense strategies.
- **Additional Measures.** The potential also exists to pilot the construction of marsh enhancement and/or horizontal levees. These alternatives would be subject to USAF and regulatory approvals, further technical feasibility studies, stakeholder buy-in and funding availability.

COASTAL RESILIENCE OTHER TRANSACTIONAL AUTHORITY (OTA)



DEMONSTRATION AREAS

	Coastal Flood Risk Reduction	Revegetation/ Sustainable Landscape	Stormwater Management/ Wetland Mitigation	Wildlife Habitat Enhancement/ Ecosystem Restoration	Recreation (MWR)/ Education	Pedestrian & Commuter Mobility
Specific Actions	• Dune restoration • Revegetation/ marshland restoration • Coast line protection • Living shoreline	• Establish plantings on islands and first line of defense • Establish plantings in all open areas and barrier islands • Plant native species • Upland landscape and revegetation	• Capture small rain events locally versus base-wide • Provide larger base-wide retention/detention ponds • Regrade vulnerable areas • Naturalize channels	• Create wetlands and marshes • Create dunes • Preserve habitats	• Provide passive recreation areas via paths and boardwalks • Provide educational signs and markers • Provide observation areas • Provide activity areas such as volleyball nets and play structures	• Include bike lanes on roads • Provide direct point-to-point transportation network • Connect to multimodal facilities
Resulting Benefits	• Protects missions • Protects investments	• Complies with INRMP • Improves water absorption • Reduces impacts to storm surge • Increases biodiversity • Improves water quality • Creates and preserves habitats • Provides erosion protection • Reduces urban heat island effect • Creates shade and reduces energy	• Controls flooding • Filters pollutants • Reduces peak flow in stormwater system • Protects wetland habitat • Provides erosion protection • Reduces surge and loading on coastal areas • Complies with stormwater permit	• Protects coastal habitat • Protects upland habitat • Provides erosion protection	• Expands educational opportunities • Improves mental health • Improves physical health • Provides leisure opportunities	• Reduces "big infrastructure" needs • Provides nature-based tertiary pathways • Improves mental health • Improves physical health


COASTAL RESILIENCE
TYPOLOGIES


Jacobs
KNOWLEDGE, DESIGN &
TECHNOLOGY TRANSFER

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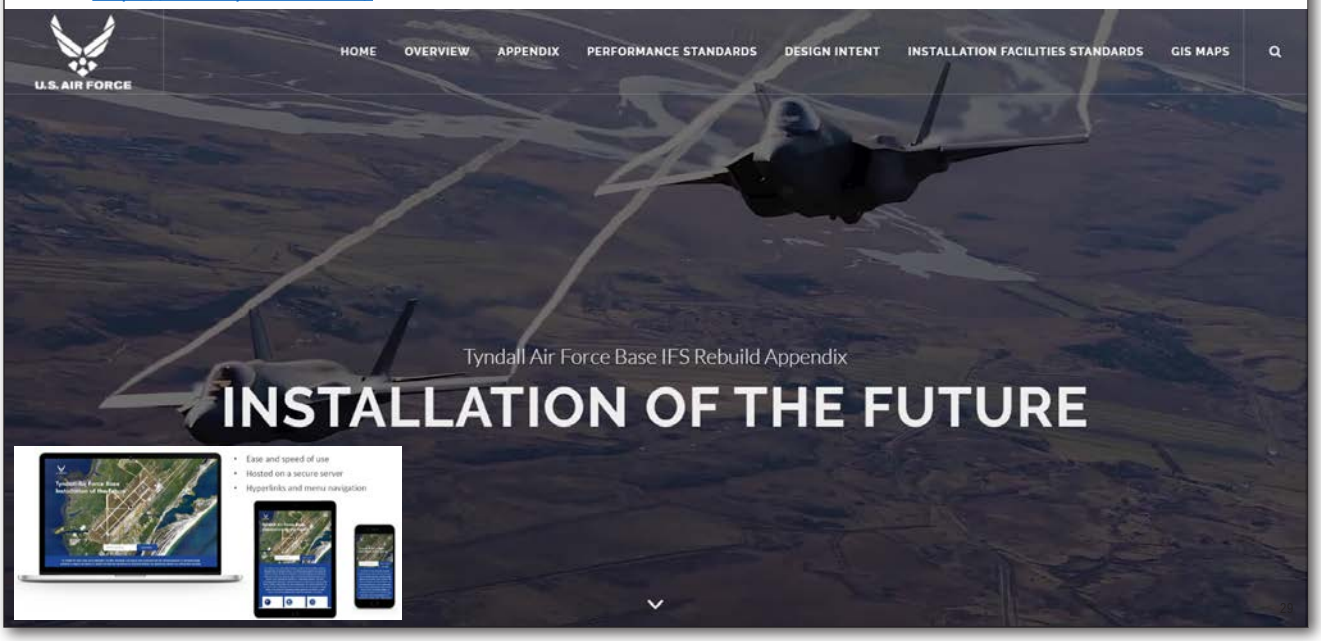
IFS UPDATE Rebuild Appendix Digital Delivery

https://www.tyndallifs.com/



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TYNDALL Design Guidance

https://www.tyndallifs.com/

A04. Authority

The Landscape Master Plan aligns with the U.S. Department of Defense's Unified Facilities Criteria (UFC) program, which streamlines the system-wide planning, design, construction, sustainment, restoration, and modernization criteria across all military and defense agencies. The plan's guidelines also follow the Air Force Corporate Facilities Standards (AFCFS), an enterprise-wide facility program for quality and performance standards.

The Landscape Master Plan guidelines were developed during the post-Hurricane Michael update of the Tyndall AFB *Installation Facilities Standards* (IFS), the local-level facilities guide. The IFS is a comprehensive, base-specific tool that replaces, consolidates, and simplifies existing facilities standards documents, such as the Architectural Compatibility Plan, and organizes information using the same structure, or Table of Contents, as presented on the AFCFS website. The IFS is a component of the base's overall Installation Development Plan (IDP). The updated IFS addresses other important design and construction standards that directly impact Tyndall AFB, including design flood elevation and wind load requirements.

This document is intended for use by the designers/contractors working on Tyndall AFB, as well as the base staff guiding and reviewing their work. All designers/contractors have a responsibility to be familiar and compliant with the overarching UFC and AFCFS requirements while designing to the local IFS and IDP requirements for the Installation of the Future.

In addition to the design details in the Landscape Master Plan, designers/contractors must follow the "Tyndall AFB Design Wind Speeds and Building Envelope Protection" memorandum (HQ USAF/A4C, 27 Aug 2019) and the "Tyndall AFB Design Flood Elevation (DFE)" memorandum (HQ USAF/A4C, 05 June 2019).

Exhibit A-2. Air Force Facilities Guidance Hierarchy

A05. How to Use This Document

Tyndall AFB has a clear vision of its future as a premier resilient, sustainable, and smart installation. This vision includes the ability to withstand disruptions and bounce back quickly to ensure mission continuity and success. It also strives toward sustainability, both in terms of lowering costs and preserving the environment. It must also be smart, deploying advanced technology.

Realizing these visionary goals requires holistic planning that weaves location and spatial analytics into the planning process so Air Force and Tyndall AFB leaders have the required information to make more informed decisions and allow these tools to live on to help consultant firms as they come on board to construct improvements.

This Landscape Master Plan supplements the IFS and should be used as a companion resource for additional detail in the implementation of the required base facilities criteria. This plan includes three additional sections, each organized to provide the appropriate level and scale of guidance, as follows.

Section B – Landscape Master Plan Framework. Based on Tyndall AFB's overarching vision and goals, Section B describes the key base-wide planning methodologies and guidance to achieve this plan's comprehensive vision for the base. Section B introduces specific elements of the framework and presents them graphically. Those elements are further detailed in Section C.

Section C – Site Development Criteria. Building on the planning framework, this section provides supplemental guidance regarding site development design criteria and coordination that is specific to the intent of this plan. The organization of this section is consistent with the IFS and provides the user with details on background for approach, context, priorities, typologies, and elements for the subject areas. The nine site development sections include user-friendly criteria worksheets to use in design development.

1. Site Design
2. Utilities
3. Parking Areas
4. Stormwater Management
5. Sidewalk, Pathways & Trails
6. Landscape
7. Site Furnishings
8. Pedestrian Signage
9. Lighting

Section C provides worksheets for each of the nine site development areas for designers/contractors to review and use prior to completing the Compliance Checklist for submittal. The worksheets describe and illustrate the various typologies to be used in the site designs and include specific applicable criteria. Designers/contractors are encouraged to use the checkbox worksheets as a communication tool among their teams and with Tyndall AFB staff. The worksheets include supplemental site development criteria and do not represent all requirements. Each designer/contractor is expected to meet the general criteria listed in Section A06.

Section D – Long-Term Maintenance. To provide guidance for maintaining the intent of this plan after construction is complete, this section describes the required long-term maintenance practices for the hardscape and softscape zones and elements.

Compliance Checklist. A Compliance Checklist accompanies this Landscape Mater Plan to provide the designer/contractor and Tyndall AFB with a comprehensive tool to demonstrate compliance with the required criteria. The user-friendly Excel-based checklist enables designers/contractors to indicate compliance with general and specific criteria outlined in this plan, and for base personnel to acknowledge acceptance or concurrence. The Compliance Checklist, which is provided as an appendix to the IFS, is required to be completed for each project.

A06. General Criteria

The general criteria listed below represent overarching guidance that much be considered for each project on Tyndall AFB. In many instances, designers/contractors must coordinate with others to determine which requirements must be met for the individual project.

Yes	No		
☐	☐	GC 1.	Comply with Architectural Barriers Act (ABA) Standards, including updated provisions for outdoor developed areas.
☐	☐	GC 2.	Comply with antiterrorism requirements and standoff distances, as directed in UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*.
☐	☐	GC 3.	Comply with the detailed design requirements for road safety and traffic control specified in the Federal Highway Administration's *Manual on Uniform Traffic Control Devices* (MUTCD) and the Surface Deployment and Distribution Command, Transportation Engineering Agency's (SDDCTEA's) *Department of Defense Supplement to the National Manual on Uniform Traffic Control Devices for Streets and Highways*.
☐	☐	GC 4.	Comply with applicable UFC and Air Force Instructions (AFIs).
☐	☐	GC 5.	Comply with AFCFS requirements.
☐	☐	GC 6.	Comply with the Tyndall AFB IFS.
☐	☐	GC 7.	Coordinate with Tyndall AFB 325th Civil Engineer Squadron for specific requirements of the U.S. Fish and Wildlife Service, Bird/Wildlife Aircraft Strike Hazard (BASH) Team, environmental regulations, and maintenance guidelines.
☐	☐	GC 8.	Coordinate with Tyndall AFB Security Forces.
☐	☐	GC 9.	Comply with required state and local codes and ordinances.
☐	☐	GC 10.	Comply with the specific requirements outlined in Sections B and C of the Tyndall AFB Landscape Master Plan.

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COASTAL RESILIENCE OTHER TRANSACTIONAL AUTHORITY (OTA)

STAKEHOLDER ENGAGEMENT

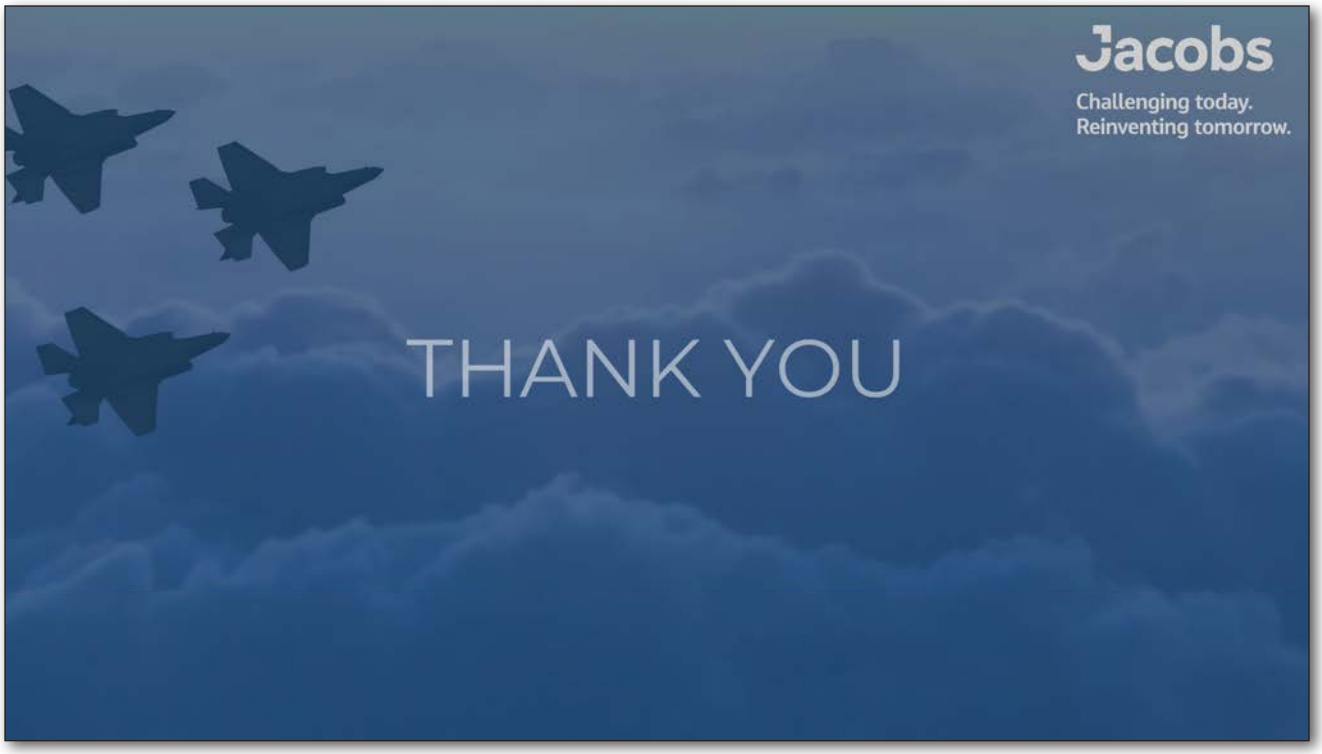
STAKEHOLDER ENGAGEMENT MEETINGS

- 3 virtual meetings
- 30 organizations represented
- 130 participants
- 10+ regional programs with synergies
- 10+ potential grant programs

ONE COMMON THEME - CONTINUE TO PURSUE PILOTS AND FUNDING

http://tyndallcoastalresilience.com/

Friends of SHELL ISLAND · UF UNIVERSITY of FLORIDA · UNIVERSITY OF GEORGIA Institute for Resilient Infrastructure Systems · BAY COUNTY Florida · NOAA · ERDC



Day 1 Presentations

Randy English: MCAS Yuma Intro Slides

Marine Corps Air Station Yuma

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Assistant Secretary of the Navy (Energy, Installations & Environment) 1

Installation Overview

- **Area of Responsibility : 1.2 Million Acres**
  - MCAS Yuma
  - Cannon Air Defense Complex *(CADC)*
  - *Barry M. Goldwater Range – West (BMGR-W)*
  - *Chocolate Mountain Aerial Gunnery Range (CMAGR)*
- **Major Sites**
  - MCAS Yuma
    - 1,717 Facilities *(PRV $3.8B)*
    - 4 Runways / 5 VTOL Pads
    - 859 On-Base PPV Single/Multi Family residences
    - 128 Off Base PPV Apartments
  - Camp Billy Machen *(R-2507) (8 buildings 2 heli-pads)*
  - CADC *(3 Tenant commands ~1000 Marines within the R-2301)*
  - BMGR-W & CMAGR
- **Outlying Airfields**
  - AUX II *(BMGR-W)*
  - KNOZ *(BMGR-W)*
  - CADC UAV Strip
- **Shared Airfield w/Yuma Airport**
  - MCAS Yuma
    - Provides Fire/Crash/Rescue services
    - Maintains Runways, Taxiways, and Airfield lighting
    - Provides Air Traffic Control services
    - Maintains Airfield Security

AOR: 1,802 sq miles – All USMC installations fit within the boundary of MCAS Yuma

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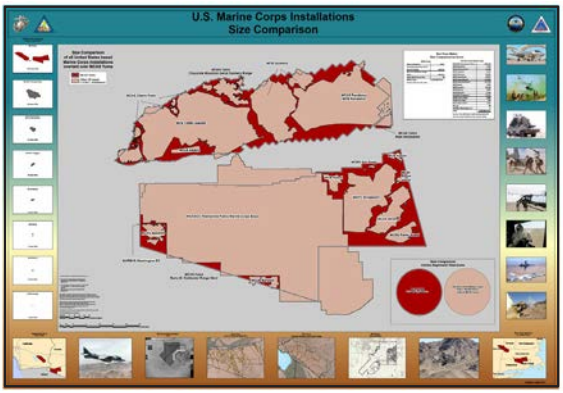
Assistant Secretary of the Navy (Energy, Installations & Environment) 2

"Unique" MCAS Yuma

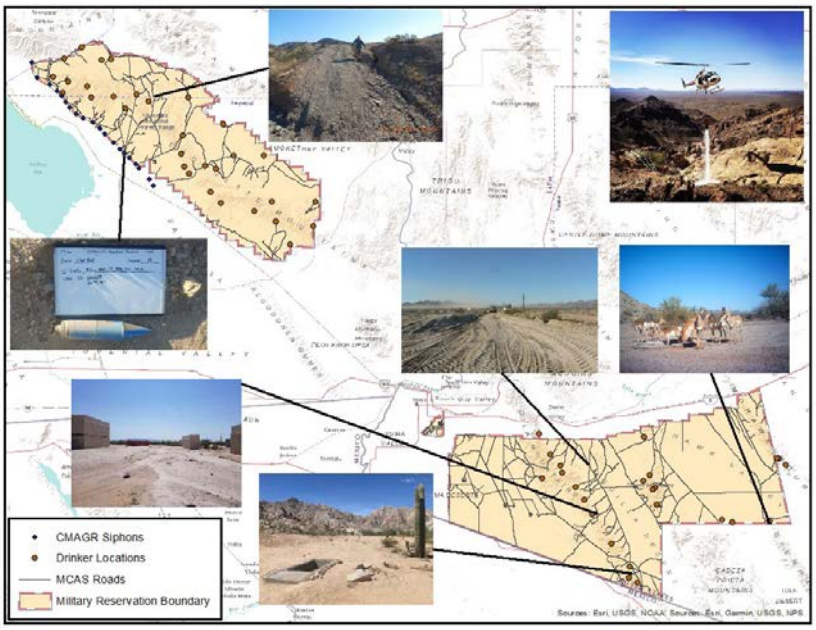
- Marine Corps' Premier Aviation Training Facility
- Third largest range complex in CONUS
  - MCAS Yuma maintains 60% of USMC owned range space
- Busiest USMC Air Facility *(173,840 Operations – CY 2020)*
- Fourth busiest Naval Air Facility *(NAS Meridian, NOLF Imperial Beach, NAS Kingsville, MCAS Yuma)*



Top Line Natural Hazard Challenges and Potential Natural Infrastructure Opportunities Associated with the Installation

- Restoring CMAGR/BMGR-W road topography to natural conditions that facilitate natural water flow supporting vegetation communities and providing resilience against higher intensity flooding events associated with climate change.
- Increasing number and capacity of wildlife water sources and forage plots to reduce water hauling operations by state wildlife agencies and volunteer groups.
- Mitigating the clean-up costs and potential hazards resulting from UXO dispersal as a result of less frequent, but more intense precipitation events due to climate change.
- Desert topography impacted by border barrier installation with minimal erosion control implementation

Locations on Installation where Risks from Natural Hazards are Greatest



Locations on Installation where Risks from Natural Hazards are Greatest

Previous Interventions that have been Proposed to Mitigate Natural Hazards

- Removing barriers created through road maintenance to restore streamflow.
- Utilizing physical barriers to curtail disturbance and allow natural recovery.
- Increasing storage capacity of existing wildlife waters and expanding distribution of wildlife water availability.
- Utilizing contract support for UXO cleanup along siphons.





Existing environmental concerns/challenges (T&E species, contaminants, water quality)

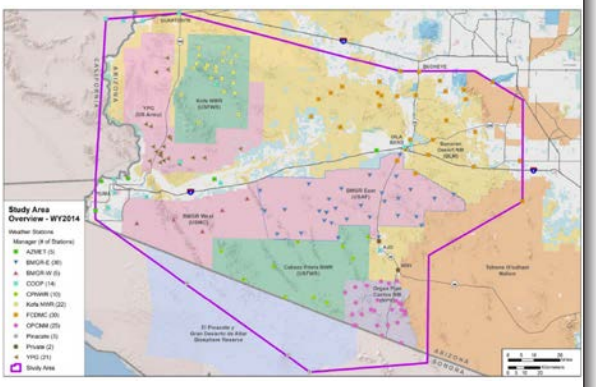
- 1.2M acres, of which only 18% surveyed for cultural resources.
- 1,063 miles of approved roads.
- One endangered species (Sonoran pronghorn), one threatened species (Mojave desert tortoise), and **two** species managed under a Candidate Conservation Agreement: flat-tailed horned lizard (FTHL) and Sonoran desert tortoise.
  - 219,115 acres of protected Sonoran pronghorn habitat
  - 187,842 acres of Mojave desert tortoise critical habitat
  - 114,800 acres of the Yuma Desert Management Area for FTHL
- Average annual precipitation of 3.5”.
- On-going road maintenance and interdiction activities by U.S. Customs and Border Protection on a regular basis.
  - Uncalculated disturbance.

Current 'nature-based' amenities on the installation that benefit soldiers, families, and civilian workforce

- Martinez Lake Recreational Site which includes housing, RV spots, boat/jet ski rentals, boat launches, and fishing pier (1 hr drive from main station).
- Multiple recreational parks in base housing, walking trails, children's playgrounds, picnic areas, and multi-use sports field.
- 75% of the BMGR-W open to recreational access with permit.
  - 26K active user accounts in permitting system.
  - Visitors to the BMGR-W typically seek a more rustic experience as opposed to a park-like experience with improved trails, bathrooms, picnic areas, etc.

Existing and relevant data sources that could help inform study

- Plans: BMGR/CMAGR Integrated Natural Resources Management Plans, Integrated Wildland Fire Management Plans, Integrated Cultural Resources Management Plans.
- GIS: 30cm Satellite Imagery Data, Vegetative Mapping Data, special status species layers, soil mapping (just starting w/ USDA).
- Regional weather station data.
- Camino Del Diablo Restoration Study funded by Cabeza Prieta NWR.



Key partners that would be interested in the NI study

- **State and Federal Agencies (Arizona and California):** Arizona Game and Fish Department, California Fish and Wildlife Department, U.S. Fish and Wildlife Service, Bureau of Reclamation, Bureau of Land Management, Department of Homeland Security, National Park Service, and U.S. Geological Service, U.S. Customs and Border Protection.
- **Non-Government Organizations:** Friends of the Sonoran Desert, Desert Wildlife Unlimited, Yuma Valley Rod and Gun Club, Safari Club International, Desert Bighorn Sheep Society, Friends of the Desert Mountains, Yuma Conservation Garden, Sonoran Institute, and the Cabeza Prieta Natural History Association.
- **Tribal Nations:** Cocopah Indian Tribe, Quechan Indian Tribe, Agua Caliente Band of Cahuilla Indians, Ak-Chin Indian Nation, Colorado River Indian Tribes, Fort Mojave Indian Tribe, Gila River Indian Community, Thohono O'Odham Nation, Torress Martinez Desert Cahuilla Indian.

Any Additional Information to Share

- BMGR-W, in conjunction with neighboring lands (BMGR-E, Cabeza Prieta, Organ Pipe Cactus National Monument, and associated BLM lands) represent the largest tract of relatively unfragmented Sonoran desert habitat left in existence.
- Over the last 20 years, the CMAGR has produced the highest Mojave desert tortoise densities per square kilometer. Densities calculated via annual Line Distance Sampling.
- MCAS Yuma leases 1,392 acres of agricultural land adjacent to the installation for Bird Air Strike Hazard (BASH) mitigation and generation of additional revenue streams to support conservation efforts on the CMAGR/BMGR-W.
- Only USMC F-35 Fleet Carrier Landing Practice (FCLP) facility on West Coast.

Jon Kersey: Naval Air Weapons Station China Lake, California

Naval Air Weapons Station China Lake, California

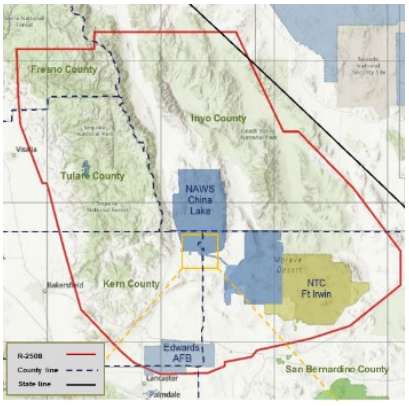
Assistant Secretary of the Navy (Energy, Installations & Environment)

Jacobs

1

Installation Overview

- NAWS China Lake supports the Naval Air Warfare Center Weapons Division's state-of-the-art and one-of-a-kind laboratories and facilities that deliver irreplaceable weapons development for the Department of the Navy.
- Airspace R-2508 – 20,000 square miles
- NAWSCL ranges extend over 1.3 million acres, majority within the Mojave Desert ecoregion.



Assistant Secretary of the Navy (Energy, Installations & Environment)

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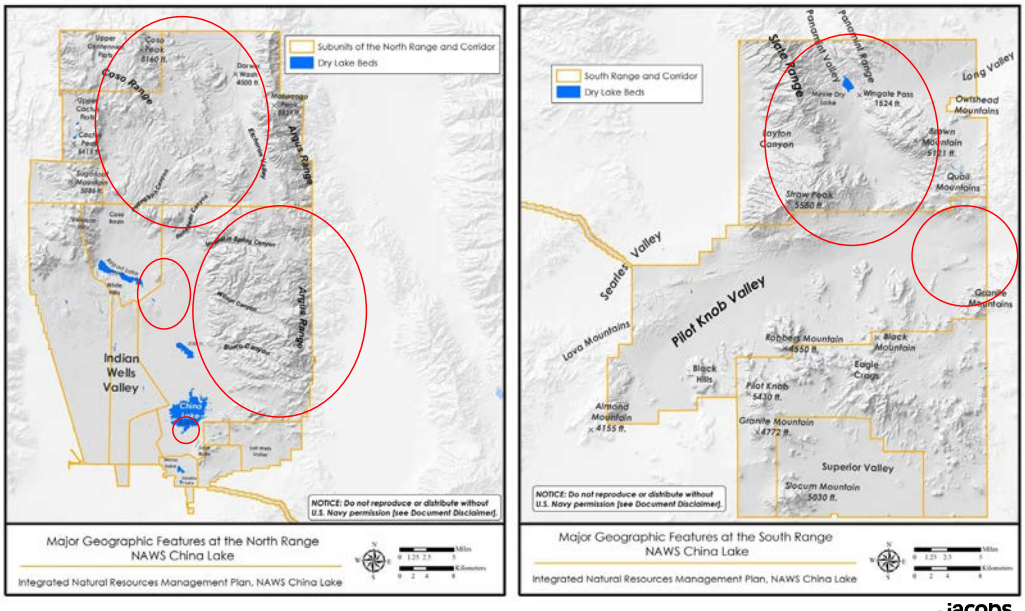
"Uniqueness" of NAWSCL

- The installation is **the Navy's largest single landholding**, representing 85 percent of the Navy's land for RDAT&E use and 38 percent of the Navy's land holdings worldwide (larger than Rhode Island).
- Makes up 12% of CA Airspace
- Within Mojave Desert (three sub regions the northern; central and western Mojave) and extends in the north into the Great Basin Desert (colder, higher proportion of precip as snow)

Locations on Installation where Risk(s) from Natural Hazards is/are Greatest.



Top Line Natural Hazard Challenges and Potential Natural Infrastructure Opportunities Associated with the Installation

- Over-draft Aquifer (Sole Source of Water)
  - Increased wind borne dust impacts air quality and visibility.
  - Dune formation in ranges.
  - Ground subsidence affects infrastructure and test facilities.
- Increased Fire Risk/Invasive species spread cycle
- Increased Temperatures/# of days above 115/120
- Increased Drought (fire hazard contributor)
- Increased weather intensity (wind/dust storms, lightning storms, flash floods, etc.)
- Earthquakes

Locations on Installation Where Risk(s) from Natural Hazards is/are Greatest.

(Bulleted List of Natural Hazards and Some Details Included on this Slide)

- Desert Tortoise/Joshua tree habitat areas (valleys/floors, 700,000 + acres on ranges)
- Mountain ranges (Inyo Towhee in Argus Range; pine/pinyon juniper, oak species)
- Natural and fed seeps on the North Range valley floor (tui chub presence)
- Washes/streams/springs (high biodiversity)

Previous Interventions (if any) that have been Proposed to Mitigate Natural Hazards

- 1. Vegetation mapping to assess fire risk (in progress)
- 2. Implement fire/fuel management (nascent)
- 3. Water conservation
  - Infrastructure
  - streams/springs
- 4. Raven Management Plan
- 5. REPI Projects
- 6. Installation Resilience Study (in Progress)

Existing environmental concerns/challenges (e.g., T&E species, contaminants, water quality, etc.)

- Three federally listed species (desert tortoise, inyo CA towee, mohave tui chub)
- Increased wildfires
- Tectonic activity that could affect aquifer
- Declining water quality (Over 50% brackish water)

'Nature-based' Amenities present

- Golf Course
- Desert playa for wind racing
- Military Housing - trails, playgrounds, etc.
- B Mountain hiking
- Limited Petroglyph Tours

Existing and relevant data sources that could help inform study

- Integrated Natural Resources Management Plan
- Comprehensive Land Use Management Plan
- IWVGA Groundwater Sustainability Plan
- Earthquake Recovery (OICC)
- Cultural Resources Management Plan
- Indian Wells Valley Ground Water Management Plan
- Ongoing Listed species management plans

Key partners that would be interested in the NI study

- The Nature Conservancy (TNC)
- Trust for Public Lands (TPL)
- Bureau of Land Management
- National Park Service (Joshua Tree NP)
- National Forest Service
- Kern, Inyo, San Bernardino Counties
- City of Ridgecrest
- Indian Wells Valley Groundwater Authority (IWVGA)
- Desert Advisory Council
- Fellow Desert installations (29 Palms, Ft Irwin, EAFB)
- California Department of Fish and Wildlife
- Tribes

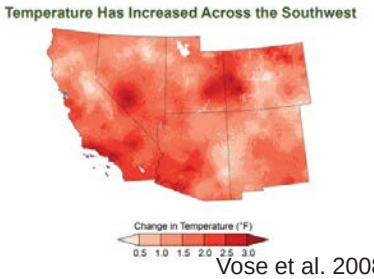
Any Additional Information to Share

- NAWSCL grazed via BLM leases for decades with cessation in 2000 and termination in 2004 due to incompatible land use.
- NAWSCL has wild horse and burros, of which the horse herd is protected
  - Centennial management area within China Lake
  - Burros called for removal in 1983
  - Populations above established herd levels
  - Annual issues with roundup/management/range

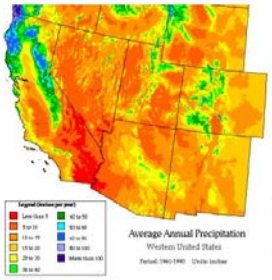
Captain Troy M. Searcy: Marine Air Ground Force Training Command Marine Corps Air Ground Combat Center

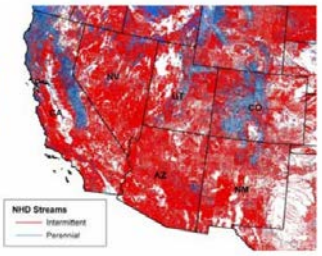
Climate

1. Arid - ca. 100mm ppt/y
   - Recovery time - long
2. Change in SW - Warming
   - Aridification, soils, ecosystem
3. Rain: Winter > Summer (sporadic)
4. Streams in SW
   - MCAGCC ephemeral v. intermittent



Vose et al. 2008





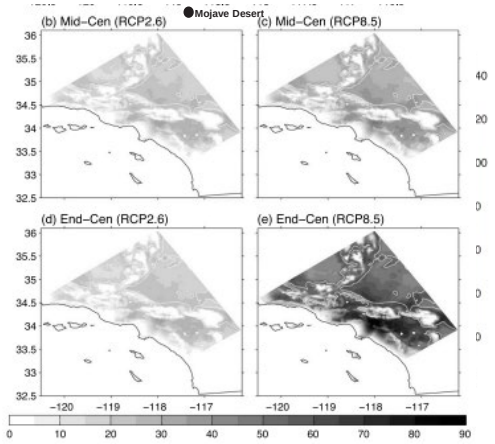
Levic et al. 2008

Ecosystems

1. Arid - inherently variable, time & space
2. Riparian
   A. Ephemeral or Intermittent Stream
   B. Ecological Functions
      i. Landscape and hydrological connections, energy dissipation, sediment mobilization, storage, transport, and deposition, nutrient cycling, floral and faunal communities
3. Training mission
   - Topography, transit, cover, staging, facilities

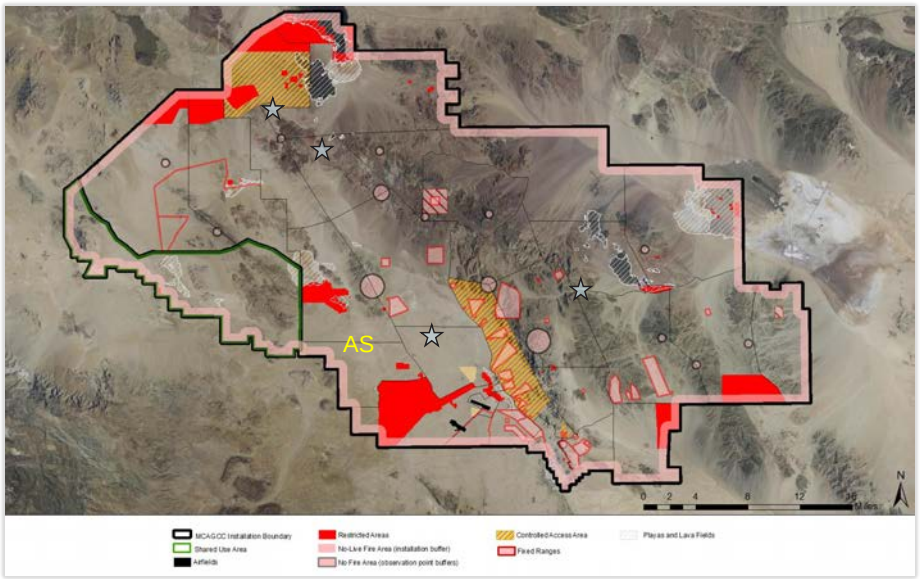
Top Line Natural Hazard Challenges and Potential Natural Infrastructure Opportunities

1. Heat & extreme heat
2. Drought
3. Wind & dust storms
4. Flashfloods
5. Rare
   A. Earthquakes
   B. Wildfires



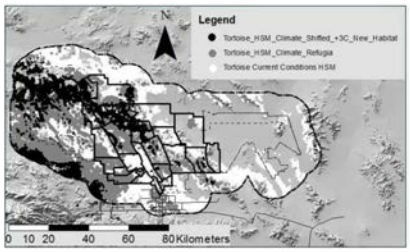
Hall et al. 2015

Locations on Installation where Risk(s) from Natural Hazards is (are) Greatest.



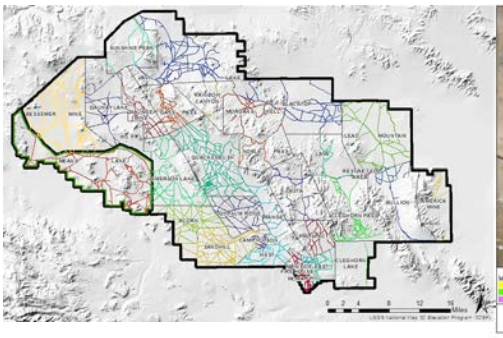
Interventions (if any) that have been Proposed to Mitigate Natural Hazards

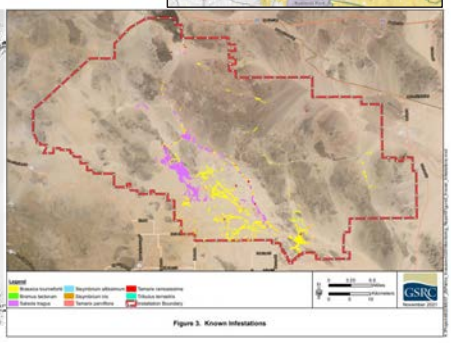
1. SDM & climate refugia modeling
2. Mapping
   - Vegetation, canyon and washes
3. Habitat restoration
   - TES, invasive spp., riparian corridors
4. Stabilize soil, vegetation & trophic levels (e.g., cryptogams)
   - Carbon Sequestration
   - Air quality
   - Landscape function
5. Synergy



Existing environmental concerns/challenges (e.g., T&E species, contaminants, water quality, etc.)

1. Desert tortoise: ESA, RASP
2. Habitat & ecosystem degradation
3. Soil erosion and compaction
4. Air quality





Current 'nature-based' amenities on the installation that benefit soldiers, families, and civilian workforce.

1. Training – Limits amenities to cantonment
2. Walking trails at Mainside (cantonment)
3. Small parks and picnic areas
4. Ball fields, golf course, OHV park

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Jacobs

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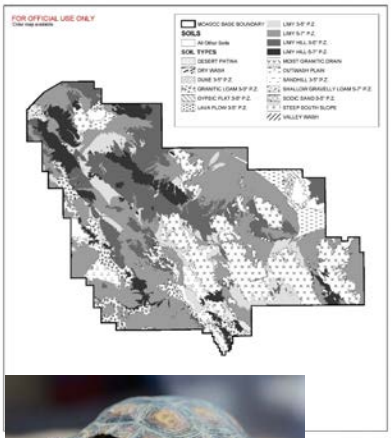
Existing and relevant data sources that could help inform study

1. In-progress, recurring
   A. Climate & disturbance modelling
   B. Canyon and wash inventory (on-going and future)
   C. Vegetation maps (updated ~ every 5 years)
   D. Non-native invasive plants
2. Existing - soil maps
3. Needed:
   A. Surface hydrology & flow maps
   B. Erosion maps



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Key partners that would be interested in the NI study

1. Government Organizations
   - A. Regulators – USFWS & CDFW
   - B. Neighbors and partners – BLM & NPS
   - C. DoD installations – MCAS Yuma, Marine Corps Logistics Base Barstow, Edwards Air Force Base, Fort Irwin National Training Center, Naval Air Weapons Station China Lake
   - D. Federally Recognized Tribes (11) – Agua Caliente Band of Cahuilla Indians, Augustine Band of Cahuilla Indians, Cabazon Band of Mission Indians, Cahuilla Band of Mission Indians of the Cahuilla, Reservation, Chemehuevi Indian Tribe, Colorado River Indian Tribes, Fort Mojave Indian Tribes, Morongo Band of Mission Indians, San Manuel Band of Mission Indians, Torres-Martinez Desert Cahuilla Indians, Twenty-Nine Palms Band of Mission Indians
2. Institutional cooperators (e.g., Universities of California, Florida, Toronto)
3. Non-profit organizations (e.g., Desert Tortoise Council, MD Land Trust)

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Sustain the Training Mission . . .







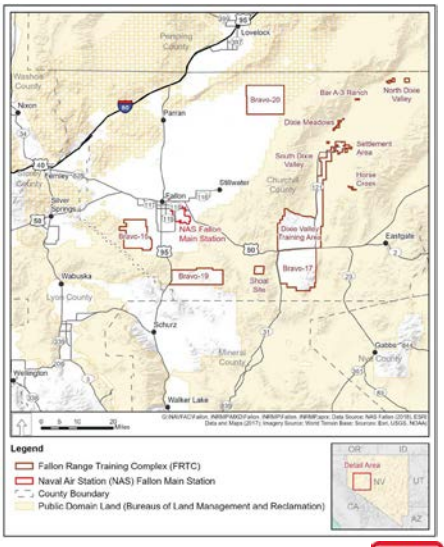

Assistant Secretary of the Navy (Energy, Installations & Environment) Jacobs 12

NAS Fallon and Fallon Range Training Complex (FRTC)

Background Information

NAS Fallon and Fallon Range Training Complex (FRTC)

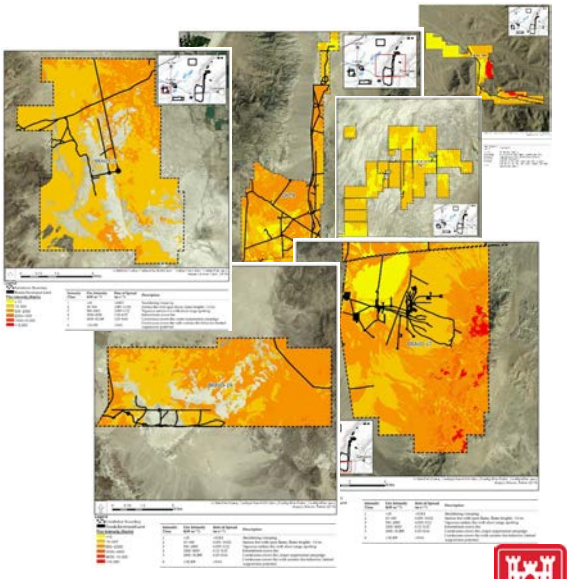
- Located in Northern Nevada ~ 240,000 acres of BLM withdrawn and Navy owned lands.
- Consists of both open and closed lands
- Navy's premier integrated strike warfare training facility
- NAS Fallon Mission: to provide the most realistic integrated air warfare training support available to carrier air wings, Marine air groups, tenant commands, and individual units participating in training events, including joint and multinational exercises, while remaining committed to its assigned personnel.



Top Line Natural Hazard Challenges and Potential Natural Infrastructure Opportunities Associated with the Installation

- 1. Wildland Fire Management on the FRTC
- 2. BASH concerns at NASF airfield
- 3. Storm water drainage improvement on main station
- 4. Water rights and wetland habitat improvement opportunities in Dixie Valley

Locations on Installation where Risk(s) from Natural Hazards is/are Greatest.



Locations on Installation Where Risk(s) from Natural Hazards is/are Greatest.

(Bulleted List of Natural Hazards and Some Details Included on this Slide)

- 1. Wildland Fire risk is greatest at B17
- 2. BASH risk is greatest around main station

Previous Interventions (if any) that have been Proposed to Mitigate Natural Hazards

- 1. Wildland fire management plan currently in development for FTRC ranges
- 2. USDA BASH biologist full time on site
- 3. Wildlife Hazard Management Plan identifies projects to reduce wildlife attraction to airfield

Existing environmental concerns/challenges
(e.g., T&E species, contaminants, water quality, etc.)

- 1. Currently no T&E species on installation
- 2. Bighorn sheep and Pinyon habitat protection a priority for wildland fire management on B17
- 3. NAS Fallon irrigation ditches included in Carson River Mercury Superfund site
- 4. Carp can be found in irrigation ditches; attracts flocks of Pelicans to agricultural fields around airfield, creates major BASH issues.

Current 'nature-based' amenities on the installation that benefit soldiers, families, and civilian workforce. Examples include: walking trails, picnic areas, kayak launch, fishing piers, etc.

- 1. Nature Trail on main station; open to public
- 2. Dixie Valley Training Area is open to public for outdoor recreation: hunting, fishing, camping, OHV.
- 3. Dixie Valley Settlement ponds stocked for fishing by NDOW- open to public.
- 4. Horse Creek parcel open to public for outdoor recreation and access point to Wilderness Study Area in the Clan Alpine Mountains

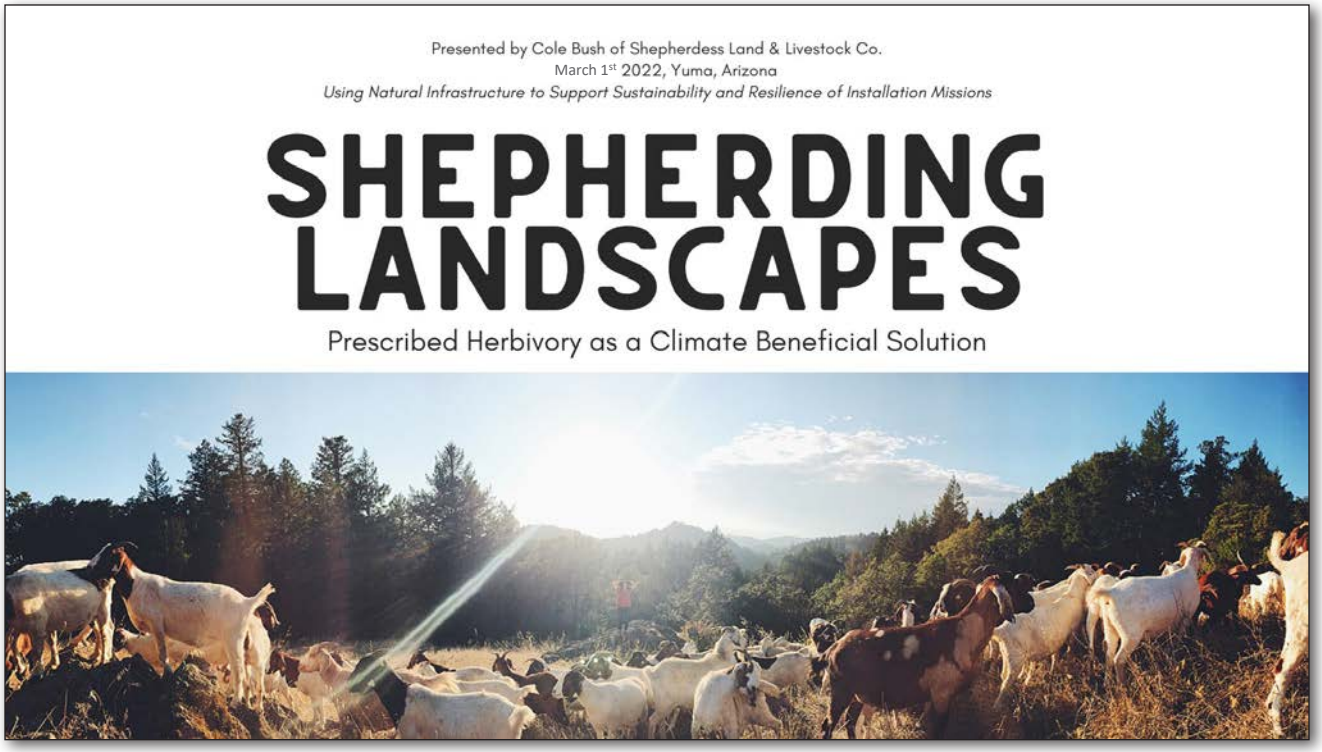
Existing and relevant data sources that could help inform study

- 1. Integrated Natural Resources Management Plan
- 2. Draft NAS Fallon Wildland Fire management Plan
- 3. BASH Plan and Wildlife Hazard Management Plan
- 4. Wildlife Hazard Assessment

Key partners that would be interested in the NI study

- 1. Sikes Act partners (USFWS, NDOW, BLM)
- 2. Tribes
- 3. NV Division of Conservation and Natural Resources
- 4. Churchill County

Cole Bush: Shepherding Landscapes



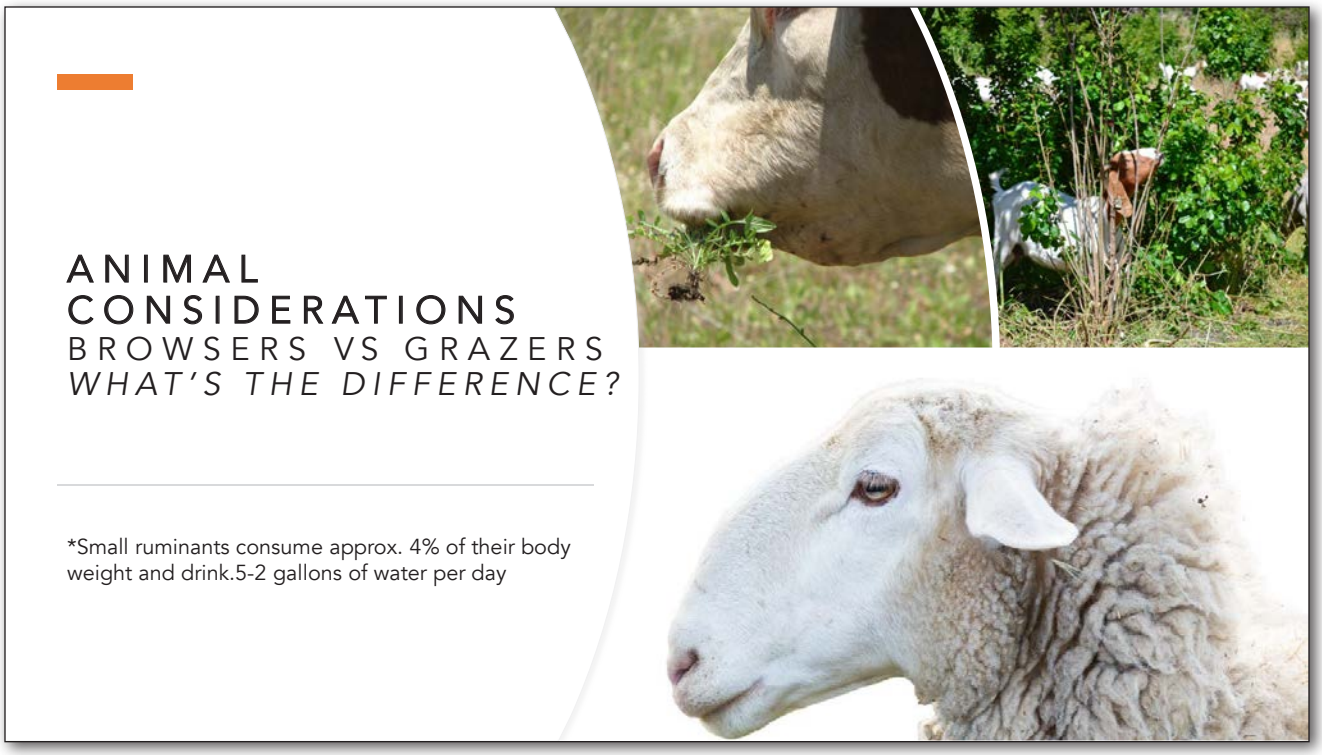
Prescribed Herbivory is the intentional use of domestic livestock to **remove, rearrange or convert vegetation** on wildlands and/or the WUI to **reduce the losses and costs associated with wildfires** and to **enhance the ecological condition** of forests, rangelands, and watersheds.

** Other names of this grazing approach include, targeted grazing, managed grazing, contract grazing, to name a few.*

Herbivores are essentially self replicating "biological masticators" that can turn biomass into lunch and then into soil organic matter

IMPACTS INCLUDE:

- *REDUCTION OR REMOVAL OF VEGETATION THROUGH GRAZING &/OR BROWSING*
- *ANIMAL IMPACT THROUGH TRAMPLING*
- *DUNGING & URINATING*
  --> FERTILIZING + BUILDING SOM


ANIMAL CONSIDERATIONS
BROWSERS VS GRAZERS
WHAT'S THE DIFFERENCE?
*Small ruminants consume approx. 4% of their body weight and drink.5-2 gallons of water per day

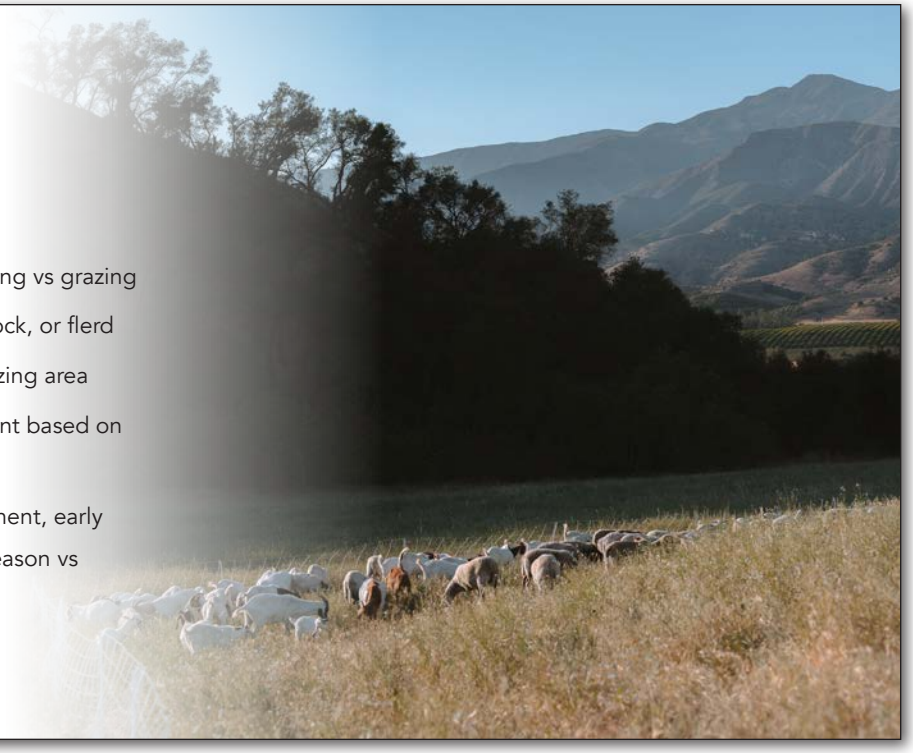

BENEFITS & CONSIDERATIONS
WHEN TO USE PRESCRIBED GRAZING
• Air Quality, when compared to the use of prescribed fire
• Noise, when compared to mechanical operations
• Steep Slopes, hard to access areas or presence of poisonous plants
• Soil Compaction and surface disturbance concerns

PRESCRIBED GRAZING
as a Climate Beneficial Solution
to enhance Ecological Resilience and Fire Safety

- **FIRE FUEL REDUCTION + DEFENSIBLE SPACE**
- **INVASIVE SPECIES MANAGEMENT**
- **HABITAT RESTORATION + BIODIVERSITY**
- **WATERSHED + MINERAL CYCLE FUNCTION**
- **ALTERNATIVE TO FOSSIL FUEL DEPENDENT MACHINERY & CHEMICAL TREATMENT**
- **BYPRODUCT-->FOOD + FIBER**

The GRAZING Rx
What are you treating?
Symptom or Systemic Cause

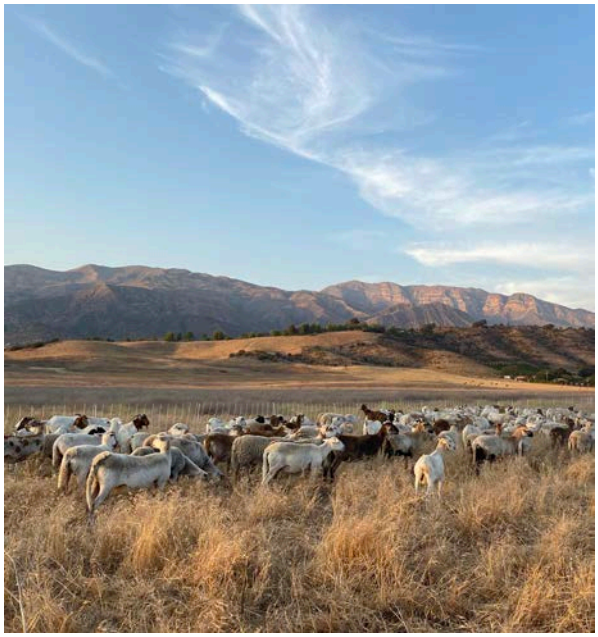
- **Species + Breed Selection**, browsing vs grazing
- **Number of animals** in the herd, flock, or flerd
- **Density**, # of animals in given grazing area
- **Duration**, how long is the treatment based on density and impact goals
- **Time of year**, seasonality of treatment, early season vs late season, growing season vs dormant season

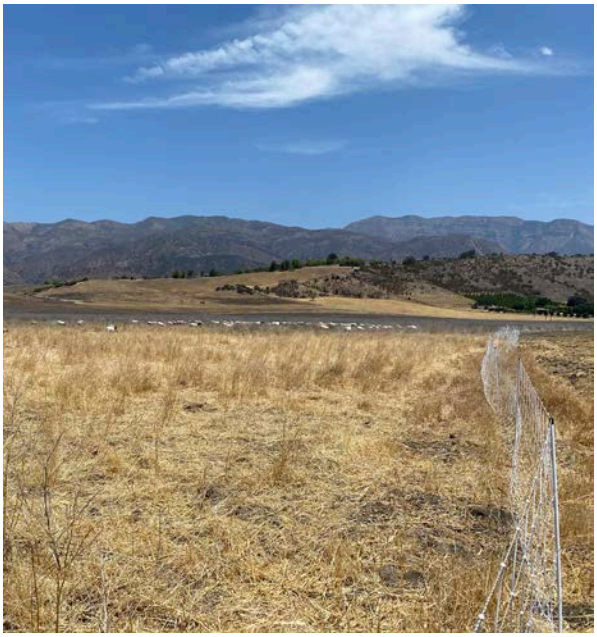



FIRE FUEL REDUCTION
DEFENSIBLE SPACE


Fine Fuels Reduction Project Grazing Rx
• Mixed-species herd of 400 sheep & goats
• 1 acre paddock per day
• 45 degree slope
• Vegetation type: primarily annual grass
(East Bay Regional Parks District, July 2015)


INVASIVE SPECIES MANAGEMENT





Canada geese near the Edward M. Brigham III Alkali Lake Sanctuary, Spiritwood, ND. Photo: Brian Chepulis/Audubon

Article

Rangeland Land-Sharing, Livestock Grazing's Role in the Conservation of Imperiled Species

Sheila Barry [1,2,*] and Lynn Huntsinger [2,*]

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Abstract: Land sharing, conserving biodiversity on productive lands, is globally promoted. Much of the land highest in California's biodiversity is used for livestock production, providing an opportunity to understand land sharing and species conservation. A review of United States Fish and Wildlife Service listing documents for 282 threatened and endangered species in California reveals a complex and varied relationship between grazing and conservation. According to these documents, 51% or 143 of the federally listed animal and plant species are found in habitats with grazing. While livestock grazing is a stated threat to 73% (104) of the species sharing habitat with livestock, 59% (85) of the species are said to be positively influenced, with considerable overlap between species both threatened and benefitting from grazing. Grazing is credited with benefiting flowering plants, mammals, insects, reptiles, amphibians, fish, crustaceans, and bird species by managing the state's novel vegetation and providing and maintaining habitat structure and ecosystem functions. Benefits are noted for species across all of California's terrestrial habitats, except alpine, and for some aquatic habitats, including riparian, wetlands, and temporary pools. Managed grazing can combat anthropomorphic threats, such as invasive species and nitrogen deposition, supporting conservation-reliant species as part of land sharing.

Keywords: livestock grazing; species conservation; land-sharing; invasive species; nitrogen deposition; conservation-reliant species

check for updates

Citation: Barry, S.; Huntsinger, L. Rangeland Land-Sharing, Livestock Grazing's Role in the Conservation of Imperiled Species. *Sustainability* **2021**, *13*, 4466. https://doi.org/10.3390/su13084466

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION

RESEARCH ARTICLE

Loss of biodiversity and hydrologic function in seasonal wetlands persists over 10 years of livestock grazing removal

Jaymee T. Marty[1,2,3]

Ecological restoration provides a means to increase biodiversity in ecosystems degraded by natural and human-induced changes. In some systems, disturbances such as grazing can be key factors in the successful restoration of biodiversity and ecological function, but few studies have addressed this experimentally, especially over long time periods and at landscape scales. In this study, we excluded livestock grazing from plots within a grassland landscape containing vernal pools in the Central Valley of California for 10 years and compared vernal pool hydrology and plant community composition with areas grazed under an historic regime. In all 10 years, the relative cover of native plant species remained between 5 and 20% higher in the grazed versus ungrazed plots. This effect was particularly prominent on the pool edges, though evidence of invasion into the pool basins was evident later in the study. Native species richness was lower in the ungrazed plots with 10–20% fewer native species found in ungrazed versus grazed plots in all years except the first year of treatment. Ungrazed pools held water for a shorter period of time than pools grazed under an historic regime. By the ninth year of the study, ungrazed pools took up to 2 weeks longer to fill and dried down 1–2 weeks sooner at the end of the rainy season compared to grazed pools. The results of this study confirm that livestock grazing plays a key role in maintaining biodiversity and ecosystem function in vernal pools.

Key words: invasive species, land management, vernal pools, wetland restoration

Received: 30 November 2020 | Accepted: 28 July 2021
DOI: 10.1111/1365-2664.14001

Journal of Applied Ecology

RESEARCH ARTICLE

Vernal pool wetlands respond to livestock grazing, exclusion and reintroduction

Julia S. Michaels[1] | Kenneth W. Tate[2] | Valerie T. Eviner[2]

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Funding information
USDA National Institute of Food and Agriculture, Grant/Award Number: 1013397; U.C. Davis Plant Sciences GSR Fellowship

Handling Editor: Joseph Bennett

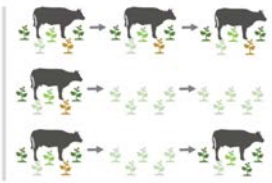
Abstract

1. In disturbance-adapted ecosystems, the removal of disturbance can lead to losses of diversity and sometimes irreversible changes in community composition. It is important to identify the thresholds at which these changes can occur, and to understand the reversibility of these shifts. We examined this question in a vernal pool ecosystem that evolved with low to moderate levels of grazing disturbance. In this system, it is not clear whether the negative effects of long-term grazing exclusion are reversible through grazing reintroduction.
2. We compared adjacent vernal pool wetlands in annual Mediterranean grasslands under three grazing management strategies: continuously grazed (100+ years), long-term excluded (40+ years) and 2 years of reintroduced grazing. We also asked whether grazing treatments altered pool characteristics that are likely to influence plant community composition, and how these relationships changed with environmental conditions.
3. Reintroducing grazing to vernal pools led to both increased diversity and native cover, but the effects on native cover were more immediate than on diversity. We identified several biotic and abiotic mechanisms related to this pattern, including changes to competitive dynamics that favour small statured native annuals and increases in hoofprint microdepressions that make soil moisture more available to plants.
4. *Synthesis and applications.* Our results show that reintroduced grazing at moderate stocking rates can have significant effects on plant communities after just 2 years and can increase native cover more quickly than overall diversity. Our findings suggest that the negative effects of long-term grazing exclusion in vernal pools may be reversible, but that land managers interested in restoring diversity should

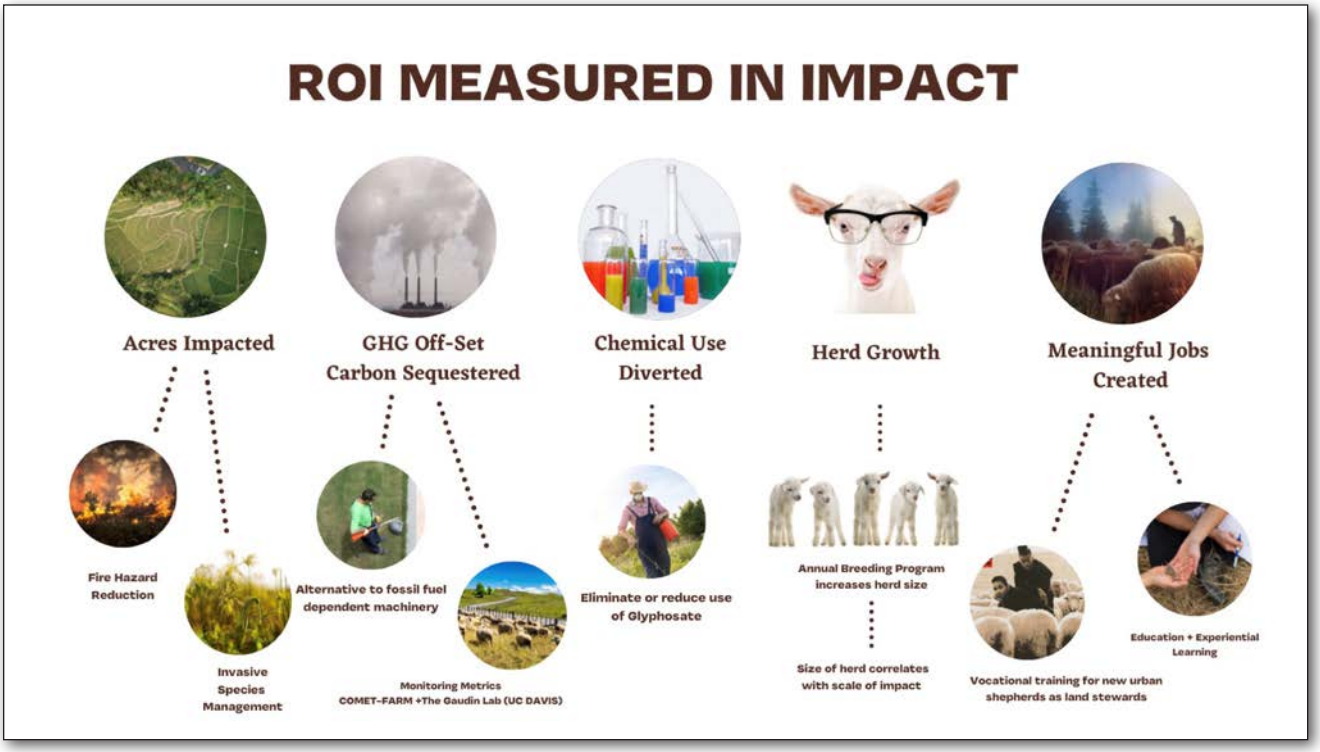
Vernal pool wetlands respond to livestock grazing, exclusion and reintroduction

Julia S. Michaels, Kenneth W. Tate, Valerie T. Eviner

Pages: 67-78 | First Published: 10 September 2021



Our results show that reintroduced grazing at moderate stocking rates can have significant effects on plant communities after just 2 years and can increase native cover more quickly than overall diversity. Our findings suggest that the negative effects of long-term grazing exclusion in vernal pools may be reversible, but that land managers interested in restoring diversity should plan to monitor beyond the first two years of grazing reintroduction.


ROI MEASURED IN IMPACT
Acres Impacted
GHG Off-Set
Carbon Sequestered
Chemical Use
Diverted
Herd Growth
Meaningful Jobs
Created
Fire Hazard
Reduction
Invasive
Species
Management
Alternative to fossil fuel
dependent machinery
Monitoring Metrics
COMET-FARM +The Gaudin Lab (UC DAVIS)
Eliminate or reduce use
of Glyphosate
Annual Breeding Program
increases herd size
Size of herd correlates
with scale of impact
Vocational training for new urban
shepherds as land stewards
Education + Experiential
Learning


EVALUATION
Is this the
right tool for
the job?
• Project goals
• Vegetation characteristics
o Species Composition
o Height
o Diameter
o Density
• Infrastructure - Roads, Water, Containment
• Environmental Characteristics
• Scale of project
• Transportation
• Proximity to public, operations, predation

COST STRUCTURES

1. **Cost per head per day** – contract grazers gives quote based on the number of head per day for the duration of the project.
   **ex. 800 head for 60 days at $.50 hd/per day= $24,000*

2. **Acreage fee** with set number of head.
   *ex. 20 acres at $950 an acre = $19,000

**Additional costs such as, transportation or "flushing" of weed-free forage may be presented.*

Considerations determining cost of services:

- Scale of project - acreage
- Duration / Time-Frame
- Seasonality
- Complexity – access, slope, veg type/density, sensitivities

Selecting the appropriate grazing contractor who has experience with the scale, landscape, community, and ecology of the site is essential to achieve project goals.

This includes selecting the right species, breed, and class of animal.

CONCLUSION

Prescribed grazing is an effective management tool for:

- *reducing fire fuels,*
- *targeting invasive species,*
- *supporting resilient watersheds,*
- *maintaining biodiversity,*
- *and creating and maintaining native wildlife and plant habitat.*

Success of grazing prescription treatments will require collaborative planning with livestock operators, science-based monitoring and adaptive management with clear goals.

Studies that incorporate site- and species-specific research would help to better understand effects of specific grazing activities in various contexts, climates, and ecosystems.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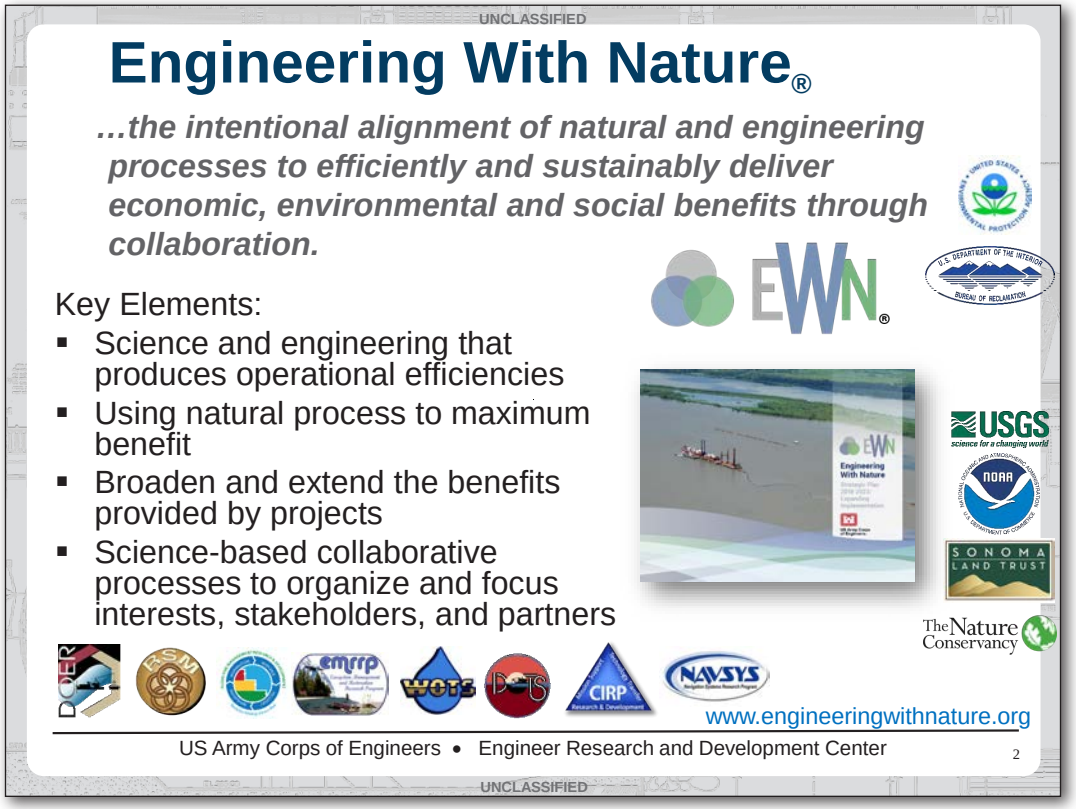
U.S.ARMY
ENGINEERING WITH NATURE
EWN
Natural Infrastructure Talk #2:
Managing Wildfire Consequences
Chris Haring, PhD, P.G., CFM
March 1, 2022
Research Physical Scientist
River Engineering Branch-Coastal and Hydraulics Lab
Engineering Research & Development Center (ERDC)
US Army Corps of Engineers
CIVIL WORKS CROSS-CUTTING RESEARCH AREA REVIEW GROUP MEETING * FY18 *
NAVIGATION
FLOOD RISK
ENVIRONMENT
US Army Corps of Engineers
ERDC
Engineer Research and Development Center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Engineering With Nature®
…the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaboration.
EWN
Key Elements:
Science and engineering that produces operational efficiencies
Using natural process to maximum benefit
Broaden and extend the benefits provided by projects
Science-based collaborative processes to organize and focus interests, stakeholders, and partners
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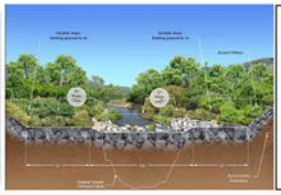
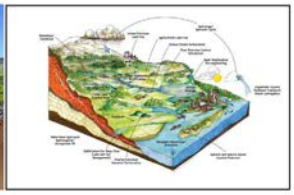
NNBF ENGINEERING PERFORMANCE

Levee Setbacks

Benefits/Processes

-decreased flood levels and velocities
-reduced frequency of maintenance and repair on levee
-reduced navigational maintenance
-reduction in erosion/scour and O&M costs
-increased recreational, cultural, and educational opportunities

Performance Factors

-amount of new floodplain affects hydrologic loading

-alignment options for improved hazard mitigation

-ecological goals of project with increased floodplain connection

-collaboration with stakeholders and other Federal agencies

Naturalization of Channel Design

Benefits/Processes

-reduced frequency of maintenance on levee and restoration projects
-naturalization of flow regimes and floodplain reconnection
-ecological benefits to floodplain habitat
-reduction in erosion/scour and O&M costs
-increased recreational, cultural, and educational opportunities

Performance Factors

-type of practice determines hydrologic loading
-practice determines options for improved hazard mitigation, erosion control, and streambed and bank stability
-collaboration with stakeholders and other Federal agencies
-sediment management options

Watershed Treatments

Benefits/Processes

-naturalization of hydrologic watershed regimes
-reduced navigational maintenance
-reduction in O&M costs
-increased recreational, cultural, and educational opportunities
-reduced frequency of maintenance and repair on levee and restoration projects

Performance Factors

-watershed management options determine effects on hydrologic loading
-practice options for improved hazard mitigation, upland erosion control, and groundwater recharge
-sediment management options
-collaboration with stakeholders and other Federal agencies

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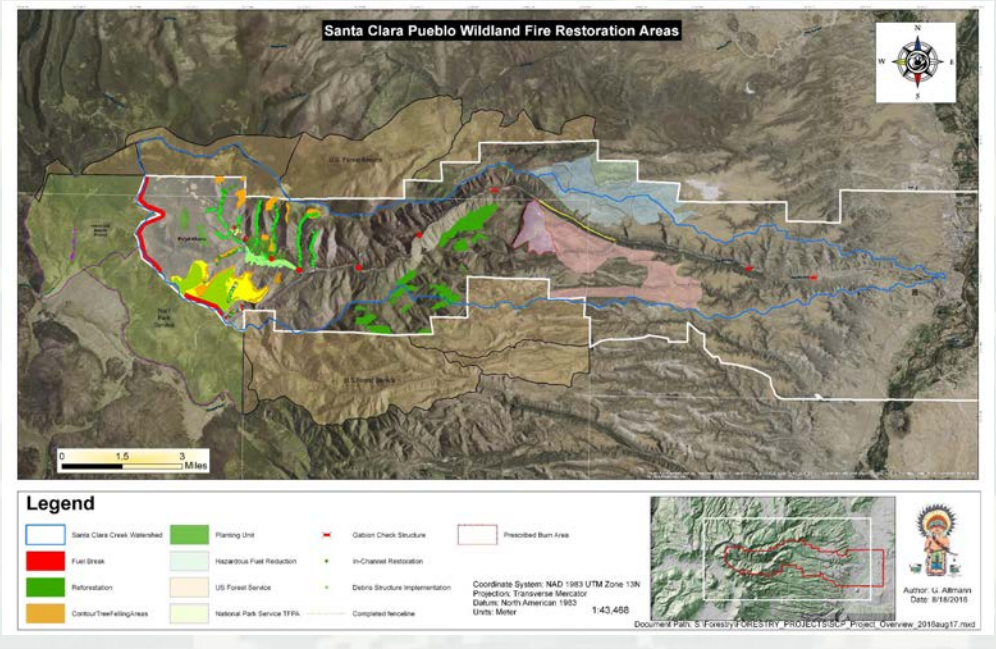
Albuquerque District-Santa Clara Canyon
Managing Wildfire Recovery



Santa Clara Canyon-Damage

Santa Clara Canyon-Damage

Santa Clara Canyon-Damage

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Santa Clara Canyon-Recovery

NNBF Applications
Santa Clara Canyon, NM

- Gabion Valley Grade Control Structures

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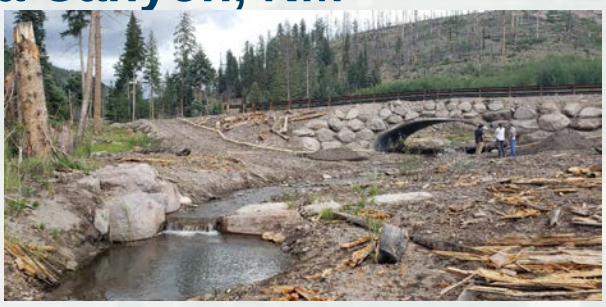
NNBF Applications
Santa Clara Canyon, NM

- Wetland & Erosion Control
- Bottomless Culvert



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tions for a safer, better world

NNBF Applications
Santa Clara Canyon, NM

- ❑ Wood structures
- ❑ Rock onsite
- ❑ Combination

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NNBF Applications
Santa Clara Canyon, NM

- ❑ Wood structures
- ❑ Rock onsite
- ❑ Combination

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DOTS Report Recommendations

1) Continue EWN-NNBF Channel Stabilization Measures

2) Modify some of the NNBF design & installation

3) Gabon valley grade control structures: consider lifespan and future stability of Santa Clara stream channel grade

4) Rio Grande Restoration recommendations

5) Gather new LiDAR, geologic mapping and other data

Next Steps:

A) Regional Sediment Management Proposal: submitted in 2018, meeting on May 8th to discuss re-scoping

B) FluvialGeomorph application: test assessment tools on pre-and post LiDAR wildfire datasets

C) Test LiDAR Change Analysis: Compare pre to post fire LiDAR

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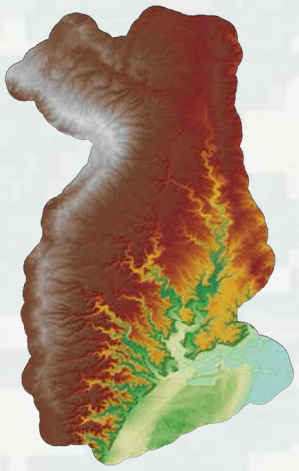
Tools to Assess Offsite and Cumulative Benefits

- **SON:** Tools to Assess Offsite and Cumulative Benefits in Watershed Assessment
- **Need:** Illinois Basin Restoration (IL519) was designed, in part, to retain sediments in upland streams to protect bottomland floodplain and backwater habitat from sediment impacts. A benefit metric evaluating sediment reduction from watershed stabilization is needed.
- **Purpose:** Develop rapid watershed analysis tools for USACE Planning Studies. Tools will prioritize sites offering the greatest downstream sediment reduction benefits:
  1) navigation (reduced dredging)
  2) flood risk management (floodway maintenance)
  3) ecosystem restoration (aquatic and floodplain habitat)



Watershed Planning Approach: Goals & Objectives

Goals:

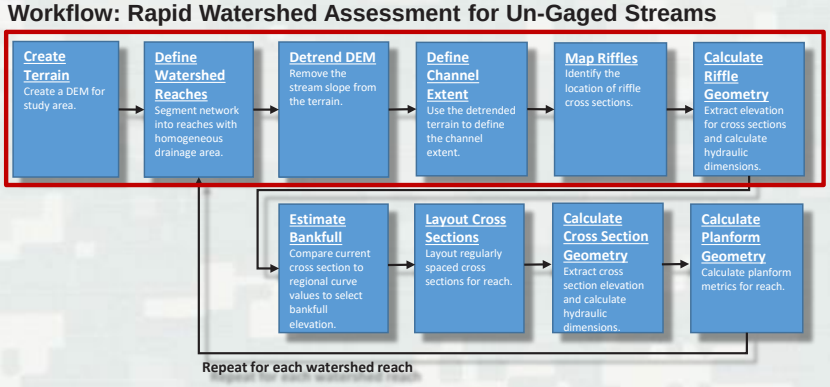
- Provide a USACE Planning method for rapid watershed assessments by developing geomorphic analysis tools using high resolution terrain data and existing empirically based fluvial geomorphic principles
- Develop a USACE Ecological Planning model based on rapid watershed assessment metrics to define restoration and mitigation benefits

Objectives:

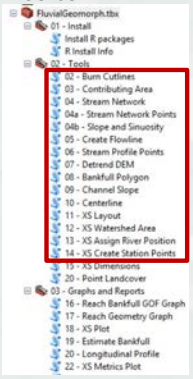
- Develop a suite of planning analysis tools to rapidly assess and identify sediment sources, pathways, and sinks for watershed analysis.
- Use existing geomorphic principles to develop metrics for analyzing LiDAR-derived channel, floodplain, valley, and watershed characteristics.
- Develop an approach to relate channel, floodplain, valley, and watershed characteristics to Ecosystem Restoration (ER) habitat evaluation and benefits.

Create Terrain and Extract Channel Dimensions

Workflow: Rapid Watershed Assessment for Un-Gaged Streams



FluvialGeomorph Toolbox



- GIS analysts follow the workflow
- Use the ArcGIS FluvialGeomorph toolbox tools to complete each task
- R used in the background to perform calculations, graphing, and reporting

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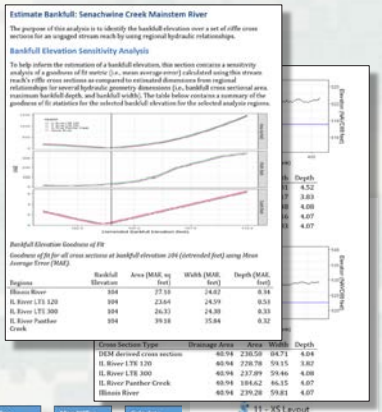
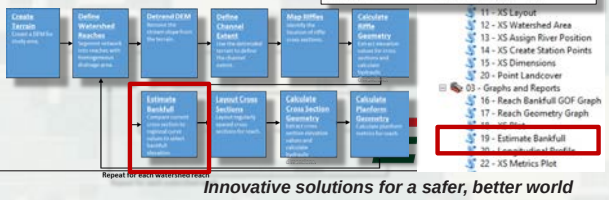
Diagnostic Role of the Estimate Bankfull Elevation Report

The purpose of this report is to help select a bankfull elevation for channel analysis on un-gaged streams.

- Detrending standardizes all cross-sections within a reach to the same elevation scale
- Detrending allows for reach-wide comparison of channel cross-section elevations and dimensions
- Helps compare a bankfull elevation that best matches specified regional curve defined bankfull channel dimensions
- Helps distinguish between candidate geomorphic bankfull indicators via cross-section interpretation
- Documents the PDT decision making process





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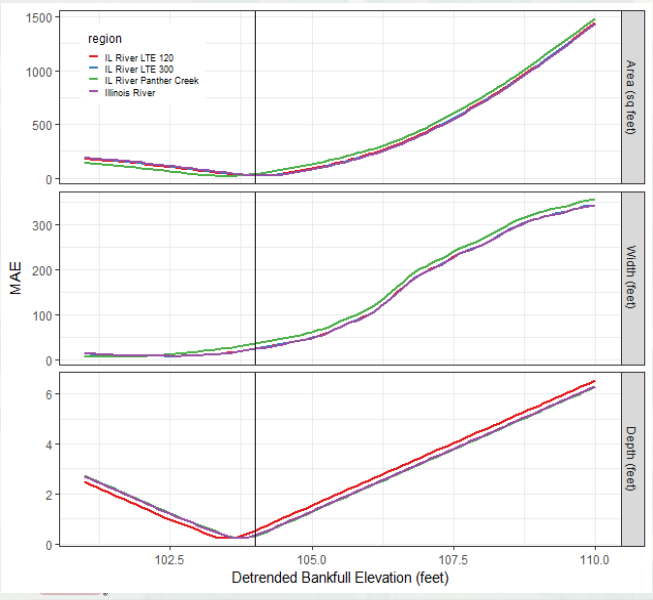
Regional Curve Goodness of Fit Graph



Compares how closely all cross-sections within a reach match the regional curve estimate for candidate detrended bankfull elevations.

Mean Average Error (MAE) between the measured cross section dimensions and the regional curve estimates.

For example:
MAE decreases as detrended bankfull elevations approach ~104. Therefore, 104 has the best fit to the regional curve for this reach.

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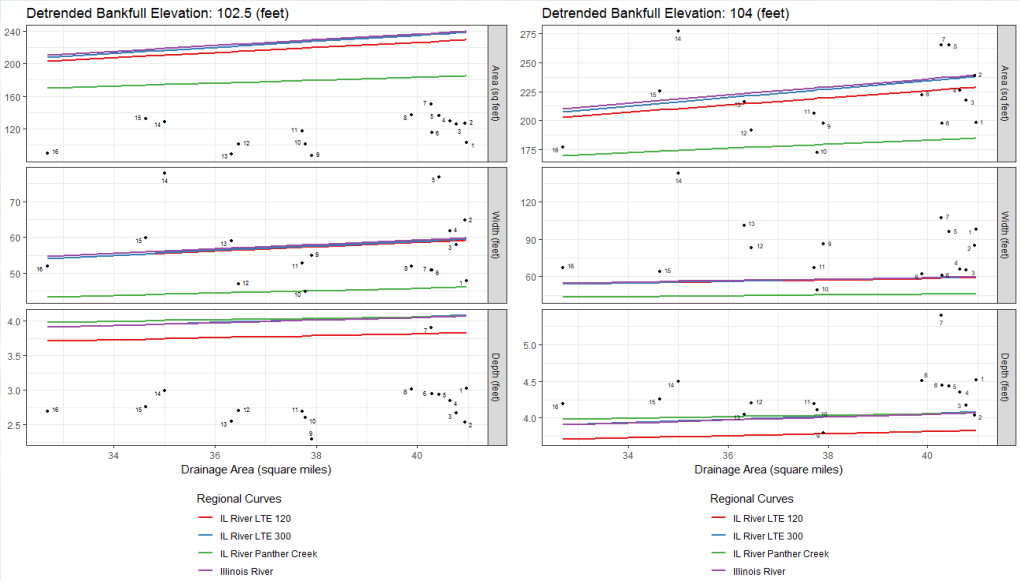
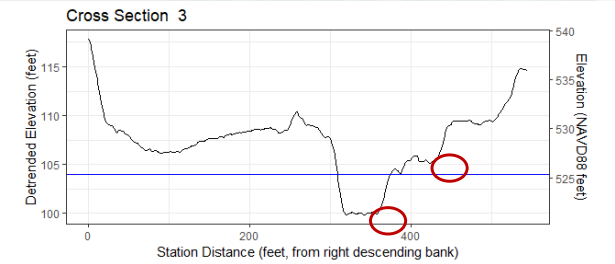
Reach Hydraulic Geometry Graph



Inspect Cross Sections

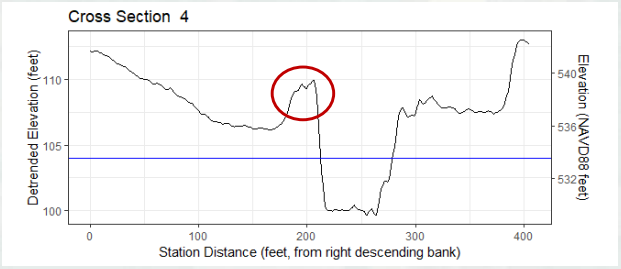


- Detrended elevation is on the left y-axis
- Actual elevation is on the right y-axis
- The black line represents the terrain surface
- The blue line represents the estimated bankfull elevation.

From the previous slides we saw that for this reach detrended elevation 104 minimized mean average error between measured cross-section dimensions and estimates from regional curves.

- This approach helps to distinguish between multiple geomorphic indicators.
- Allows geomorphic indicators to be rapidly compared between cross-sections.
- Helps ensure consistency in bankfull indicator selection throughout a reach.

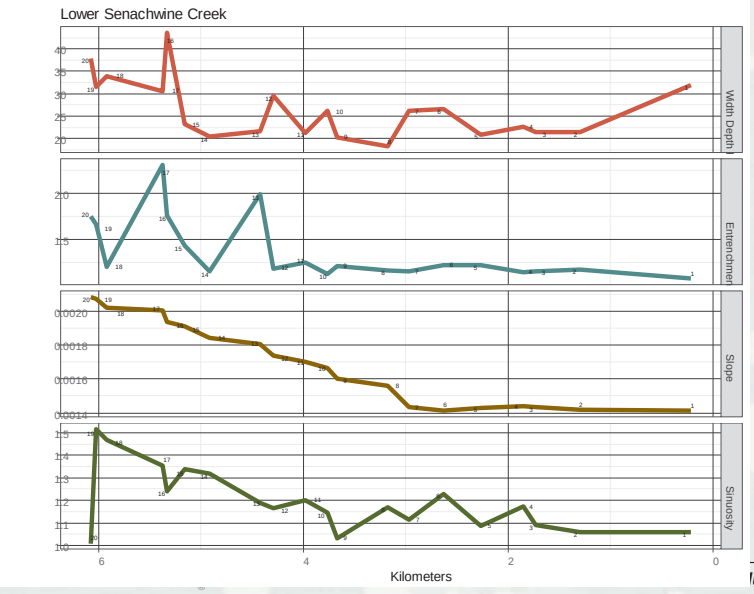
Inspect Cross Sections



Standardized cross-section graphs permit rapid identification of salient stream features and conditions.

- Since the bankfull elevation was estimated to be 104 for this reach, this cross section appears to be entrenched.
- The red circle clearly indicates the presence of a levee preventing access to the floodplain.

Reach Metrics Graph



Standard reach metrics are calculated and specialized graphs are created to:

- compare related metrics
- aid rapid interpretation
- facilitate PDT integration of disparate metrics

lutions for a s

Predicting Fish Habitat using FluvialGeomorph

Research Question
Can fish habitat (measured using fish community data) be predicted using fluvial geomorphic characteristics?

Dependent Variables
Fish community data collected for the MN Index of Biological Indicator (IBI) will be used as response variables (e.g., species richness, IBI, etc.).

Independent Variables
FluvialGeomorph calculated metrics will be used as predictor variables (e.g., W/D, entrenchment ratio, slope, sinuosity, stream power, etc.).

Current Efforts
Preparing terrain data and calculating FluvialGeomorph metrics for a stratified sample of ~100 MN IBI sampling sites.

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Project Developments

- **Project Planning**
  - Stream channel delineation methods identified need for Regional Curves: Ecoregion specific regional curves were created for use estimating conditions in ungagged streams/reaches.
  - Developing Minnesota River terrain data for FluvialGeomorph analysis of fisheries data (IBI)
  - Developing channel planform measurement methods for analysis of physical floodplain, valley, and watershed metrics (IL, MN, NM, CA, OR)

- **Reporting**
  - *Tech Note #1 (In review)*: Rapid Watershed Assessment Planning Tools Based on High Resolution Terrain Analysis
  - *Tech Notes #2 & #3 (draft form)*
  - Develop as a *ecological benefit evaluation model*
  - Develop (2-3) Technical Reports/Manuals on tool usage
  - Develop multiple (6) Technical Notes describing channel and watershed tools/metrics

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Summary: Watershed Assessment Planning Tool

- Developed and continue to refine and test a new watershed assessment tool-Fluvial Geomorph
- FluvialGeomorph is an R package based GIS toolbox to make watershed planning and assessments efficient, cost effective, and less-time consuming.
- Tools will be transferable wherever appropriate terrain data exists.
- Testing in different regions of US (Albuquerque & Portland Districts)
- Assessing Minnesota River Fisheries habitat data and the ability to predict habitat relationships from FluvialGeomorph

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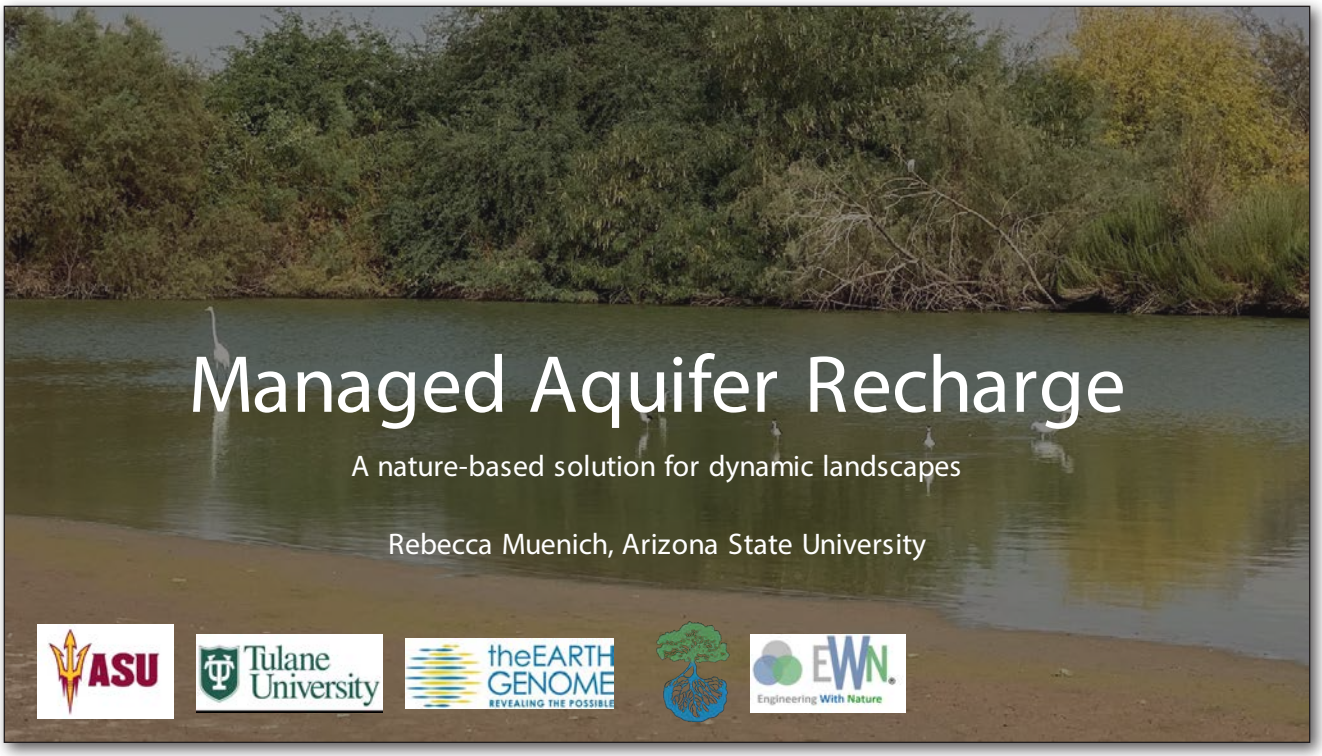
Day 2 Presentations

Rebecca Muenich: Managed Aquifer Recharge



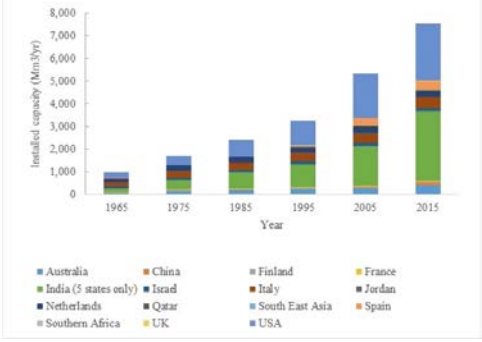
What is MAR?

- Suite of methods to help maintain, enhance, and secure groundwater resources under stress
- Intended to counteract historical misuse of aquifers
- Different kinds:
  - Streambed channel modifications
  - Water "spreading"
  - Recharge wells
  - Reservoir releases
  - More..

Dillon, P et al.., 2019. Sixty years of global progress in managed aquifer recharge. Hydrogeol J 27, 1–30. https://doi.org/10.1007/s10040-018-1841-z

History of MAR

- ~60 years in the making
- Originally called artificial recharge
- Sites all over the world and growing



Dillon, P et al., 2019. Sixty years of global progress in managed aquifer recharge. Hydrogeol J 27, 1–30. https://doi.org/10.1007/s10040-018-1841-z

MAR in Arizona

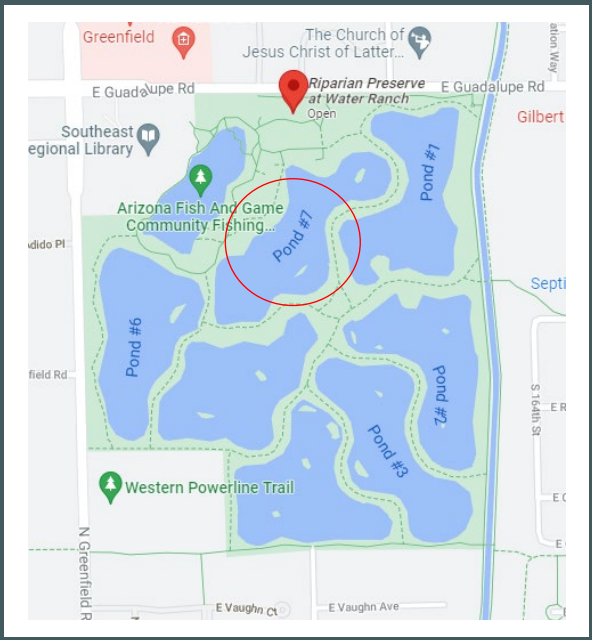
- Commonly water spreading
- Began in 1960s in Arizona
- Often tied to storage of Colorado River (CAP) water, but happening with other resources like Salt River Project
- Helps store discharges where they can't discharge, or store credits during excess for future use
- Many facilities use wastewater
- Overseen by ADWR

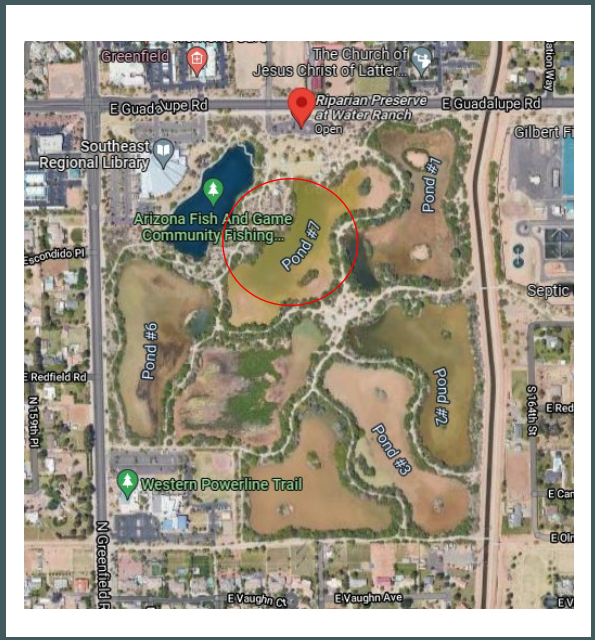
https://storymaps.arcgis.com/stories/70f626809fd84e228c0f32aef4222dda

https://new.azwater.gov/ama

Riparian Preserve at Water Ranch (Gilbert)

- https://www.gilbertaz.gov/departments/parks-and-recreation/riparian-preserve-at-water-ranch
- Effluent recharge basin in Town of Gilbert, AZ
- Organized into 7 recharge basins
- Allowed to infiltrate on average of 10 MGD
- Popular birding, recreational, community spot



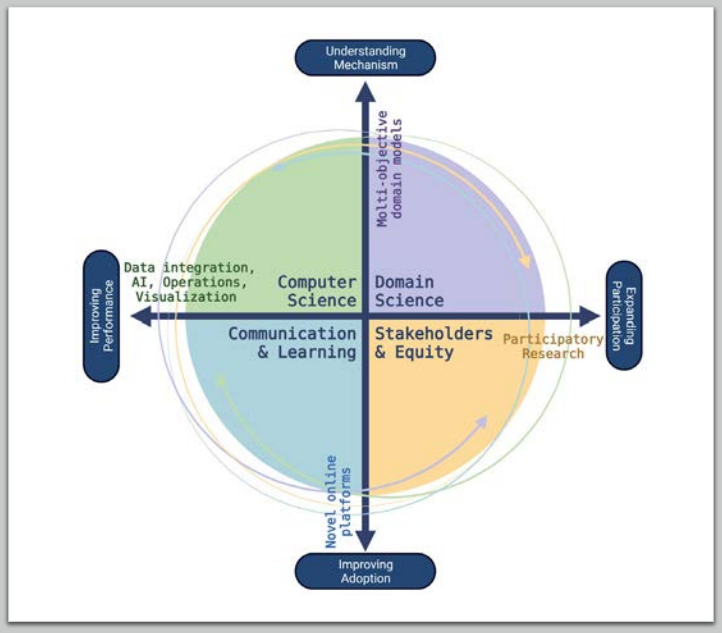


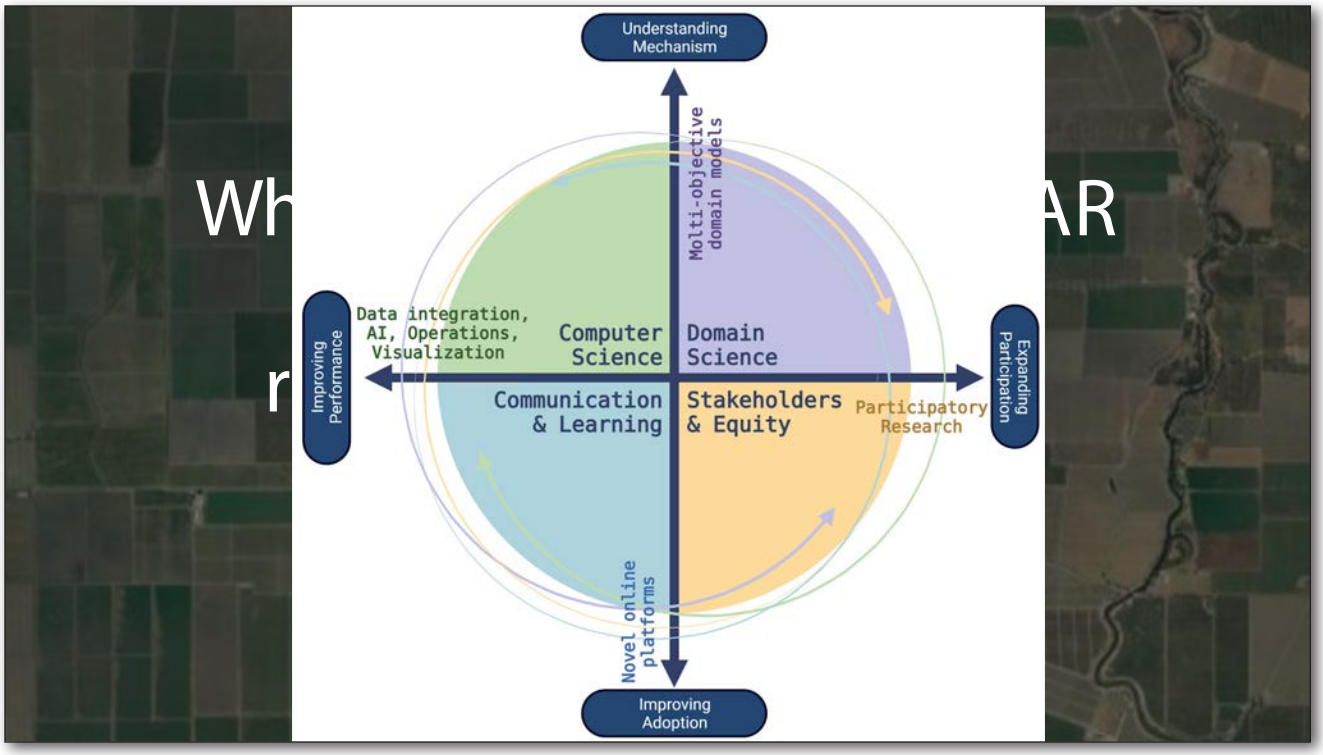
Research at the Preserve

- Groundwater and vadose zone modeling
- Solute and pathogen transport
- Student field days!

ASU-EWN Ongoing & Related Work

- *Generally*, integrating data science with hydrological sciences
  - Coordinating agricultural land MAR and reservoir operations (Muenich, Liu)
  - Modeling Flood-MAR in the San Joaquin Valley (Xu, Mascaro, Low)
  - Improved data integration and visualizations (Candan)
- Developing educational methods to expand EWN





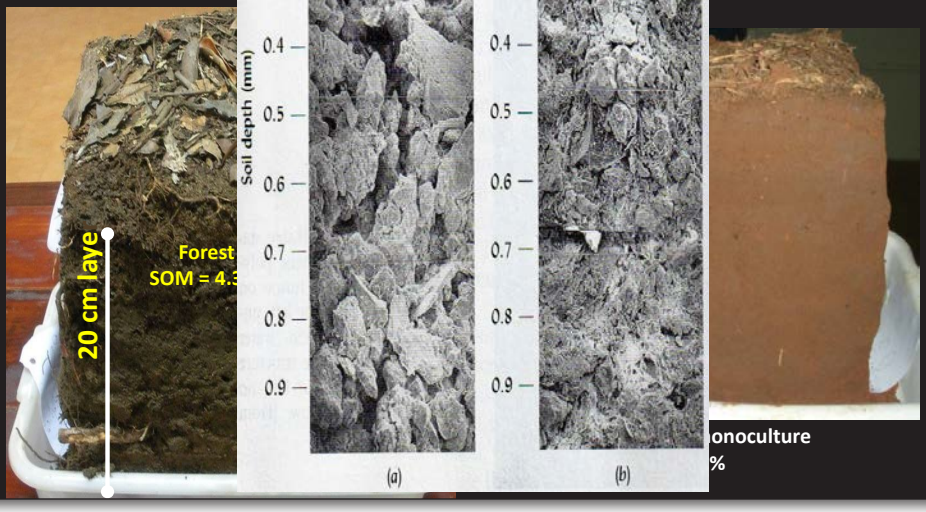
Gabe Brown: Understanding Ag

Understanding Ag

What Have WE Learned In 79 Years?

Disrupted Soil Ecosystem

Symptom: Poor Soil Structure



Our Ecosystems Are A Reflection Of Us!

We Can Regenerate Our Soils!

- Our Management (Stewardship) Makes The Difference!
- Every decision we make has compounding and cascading effects!

How Do We Heal Our Soils?
By Practicing Regenerative Agriculture!

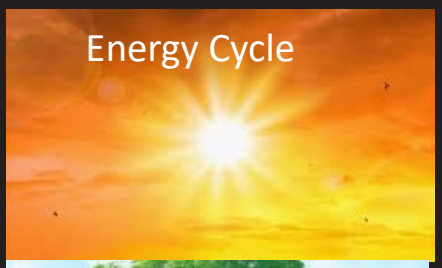
What is Regenerative Agriculture?

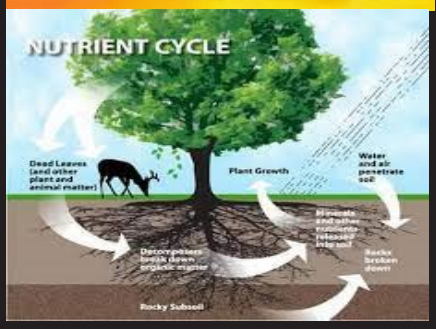
- ***Farming and ranching in synchrony with nature to Repair, Rebuild, Revitalize and Restore ecosystem function starting with life beneath the soil and moving to all life above the soil.***

Nature's Way
Six Principles

- Nature always acts in context
- No mechanical and limited chemical disturbance
- Armor on the soil surface
- Thrives on diversity
- Living plants as long as possible
- Always with animals and insects

Four Ecosystem Processes





Liquid Carbon Pathway

- This is the **ENERGY CYCLE**
- Plants take in CO2
- Photosynthesis occurs
- Converted to “liquid carbon”
- A portion of this is translocated to the roots
- Exuded into the soil

Credit to Dr. Christine Jones

Liquid Sun: Roots leaking exudates!

Which Feeds Biology!

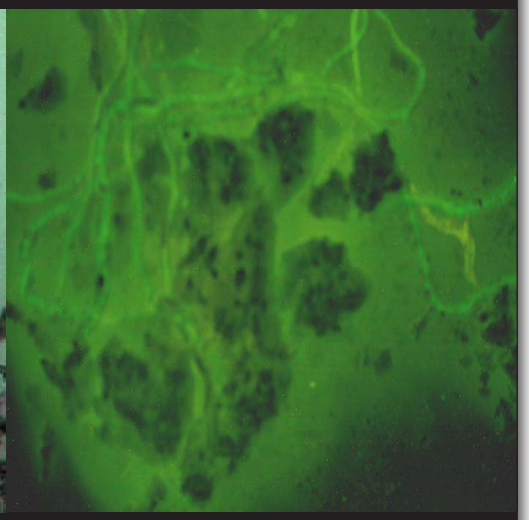
Liquid Carbon Pathway

- A large part of this is consumed by bacteria which are consumed by protozoa and nematodes (predators).
- This is a part of the **NUTRIENT CYCLE.**

Sand Silt Clay

Enlarged Soil Aggregates

Glomalin and Hyphae



Dr. Kris Nichols, Microbiologist, ARS, Mandan, ND

Well Aggregated Soil

- More Pore Spaces
- More Biology
- Higher Water Infiltration Rates
- Higher Water Retention
- More Oxygen to Roots
- Easier for Roots to Access Nutrients
- Resiliency!

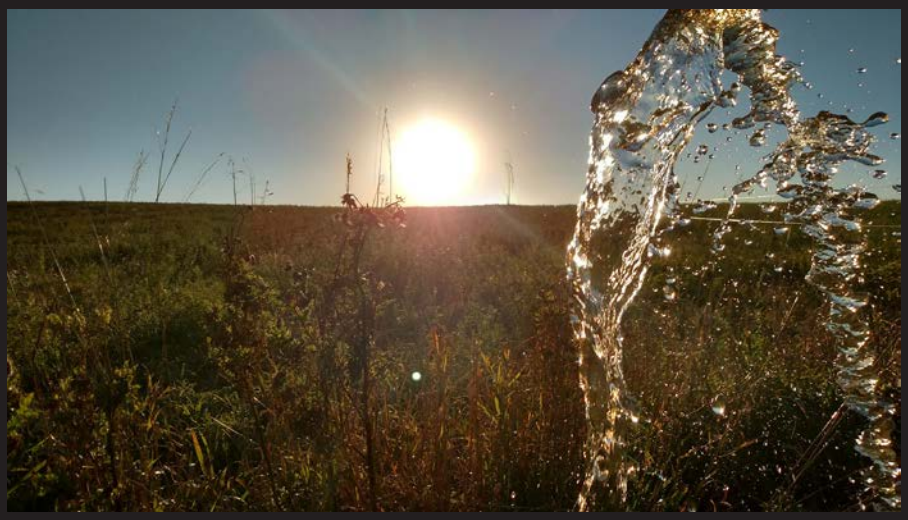
Organic Matter and Available Water Capacity
Inches of Water/One Foot of Soil

Percent SOM	Sand	Silt Loam	Silty Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

Berman Hudson
Journal Soil and Water Conservation 49(2) 189-194
March – April 1994
Summarized by:
Dr. Mark Liebig, ARS, Mandan, ND
Hal Weiser, Soil Scientist, NRCS, Bismarck, ND

- For every 1% increase in organic matter, soil can hold an additional 18,000 to 27,000 gallons of water per acre per 1 foot of the soil profile.
- This is key to water security!

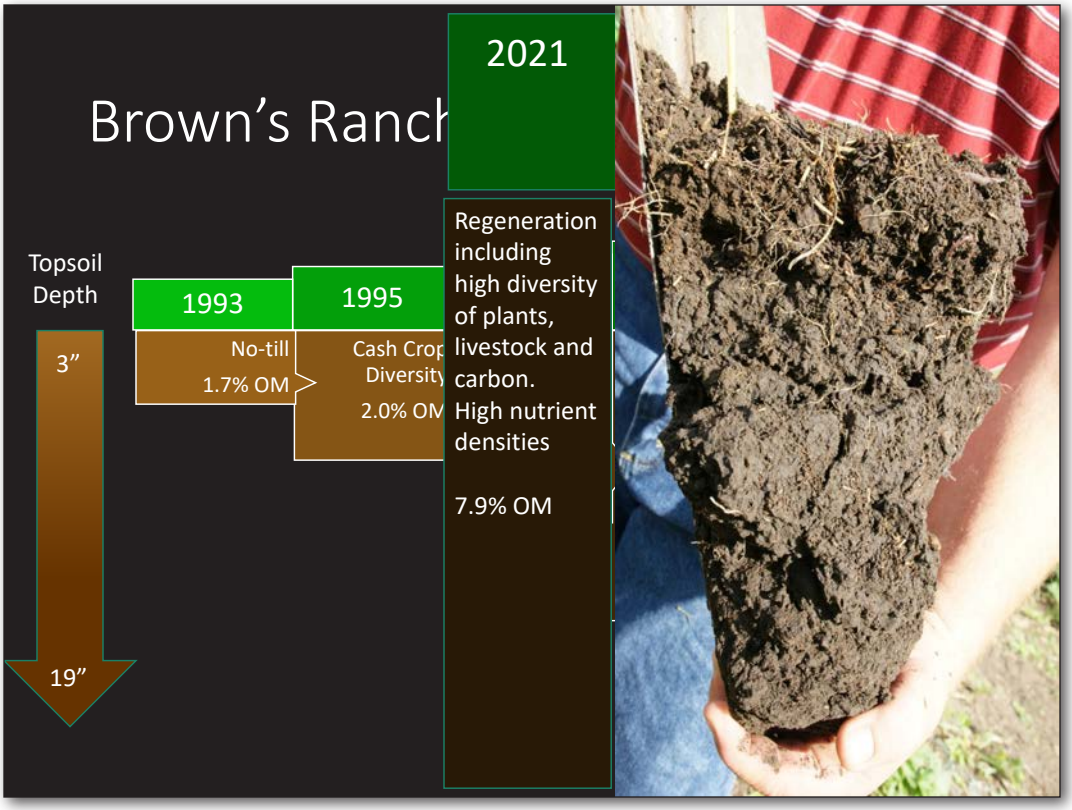
The **WATER CYCLE** Depends On Mycorrhizal Fungi And Biology



Nature Thrives With Diversity

DIRT TO SOIL

Brown's Ranch



UnderstandingAG

Restoring Soil, Profits, Farms and Futures.

- Our mission is to use our passion and experience to educate farmers, ranchers, businesses and communities in applying time-tested ecological principles to regenerate our living ecosystems, thereby restoring the health of all.

UnderstandingAG

Currently Consulting On 30+ Million Acres

SOIL HEALTH ACADEMY

- GROW HEALTHIER SOIL, FOOD AND PROFITS
- The Soil Health Academy will show you how.
- Intensive On-Farm Instruction


COMMON GROUND
For
COMMON GOOD

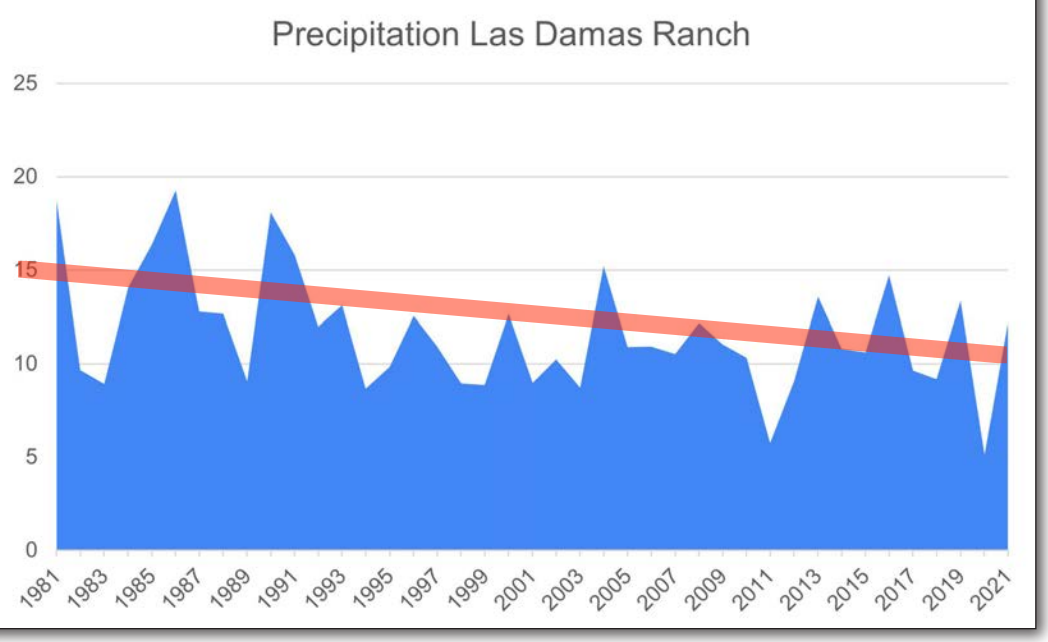
Alejandro Carrillo
alejandro@understandingag.com

BRINGING A RANCH BACK TO LIFE
ENGINEERING WITH NATURE
NAVY WORKSHOP / MCAS - YUMA

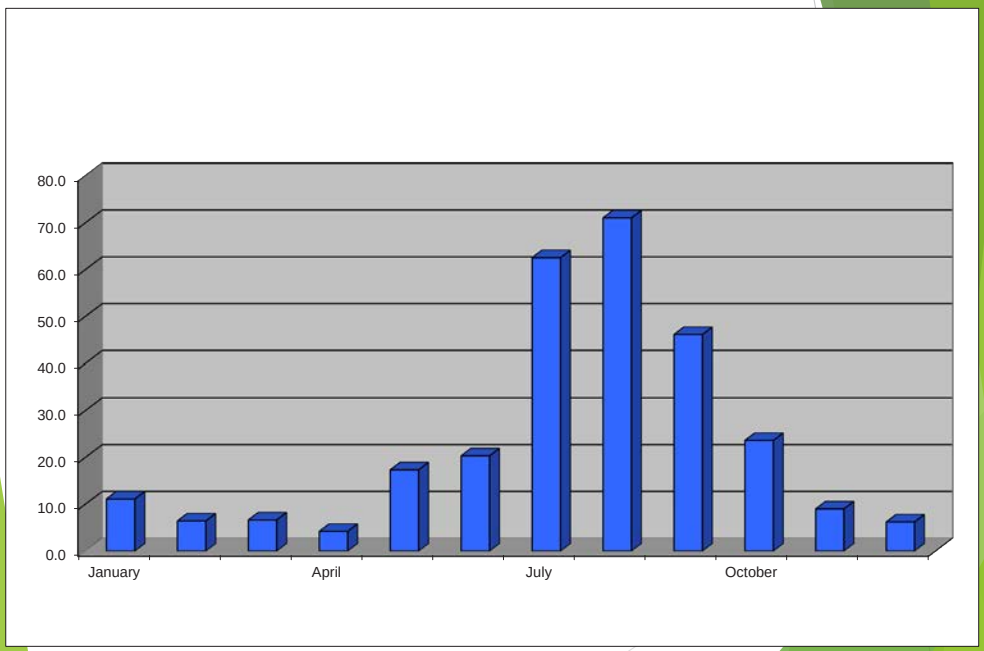
WHERE ARE WE LOCATED?

HIGH TEMPS ON BARE GROUND

WE NEED TO DO MORE WITH LESS



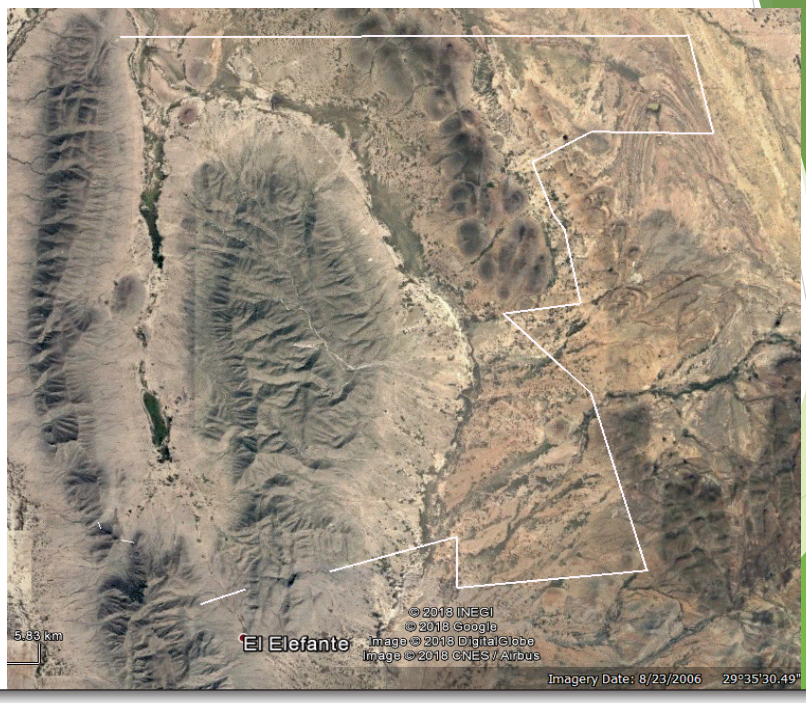
MOST OF THE RAIN FALLS IN THREE MONTHS.



WHAT'S GOOD ABOUT OXIDIZED GRASS?

NO MIDDLE GROUND …
We are either going forward or backwards – it depends on our UNDERSTANDING of the natural processes.

LAS DAMAS CATTLE RANCH



OUR CONTEXT

- 30,000 ACRES NESTED IN THE CHIHUAHUAN DESERT IN NORTHERN MEXICO
- COW-CALF OPERATION WITH 550 COWS & 200 SHEEP
- AVERAGE YEARLY RAINFALL OF 10” ON THE LAST 20 YEARS
- WE USE ONLY SEA SALT FOR OUR COWS
- WE HAVE NOT USED ANY CHEMICAL, MECHANICAL OR SEEDING TO RESTORE NATIVE GRASSLANDS
- OUR ONLY TOOL TO REGENERATE GRASSLANDS IS COWS **RATIONALLY** MANAGED.
- WE ARE PART OF A REGENERATION NETWORK IN THE CHIHUAHUAN DESERT COVERING > **2M ACRES**

TOURING THE RANCH AND SORROUNDINGS AREAS

HOW NEARBY PROPERTY LOOKS LIKE IN SUMMER WITH 6" OF RAIN YTD

HOW OUR PROPERTY LOOKS LIKE IN SUMMER WITH 6” OF RAIN YTD

SAME DAY, SAME REGION, DIFFERENT MANAGEMENT, LAST SPRING

IT IS GREENER ON THE SIDE OF MY FENCE!!! LATE SPRING

TOBOSA GRASS: PICTURE TAKEN SAME DAY IN WINTER UNDER SAME PRECIPITATION, BUT DIFFERENT MANAGEMENT

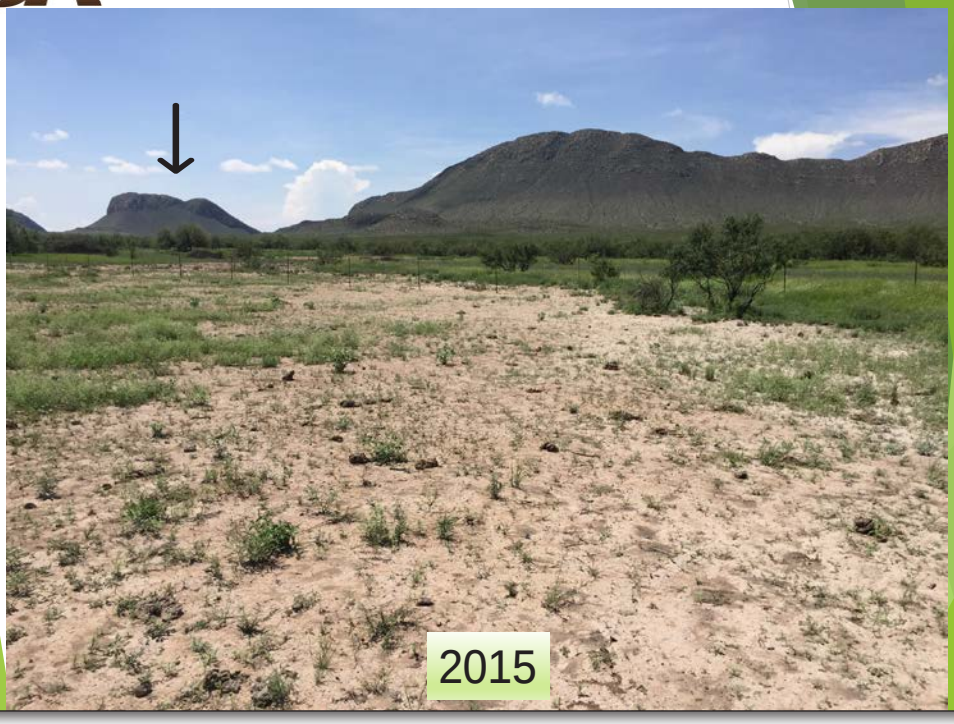
20

CLOSER LOOK AT THE SAME SPOTS OF THE PREVIOUS PICTURE. IF GRASS IS DEAD ON TOP, SOIL IS DEAD AS WELL

TWO REALITIES DURING SUMMER LAST YEAR: SAME DAY, SAME REGION, SAME PRECIPITATION

22

FROM BARE GROUND, TO WEEDS, TO ANNUALS & PERENNIALS ON A 6 YEAR PERIOD (12,8,8,9,10,5,11)



FROM BARE GROUND, TO WEEDS, TO ANNUALS & PERENNIALS ON A 6 YEAR PERIOD (12,8,8,9,10,5,11)

FROM BARE GROUND, TO WEEDS, TO ANNUALS & PERENNIALS ON A 6 YEAR PERIOD (12,8,8,9,10,5,11)

THERE IS MORE THAN ANIMAL IMPACT TO HAVE SUCH DRASTIC CHANGES ON 10" ANNUAL PRECIPITATION

26

DOES IT RAIN MORE IN REGENERATIVE RANCHES? THE 60/40 RAIN PATTERN

CLOUDS ARE THE FIRST LINE OF DEFENSE AGAINST HIGH SOIL TEMPS!

WATER INFILTRATION RATES: KEEPING WATER FOR GREENER PLANTS

HOW ABOUT THE SOIL ENGINEERS? DO THEY MAKE A DIFFERENCE?

WHAT BENEFIT AN OXIDIZED COW PIE BRINGS?

LET NATURE DO THE HEAVY LIFTING ...

TWO THIRDS OR 66% OF EACH COW PIE IS BURIED IN THE SOIL BY DUNG BEETLES ...

COW PIE WORKED BY DUNG BEETLES

RESPECTING NATURAL PROCESSES; HELPING NATURE HEAL HERSELF

TERMITES: NATURAL RE-CYCLERS
NOTHING GETS WASTED IN NATURE

TERMITES IN ACTION CONVERTING OXIDIZED GRASS INTO NITROGEN

LOW MAINTENANCE HEREFORD COW

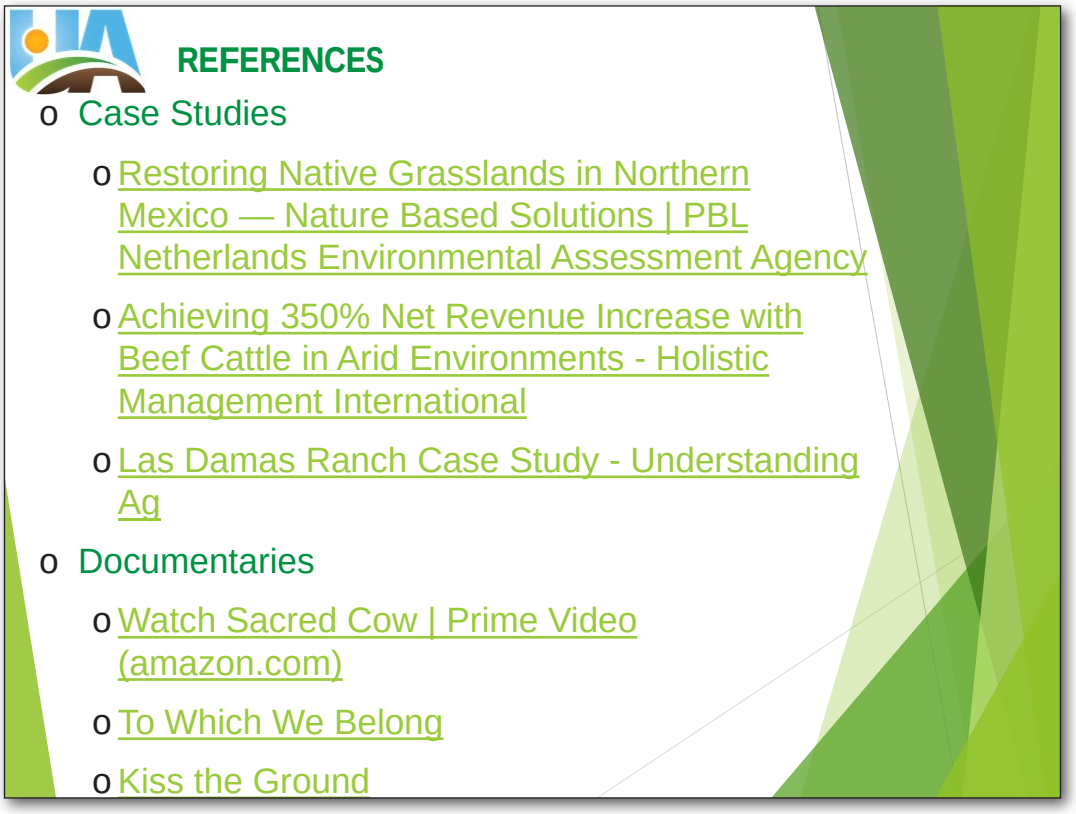
COWS ADAPTED TO THEIR ENVIRONMENT

COWS ADAPTED TO THEIR ENVIRONMENT

TAKING FULL ADVANTAGE OF WHAT IS OUT THERE. PRICKLY PEAR CACTUS EATEN

REGENERATION OF AN OPEN PIT MINE: FROM GRAVEL TO SOIL!


BELIEVE AND YOU WILL ...


REFERENCES
Case Studies
Restoring Native Grasslands in Northern Mexico — Nature Based Solutions | PBL Netherlands Environmental Assessment Agency
Achieving 350% Net Revenue Increase with Beef Cattle in Arid Environments - Holistic Management International
Las Damas Ranch Case Study - Understanding Ag
Documentaries
Watch Sacred Cow | Prime Video (amazon.com)
To Which We Belong
Kiss the Ground

WEST Consultants, Inc.

Land Management and Water Security

How to Deliver a Land Management Project as an Alternative to Traditional Engineering

Ricardo Aguirre, P.E., CFM, AP
Director of Land Management and Water Security
Executive Director of Drylands Alliance Addressing Water Needs (DAAWN) –
The Arizona Savory Hub

Savory

DAAWN

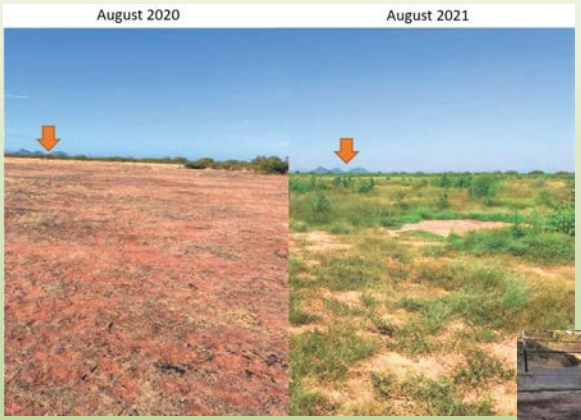
WEST Consultants, Inc.

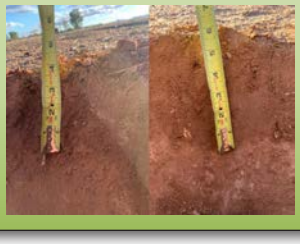
Overview

- From Pipes Channels & Holes to Regenerative Practices
- First Principles Thinking
- Land Management Practices
- Project Delivery
- Management vs Technology

From Pipes, Channels & Holes in the Ground…

…to Regenerative Practices



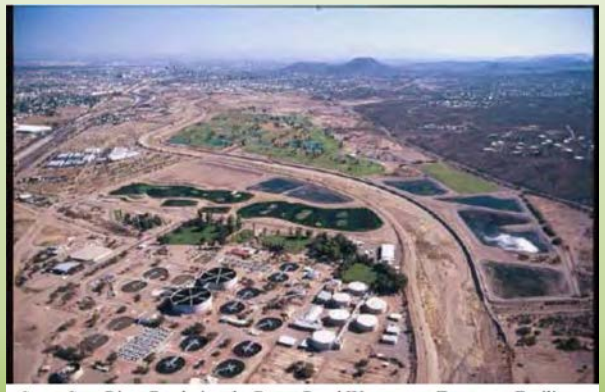


First Principles Thinking

1800's

Santa Cruz River Perennial Flow North of Tucson, late 1800's

Today



Santa Cruz River Bordering the Roger Road Wastewater Treatment Facility

First Principles Thinking

Zimbabwe

First Principles Thinking

Soil Organic Matter 1.7%
Next Day - Practically no infiltration

Soil Organic Matter 5%
Next Day - Practically total infiltration

North Dakota - Courtesy: Gabe Brown

- **Soil Organic Matter (SOM) and Soil Water Holding Capacity**
- **On average 1% of SOM can retain 20,000 gallons of water / acre**

First Principles Thinking

Conventional Grazing
- Few animals
- Large area
- Long time (months-yrs)

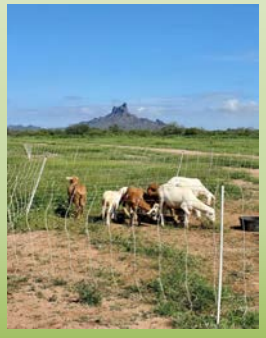
Holistic Planned Grazing
- Many animals
- Small area
- Little time (hours-days)

Northern Arizona

First Principles Thinking

Land Management Practices

- Biological Soil Amendments
- Subsoil plowing
- Planned Grazing -> SCALABLE!

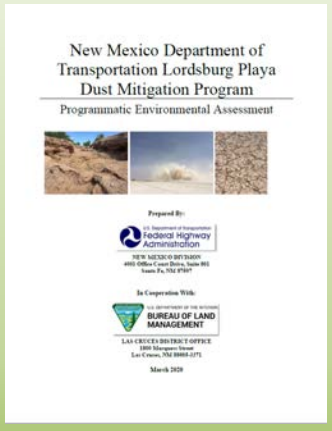


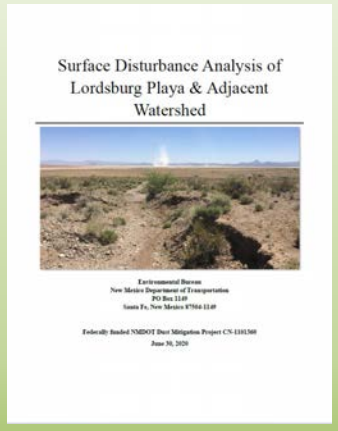
Project Delivery

- Phase 1 – Restoration Concept
  - Determine existing site conditions
  - Develop land plan alternative
  - Preliminary Cost Estimates

Cochise County, Arizona (480 acres)

New Mexico Department of Transportation (30,000 acres)





Project Delivery

- Phase 2 – Land Plan Improvements Installation
  - Research materials and final cost estimates
  - Installation (Fencing, Watering, and Handling)
  - Construction administration

Cochise County

New Mexico Department of Transportation

Project Delivery

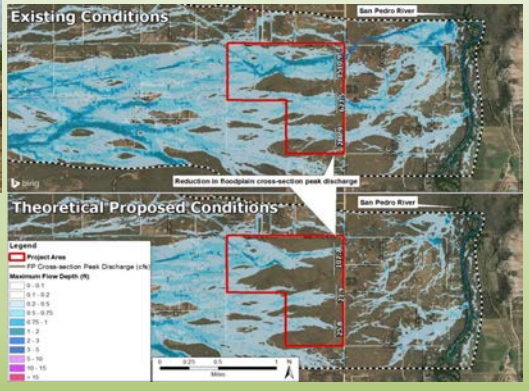
- Phase 3 – Land management implementation
  - Soil biology plan
  - Monitoring and recording
  - Treatment management

New Mexico Department of Transportation

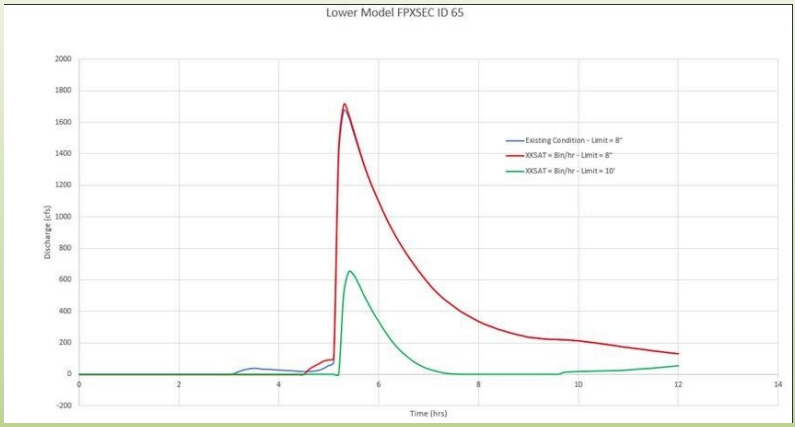
Project Implementation - Outcomes

From this

To this



Project Implementation - Outcomes



The 1403.2 cfs is now reflected as 227 ac-ft of recharge potential by taking the difference of the two hydrograph curves.

Management vs. Technology

Decentralized Animal Impact

- **Cost**
  - Multi-six figure < $1 Million
  - Continual Management
- **Benefit**
  - Flood control
  - Groundwater recharge
  - Water Quality Mitigation
  - Improves Soil Loss
  - Dust Mitigation
  - Control wildfire feedstock
  - Heat Island

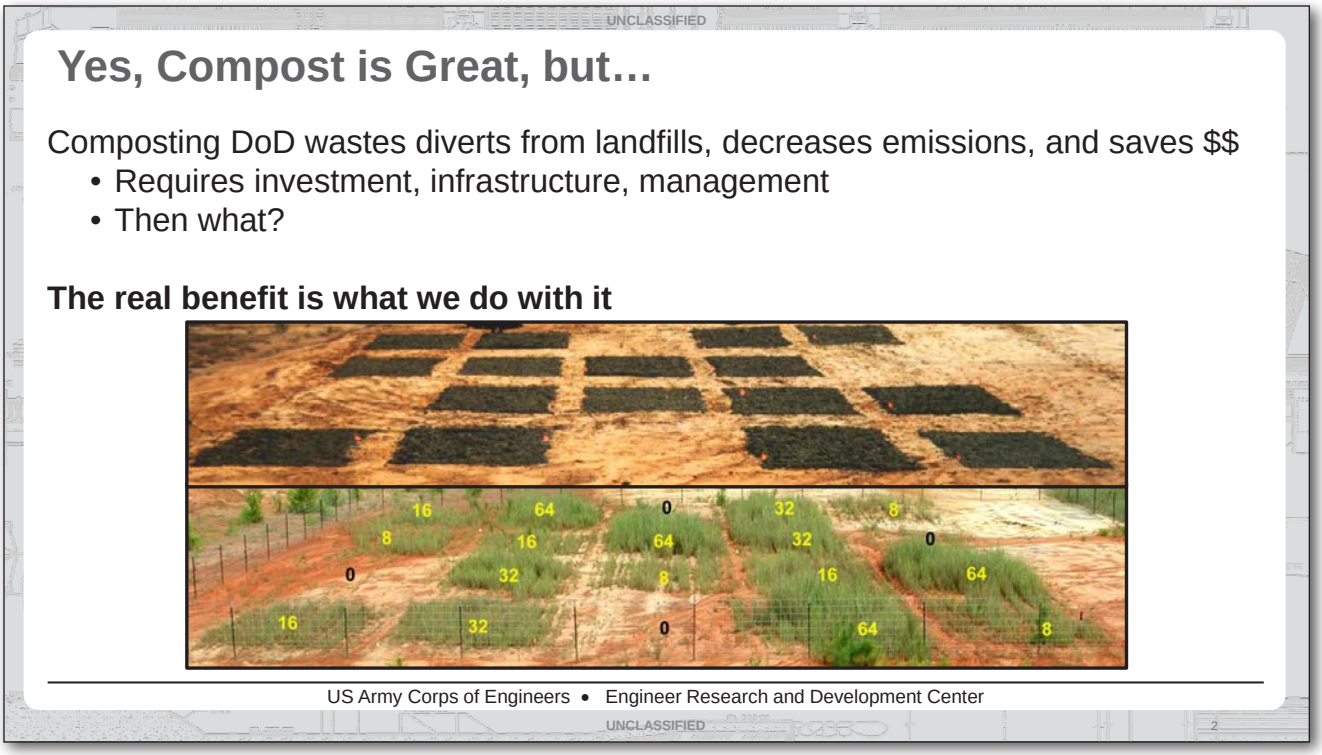
Centralized Expensive Infrastructure

- **Cost**
  - $Multi-Million
  - Continual Maintenance
- **Benefit**
  - Flood control only (symptomatic relief)

Questions

Day 3 Presentation

Ryan Busby: Compost for Climate Resilience



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Where is Compost Most Beneficial?

Military training diminishes soils:

- DoD soils are disturbed and compacted:
  - reduced organic matter
  - increased bulk density
  - lower water infiltration
  - lower water holding capacity
  - increased nutrient availability
  - increased erosion

Vegetation is diminished, soil is lost, habitat is reduced, and training is inhibited

Compost alleviates all of these environmental quality/operational reductions

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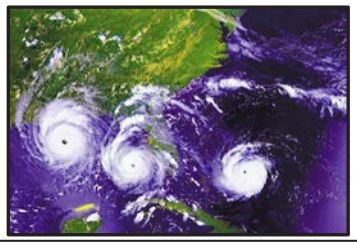
UNCLASSIFIED 3

UNCLASSIFIED

Compost Improves Climate Resilience

Adding organic matter to soil improves soil health and ecosystem services provision

- Decreased bulk density (better vegetation, less runoff, less erosion)
- Increased water infiltration (less flooding, better water quality)
- Increased water retention (drought tolerance, less flooding)
- Increased root penetration (drought tolerance, landslide protection, fuel reduction)
- Increased nutrient retention and exchange, increased carbon sequestration, contaminant binding and decomposition, pH buffering, increased microbial diversity and function, soil aggregation, etc. (improved ecosystem function overall)



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Compost and Soil Bulk Density

Compost feedstock[b]	Incorporation depth (cm)[c]	Application rate (s)	Soil type[d]	Effect	Time (years)[e]	Percent Change[f]	Reference
Mixed	15	0.75, 1.5, 3 cm[a]	Clay	Decreased	1	6, 12, 16	Aggelides and Londra (2000)
Mixed	15	0.75, 1.5, 3 cm[a]	Loam	Decreased	1	12, 18, 20	Aggelides and Londra (2000)
Mixed	20	11.2 cm[a]	Sandy loam	Decreased	5	15	Cannavo et al. (2014)
Yard waste	20	11.2 cm[a]	Sandy loam	Decreased	5	20	Cannavo et al. (2014)
Yard waste	60	10 cm	Loam	Decreased	5	No data	Chen et al. (2014)
Mixed	No data	1 cm	Loam	Decreased	3	9	Chen (2015)
Yard waste	20	7.6 cm	Sandy loam	Decreased	6	15	Crogger et al. (2008)
Yard waste	60	270, 540 Mg ha^{-1}	Loam	Decreased	2	No data	Curtis and Claassen (2005)
Yard waste	50	540 Mg ha^{-1}	Sandy loam (sandstone)	Decreased	1	20	Curtis and Claassen (2009)
Yard waste	50	540 Mg ha^{-1}	Loam (serpentinitic)	Decreased	1	19	Curtis and Claassen (2009)
Yard waste	50	540 Mg ha^{-1}	Sandy loam (lahar)	Decreased	1	20	Curtis and Claassen (2009)
Yard waster	50	540 Mg ha^{-1}	Sand (DG)	Decreased	1	21	Curtis and Claassen (2009)
Mixed	7 to 10	2.5, 5 cm	Sandy loam	Decreased	3	6, 11	Evanylo et al. (2016)
Yard waste	60	10 cm	Loam	Decreased	2	16	Layman (2010)
Sludge	10 to 15	1.3, 1.02 cm	No data	Decreased	1	No data	Loschinkohl and Boehm (2001)
Yard waste	30	5 cm	Fine sandy loam	Decreased	<1	55	Mohammadshirazi et al. (2016)
Yard waste	15 and 30	5 cm	Sand	Decreased	2	11, 15	Mohammadshirazi et al. (2017)
Yard waste	15 and 30	5 cm	Sandy clay loam	Decreased	2	14, 19	Mohammadshirazi et al. (2017)
Yard waste	30	5 cm	Sandy clay	Decreased	2	40	Mohammadshirazi et al. (2017)
Yard waste	30	5 cm	Clay loam (fill)	Decreased	2	11	Mohammadshirazi et al. (2017)
Mixed	122	15.24 cm	Unclassified	Decreased	12	39	Sax et al. (2017)
Yard waste	30	1.52, 6.04 cm[a]	Sandy loam	Decreased	2	15, 27	Schmid et al. (2017)
Yard waste	12.5	7.5 cm	Loam	Decreased	2	11	Schwartz and Smith (2016)
Sludge	20, 50	50% v/v	Loamy coarse sand	Decreased	1.5	27, 34	Somerville et al. (2016)
Sludge	20, 50	50% v/v	Coarse sandy loam	Decreased	1.5	27, 33	Somerville et al. (2016)
Sludge	20, 50	50% v/v	Loam coarse sand	Decreased	1.5	33, 23	Somerville et al. (2016)
Yard waste	25	7.2, 14.4 OM per hectare	Sandy loam	Decreased	4	22, 27	Tejada et al. (2009)
Yard waste	25	3.5, 7.2 OM per hectare	Sandy loam	Decreased	4	15, 19	Tejada and Gonzalez (2008)
Yard waste	25	3.5, 7.2 OM per hectare	Sandy loam	Decreased	4	28, 34	Tejada and Gonzalez (2008)
Yard waste	25	3.5, 7.2 OM per hectare	Sandy loam	Decreased	4	23, 29	Tejada and Gonzalez (2008)

41 treatments averaged 22% bulk density reduction

Kranz et al. 2020

Compost and Water Infiltration

Table 2
Effects of compost material on soil infiltration rate. All studies are in a non-agricultural setting and use some kind of compost and soil incorporation method. No manure compost studies included.

Compost feedstock[a]	Incorporation depth (cm)[b]	Application rate (s)	Soil type[c]	Effect	Time (years)[d]	Percent Change[e]	Reference
Sludge	No data	2 cm	Loam	Increased	1	24	Agassi et al. (1998)
Mixed	60	1 cm	Loam	Increased	3	162	Chen (2015)
Yard waste	20	7.6 cm	Sandy loam	Increased	4	250	Crogger et al. (2008)
Yard waste	5 to 10	5 cm	No data	Increased	4	24	Logsdon et al. (2017)
Yard waste	5 to 10	5 cm	No data	Increased	4	50	Logsdon et al. (2017)
Yard waste	30	5 cm	Sand	Increased	2	189	Mohammadshirazi et al. (2017)
Yard waste	30	5 cm	Sandy clay loam	Increased	2	359	Mohammadshirazi et al. (2017)
Yard waste	30	5 cm	Sandy clay	Increased	2	305	Mohammadshirazi et al. (2017)
Yard waste	30	5 cm	Clay loam (fill)	Increased	2	396	Mohammadshirazi et al. (2017)
Mixed	No data	2:1 soil: compost	Sandy loam	Increased	<1	No Data	Pitt et al. (1999)
Yard waste	20	2.5, 5, 7.5 cm	Loam	Increased	1	74, 100, 137	Weindorf et al. (2006)
Yard waste	20	2.5, 5, 7.5 cm	Clay loam	No significant change	1	–	Weindorf et al. (2006)
Yard waste	20	2.5, 5, 7.5 cm	Clay loam	No significant change	1	–	Weindorf et al. (2006)

18 treatments averaged 115% increase in water infiltration

Compost Incorporation vs. Mulch Application

Unit	Incorporated	Mulch	Control	Source
% percolation of 10" simulated rainfall	52%	85%	42%	Agassi et al. 1998
mm/min. infiltration	2.1 mm	1.7 mm	0.6 mm	Grogger et al. 2008
mm/min. infiltration	1.1 mm	1.0 mm	0.7 mm	Logsdon et al. 2017
time to runoff of 70 mm/h simulated rainfall	27 min.	51 min.	9 min.	Logsdon et al. 2017

10-15 tons/acre (0.25 inches thick) has a significant effect

Compost can be top dressed virtually anywhere, incorporated in highly disturbed areas undergoing restoration

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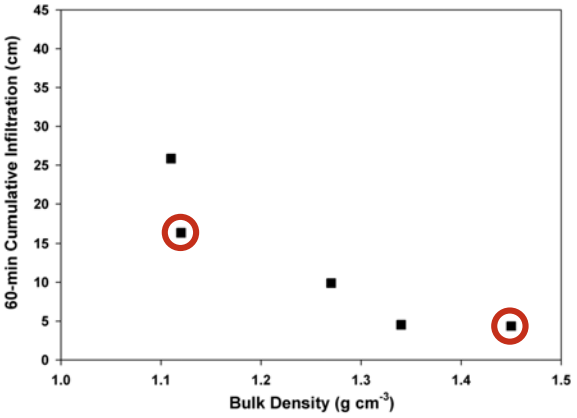
How Important is This?



Bharati et al. 2002

- ¼ inch absorbed over 100 acres is 680,000 gallons or 76 seconds of water currently flowing through the Grand Canyon
- Average US subwatershed is around 25,000 acres
  - ¼ inch absorbed = 170 M gallons
    - = 38 seconds of Mississippi River discharge into Gulf of Mexico

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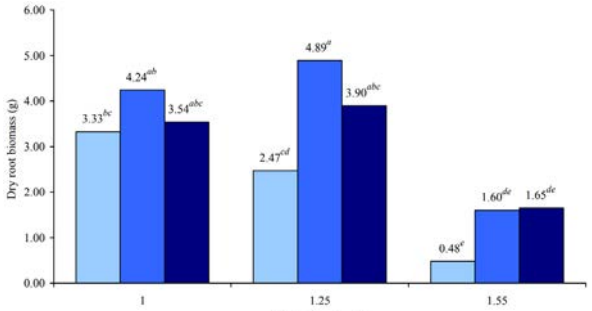
Wide Ranging Impacts



Tokunaga 2006

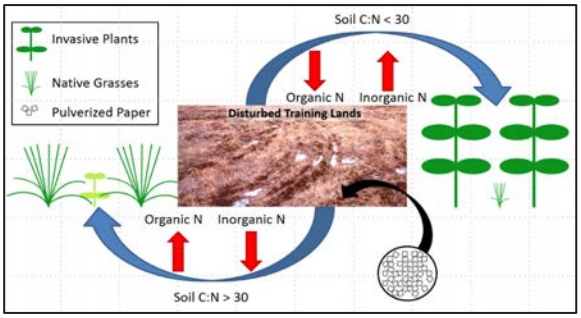
Table 4 Total root length (m) per pot stratum as affected by soil bulk density in Stratum B. Total root length per pot computed by summing Strata means.

Bulk density (Mg/m^3)	Stratum A (0–4 cm)	Stratum B (4–14 cm)	Stratum C (14–24 cm)	Total
0.9	9.6	20.4	3.5	33.5
1.0	12.2	11.2	2.2	25.6
1.1	15.0	10.3	1.6	26.9
1.2	12.8	8.4	0.7	21.9

Houlbrooke et al. 1997

Sometimes Compost is Not the Answer

Compost is not beneficial everywhere
- Too much N can be a detriment
- C:N ratio very important for applicability
  - Too low causes restoration failure and selects for weeds
  - Too high causes plant starvation



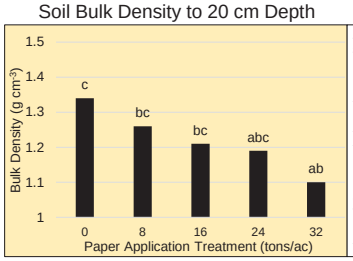
DoD has some very unique, consistent organic waste streams for beneficial reuse
- Highly effective in situations where compost is not

Pulverized Paper- The Secret to Healthy Soils?

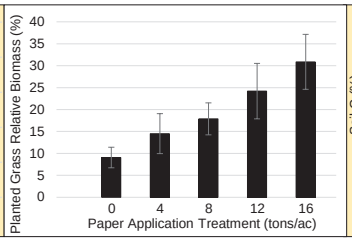
12 months

18 months

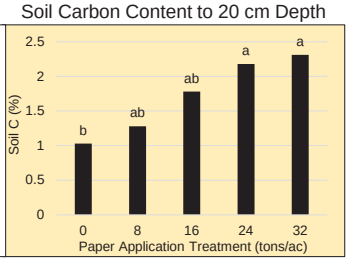
Soil Bulk Density to 20 cm Depth



Relative Planted Grass Biomass



Soil Carbon Content to 20 cm Depth



70 tons/year/installation

DoD has no Shortage of Unique Organic Wastes

TNT shipping boxes from an ammunition plant

- Disposal requires a $$ hazwaste landfill
- Composting breaks TNT ring structure
- Compost can be used for soil cleanup or other needs

Army Food Waste Composting Pilot (2016)

FLW continuous feed, closed loop, 2 cubic yards per day rotary drum system

5:1 landscape to pulped DFAC food waste was ideal to maintain moisture and bulk density levels

Questions?


EWN
Jacobs