



## **Coronado Disasters**

*Investigating Geohazards & Slope Failure Susceptibility Utilizing NASA Earth Observations*

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### **Project Team**

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### **Project Overview**

#### ***Project Synopsis:***

NASA DEVELOP partnered with the National Park Service (NPS) Southeastern Arizona Group (SEAZ) focusing on the Coronado National Memorial (CORO), located in Hereford, Arizona to conduct a feasibility assessment of Earth observations for identification of geohazards and slope failure susceptibility. Leveraging remote sensing methods and data between 2019 and 2023, the study aimed to provide tools to determine the focus for damage mitigation, identify areas most susceptible to slope failures, and prioritize at-risk assets. By providing these tools, the project addresses a critical gap in remediation strategies and aims to enhance the conservation and safety of the region.

#### ***Abstract:***

The Coronado National Memorial (CORO), located in Hereford, Arizona, is situated along the United States' southern border, featuring recently established but still incomplete border barriers roads. This landscape is inherently prone to geohazards, and debris flow due to the steep mountainous topography, complex terrain, monsoonal rains, and freeze/thaw action - and the new infrastructure has exhibited these processes in the form of rockfall, embankment failure, and debris flow. NASA DEVELOP partnered with CORO to conduct a feasibility assessment of Earth observations for identification of geohazards and slope failure susceptibility. Leveraging Earth observations (United States Geological Survey 3D Elevation Program Digital Elevation Model and a locally obtained Light Detection And Ranging-derived Digital Elevation Model) from 2019 to 2023, and geospatial datasets starting from 2008, the study was able to provide tools to determine the focus for damage mitigation, identify areas most susceptible to slope failures, and prioritize at risk assets through three products: change detection maps, slope failure susceptibility maps, and a slope failure prioritization model. With an emphasis on monitoring high-risk areas and prioritizing mitigation efforts, the project addresses a critical gap in remediation strategies and aims to enhance preservation and safety of the region. Results of this study found that (i) the most identifiable areas of change were the road cuts and debris directly adjacent to the roads created for border construction, (ii) areas of highest slope failure susceptibility are

located in mountainous areas with erosive geology, and (iii) roads resulting from border construction have approximately twice the risk of slope failure as roads created by the national park service.

**Key Terms:**

Geohazard, monsoon, slope failure susceptibility, heuristic method, change detection, slope failure prioritization, National Park Service

**Application Area:** Disasters

**Study Location:** Coronado National Memorial (CORO) in Hereford, AZ

**Study Period:** 2019 – 2023

**Community Concerns:**

- The SEAZ management has been concerned with safety and environmental issues related to slope instability and gully erosion. CORO has a history of slope instability exacerbated by seasonal monsoonal storms and burn area scars, creating cause for concern with the border road construction. Project partners initiated this project to respond to already identified hazards (e.g., debris flows blocking natural drainages, rockfall, etc.) and proactively identify future hazards within the CORO, prioritizing those resulting from border road construction.
- Remediation efforts along the border road have thus far included only monitoring. Along the border road, SEAZ has taken repeat photos in conjunction with measurements of gully erosion head cuts and road loss. Identification of slope failure is necessary for the safety of SEAZ personnel, their land management practices, and continued border remediation and construction.

**Project Objectives:**

- Determine focus for damage mitigation
- Identify areas most susceptible to slope failure
- Prioritize safety at most vulnerable assets

**Partner Overview**

**Partner Organizations:**

Organizations	Contact (Name, Position/Title)	Partner Type	Sector
National Park Service, Southeast Arizona Group	Jessica Garcia, Physical Scientist	End User	Federal Government

**Decision-Making Practices & Policies:**

To date, the NPS SEAZ has employed retroactive in-situ monitoring and risk mitigation of slope instability and geologic hazards in CORO, including repeat photography efforts, measurements of slope failure, and obtaining local imagery datasets (e.g., LiDAR and photogrammetry). Project partners receive guidance from the NPS Unstable Slope Management Program, which is an interagency effort to assist in creating an asset-based approach on managing geohazards (“Resource Management and Risk Mitigation”, 2018). This program provides support for retroactive management but emphasizes the importance of proactive efforts to plan for and prevent future hazards, including identification and prioritization of areas prone to future slope instability.

**Earth Observations & End Products Overview**

**Earth Observations:**

Platform & Sensor	Parameter(s)	Use
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<b>USGS 3DEP 10-meter</b>	Slope, Plan Curvature	Parameter layers were used as inputs to the slope failure susceptibility map, the result of which was used as an input to the slope failure prioritization model.
<b>USGS 3DEP 1-meter (2020)</b>	Digital Elevation Model	This was used for the change detection map created by subtracting the 2020 DEM from the 2023 DEM.
<b>Locally Flown LiDAR 10-centimeter (2023)</b>	Digital Elevation Model	This was used for the change detection map created by subtracting the 2020 DEM from the 2023 DEM.

***Ancillary Datasets:***

- NPS SEAZ Digital Geologic-GIS Map of Coronado National Memorial – Field 5 which quantifies erosion risk was used as an input for the slope failure susceptibility map, and therefore the slope failure prioritization model.
- NPS SEAZ Fault Layer – Used to calculate Euclidian distance from faults.
- NPS SEAZ Roads, Border Road, Trails – Used as assets which overlayed the slope failure susceptibility map to create the slope failure prioritization model.
- NPS SEAZ Debris Flow layer – Used to optically validate findings from the end products.

***Software & Coding Languages:***

- Esri ArcGIS Pro 3.2.0 – Used for data processing and analysis.
- Google Earth Engine (GEE) - Used to observe and digitize rock fall occurrences.
- Google Earth Pro – Used for optical qualitative validation.

***End Products:***

End Products	Earth Observations Used	Partner Benefit & Use
<b>Change Detection Map</b>	Locally flown LiDAR (10-centimeter), USGS 3DEP DEM (1-meter)	Change Detection Maps will show landscape change within areas of newly constructed border roads and will be used to determine where to focus damage mitigation efforts associated with this infrastructure.
<b>Slope Failure Susceptibility Map</b>	USGS 3DEP DEM (10-meter)	Maps of Slope Failure Susceptibility will allow the NPS to identify areas within CORO having a high susceptibility for slope failure based on physical properties.
<b>Slope Failure Prioritization Model</b>	USGS 3DEP DEM (10-meter)	A model of Slope Failure Prioritization will allow the NPS to prioritize asset monitoring and mitigation efforts based on areas that are most susceptible to damage from slope failure.

***Product Benefit to End User:***

The project team has identified useful datasets and created products which partners at the NPS SEAZ can implement into their risk mitigation and resource management efforts. The partners will have access to tools with which they can identify focus areas for damage mitigation, categorize inherent susceptibility to slope instability, and prioritize areas of importance. Products provide insight into areas of high-risk slope failures, which should be the focus of in-situ monitoring (e.g., repeat photography efforts and measurements of slope

failure) and be considered for remediation. Additionally, with the methods described in the tech paper, NPS employees can replicate products using future datasets. This future capability is vital to CORO for maintaining safe engagement for visitors, preserving resources, and understanding potential failures during further infrastructure construction.

## References

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National Park Service. (2018, October 4). *Resource Management and Risk Mitigation*. National Park Service. <https://www.nps.gov/subjects/geohazards/managing-risk-and-mitigating-hazards.htm>