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Utah Water Research Laboratory •
Department of Environment & Society

Vulnerabilities Downstream of Dams: A Web-Based Dashboard and Utah Application

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Overview

Dams serve important purposes – water storage, flood control, and hydropower, as well as recreational uses of associated reservoirs. However, dams are aging across the U.S., often exceeding their anticipated lifespan (1,2) (Figure 1). Additionally, the rising likelihood of extreme rainfall events is increasing the threat of dam overtopping (3). Recent dam failure events (e.g., Edenville Dam in Michigan) or close calls (e.g., Panguitch Dam in Utah) draw attention to contemporary risks associated with U.S. dams and the question, *who and what is vulnerable downstream of dams?*

Figure 1: Repairs to El Vado Dam (Built in 1935)

This report highlights a web-based dashboard for visualizing downstream vulnerabilities, draws insights about Utah's high-hazard dams, and invites use of the tool by other state dams, federal agencies, and beyond.

High-hazard dams are defined by the risk they pose to human life (4). While the paramount concern, this singular definition does not address contextual information about human populations as well as critical infrastructure and ecological considerations. To address multi-faceted vulnerabilities downstream of dams, we broadened the lens by applying the Social-Ecological-Technological Systems (SETS) framework (5,6) to map and highlight populations, protected ecosystems, and critical infrastructures within potential dam inundation zones (Figure 2).

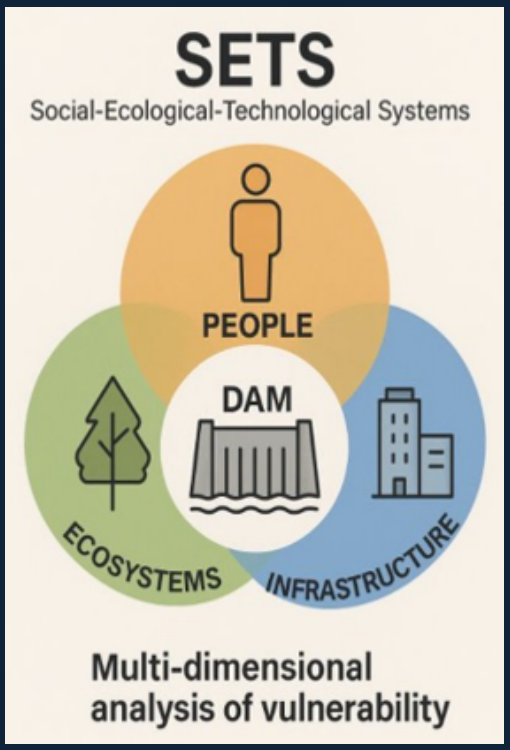

Figure 2: Depiction of Social-Ecological-Technological Systems downstream of dams

Using a SETS framework, we created a web-based dashboard for visualizing vulnerabilities downstream of dams (https://dams.i-guide.io) (Figure 3). This tool provides dam managers, emergency managers, and other interested parties an opportunity to visualize, explore, and compare vulnerabilities associated with any set of dams. The web-based dashboard for visualizing vulnerabilities downstream of dams is hosted on the I-GUIDE Platform, developed to foster exploration of geospatial data related to sustainability and resilience challenges and funded by the National Science Foundation. A matrix approach was used to maintain the capacity to visualize specific vulnerabilities falling within potential inundation zones downstream of each included dam. Guidance for how to navigate the dashboard follows further below.

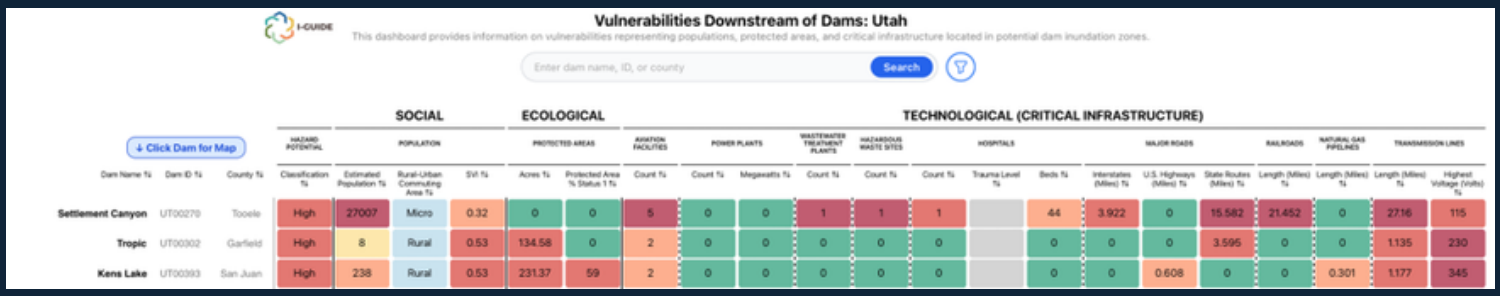

Figure 3: Screenshot of a portion of the web-based dashboard designed to visualize Social-Ecological-Technological Systems (SETS) vulnerabilities downstream of dams

This web-based visualization dashboard was developed using data associated with Utah's 189 state-regulated, high-hazard dams (Figure 4). Estimated potential inundation maps for these dams are publicly available from the Utah Division of Water Rights (7) and provided an initial prototype of this tool. Where multiple inundation zone maps were available, those representing the largest mapped scenario was selected for each dam.

Collaboration with and feedback from the Dam Safety Section of the Utah Division of Water Rights was critical to the creation of the dashboard tool. All involved acknowledge the potential inaccuracies of the inundation zone maps used as they were often produced decades ago using outdated technology. Nevertheless, they represent the available potential inundation information for Utah's dams.

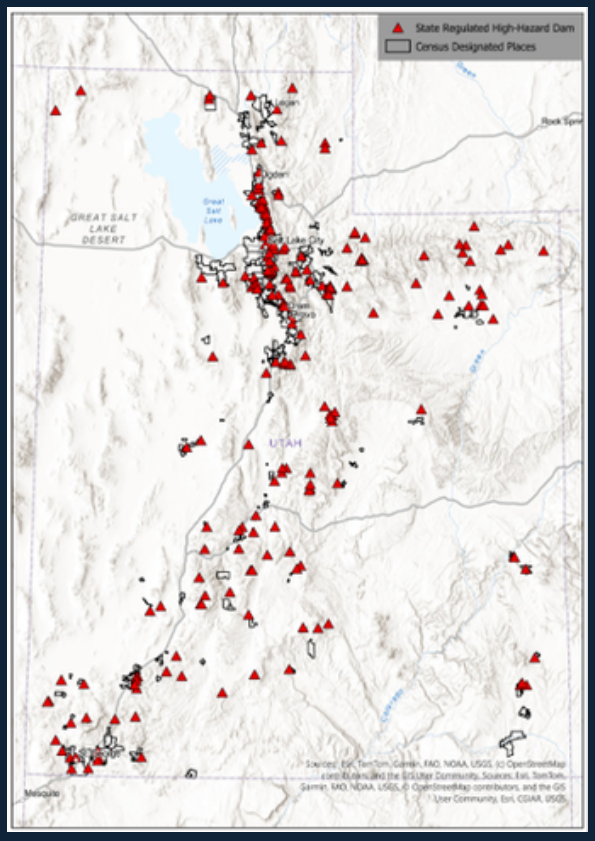

Figure 4: Map of high-hazard, state-regulated dams in Utah

Vulnerabilities Highlighted in the Web-Based Dashboard

To identify potential vulnerabilities, publicly available national databases in 2024 or more recently were used to provide geospatial layers to highlight intersections with potential inundation zones (Table 1). They allow for future reproduction of the project's visualization tools wherever there may be interest across the US. Variables included are listed with sources in the table below.

Table 1: Variables included in the dashboard with sources

Domain	Variable Descriptions	Source
Social	• Estimated population in inundation zone based on census tract intersections • Rural-Urban setting of inundation zone based on Rural-Urban Continuum Codes (rural, micropolitan, metropolitan) • Estimated Social Vulnerability Index Score representing population weighted score for all census tracts overlapping inundation zone. Value 0-1 with higher values representing higher vulnerability.	• US Census Bureau (8) • US Department of Agriculture's Economic Research Service (9) • US Centers for Disease Control and Prevention (10)
Ecological	• Protected area acreage in status 1 or 2 classifications for highest biodiversity protection. • Percentage of protected area acres designated status 1 (highest biodiversity protection)	• USGS Gap Analysis Project, Protected Areas Database (11)
Technological	• Aviation facilities • Power plants and associated megawatts • Wastewater treatment plants • Hazardous waste sites • Hospitals, associated highest trauma level, and total number of beds • Major roads, including interstates, US highways, and state routes (miles) • Railroads (miles) • Natural gas pipelines (miles) • Transmission lines and associated highest voltage	• US Department of Homeland Security, NIFLD Database (Note: no longer publicly available) (12) • US Department of Transportation (13) • ESRI (14)
Dam Attributes & Location	• Dam name, number, county, river or stream, primary owner type, owner names, primary purpose, year, height, storage ac-ft, condition assessment, condition assessment date, EAP prepared, EAP last revision date, RUCA Code for dam location	• US Army Corps of Engineers, National Inventory of Dams (15)

How to Use the Web-Based Dashboard on Vulnerabilities Downstream of Dams

The web-based dashboard on vulnerabilities downstream of dams currently hosts data from Utah dams (Figure 5). The left side of the dashboard shows dam names, dam ID, county of dam location, and the dam's hazard potential classification. There is a search feature at the top to highlight a specific dam using name or dam ID or all dams within a county. The user can scroll to see all available dams. The dataset shown in the initial view includes variables associated with the and social, ecological, and technological dimensions for each dam and an option at the lower right of the screen to take a tour of the dashboard for use guidance and a button to click to send feedback about the dashboard. Exposure levels have been delineated and included.

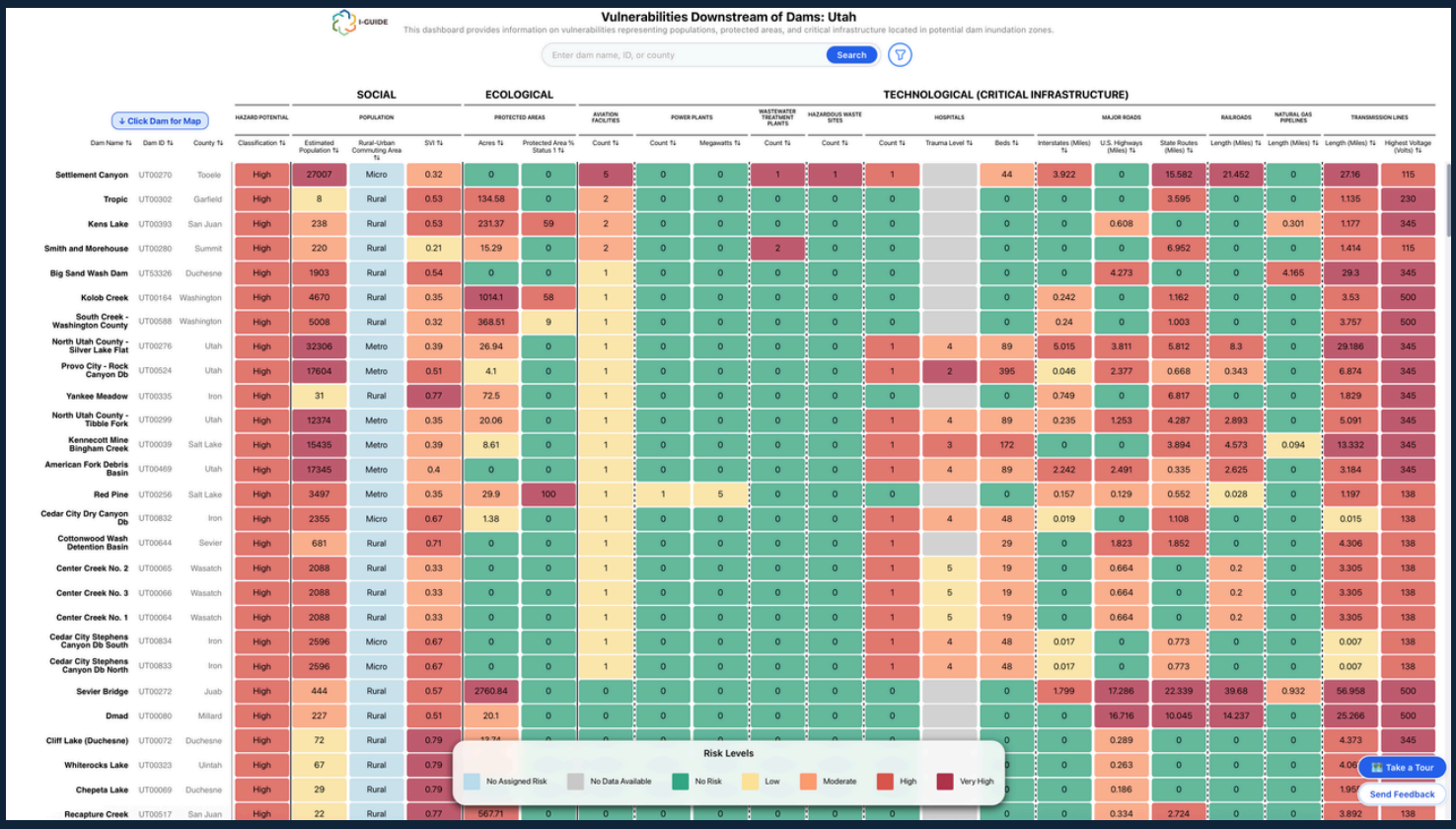

Figure 5: Screenshot of the web-based dashboard designed to visualize Social-Ecological-Technological Systems (SETS) vulnerabilities downstream of dams.

Visualizing Inundation Zones

Another important feature of the dashboard is the mapping of the inundation areas for every dam, showing associated vulnerabilities (Figure 6). These are accessed by clicking on a dam name or ID number.

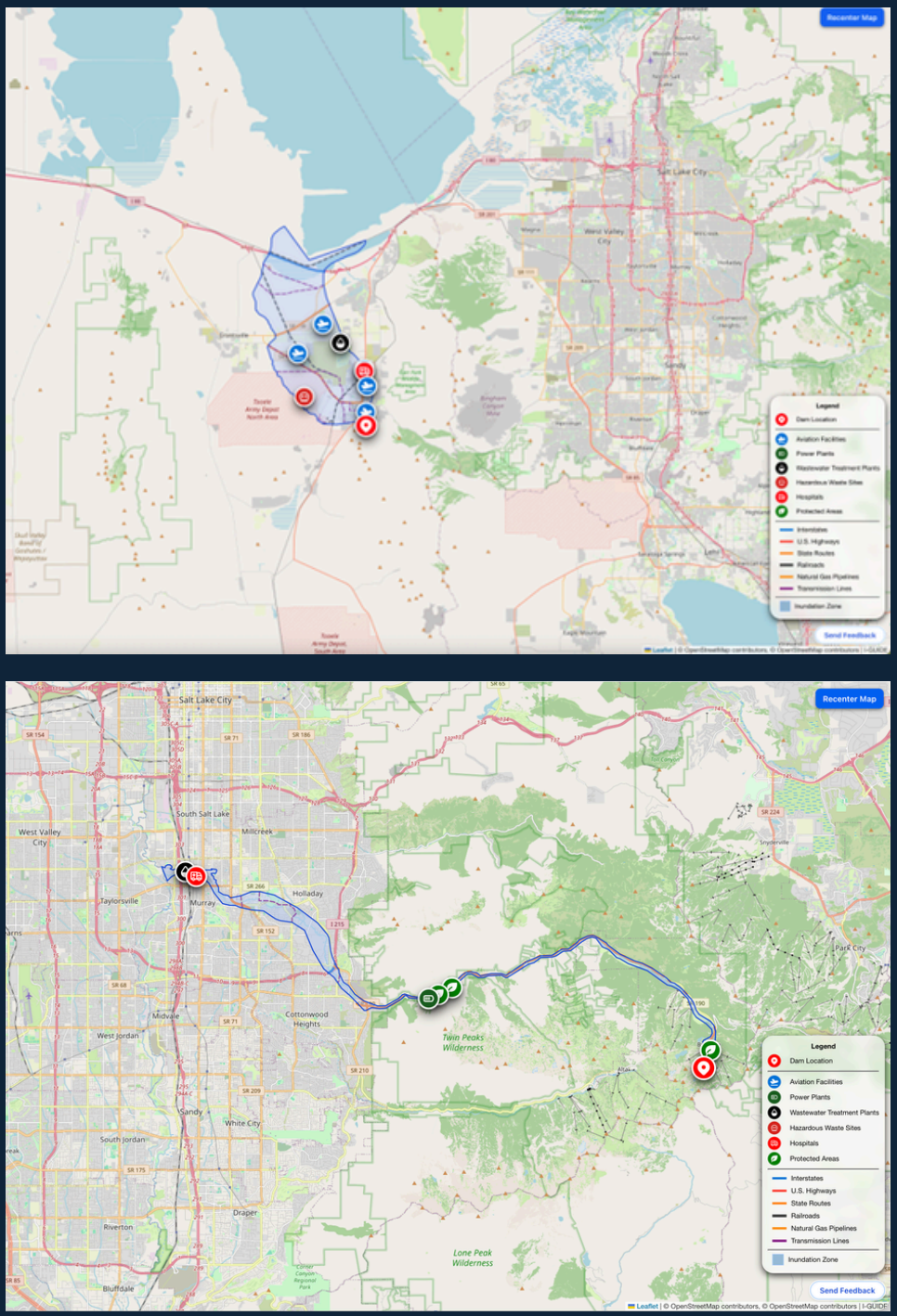

Figure 6: Screenshot of map of the inundation zone and vulnerabilities shown on the web-based dashboard for Settlement Canyon Dam (top) and Lake Mary-Phoebe Dam (bottom).

Findings from Assessment of Utah's State-Regulated, High-Hazard Dams

The dashboard and related underlying dataset provide not only visualization opportunities, but also vehicles for analysis and comparison. The 189 state-regulated, high-hazard dams in Utah are the initial prototype offered through this process. The following represent a few key findings tied to a review of these Utah dams:

- There are complex vulnerabilities downstream of Utah's high-hazard, state-regulated dams, including an estimated 375,973 people, 8,301.97 acres of Status 1 and Status 2 protected areas for biodiversity, and an array of aviation areas, hospitals, hazardous waste sites, powerplants wastewater treatment facilities, and nearly 1,000 miles of roads, railroads, natural gas pipelines, and transmission lines.
- Vulnerabilities downstream of high-hazard, state-regulated dams often include both populations (social vulnerabilities) and critical infrastructures (technological vulnerabilities) (62%). An additional 30% also have protected area acreage in addition to social and technological vulnerabilities, mostly in status 2 acreage. This suggests a need to look beyond the potential for loss of human life to the secondary impacts of possible dam failure.
- The estimated number of people living in potential inundation zones associated with Utah's high-hazard, state-regulated dams varies widely, from 0 to 32,306 estimated people. The settings in which these people live cover rural, micropolitan, and metropolitan settings.
- The social vulnerability of people living in inundation zones associated with Utah's high-hazard, state-regulated dams is estimated to be higher for those in rural settings, followed by those in micropolitan areas, with those in metropolitan areas having the lowest estimated social vulnerability. This suggests there may be varying degrees of response capacity associated with those facing the threat of dam failures.
- Critical infrastructures most often found in inundation zones associated with Utah's high-hazard, state-regulated dams are network infrastructures such as transmission lines, major road networks, rail lines, and natural gas pipelines. This suggests that there could be cascading impacts from dam failures that could affect large regions beyond potential inundation zones due to the network connections of these infrastructures.

Additional findings related to Utah's high-hazard, state-regulated dams can be found in the Master's project of Michael Englert in USU's Digital Commons repository (16).

Summary and Opportunities for Future Use of the Dashboard Tool

This short report summarizes the web-based dashboard produced to visualize vulnerabilities downstream of dams, with specific use of data from Utah's high-hazard, state-regulated dams. The Social-Ecological-Technological Systems approach used to explore vulnerabilities downstream of dams reveals more complexity than the typical emphasis on potential loss of human life.

The dashboard produced to visualize these vulnerabilities and prototyped with data from Utah's high-hazard, state-regulated dams is a potential resource for other states, federal agencies, or private entities. This dashboard can be reproduced for any set of dams in the US that have geospatial data for their potential inundation zones. Some geospatial processing may be needed for inundation zones without clearly delineated boundaries, but that is possible. For any entity wishing to visualize data, but without public access, a secure version of the dashboard is available.

In addition to the web-based dashboard, our team has also assembled matrix tools for visualizing dam attributes, land cover types within potential inundation zones, and the potential for extreme precipitation in dam locations. These tools are produced using ArcGIS and R and projects to expand this work in new ways can be discussed by contacting the lead author of this report.

Check out the dashboard here →

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(12) https://geodata.bts.gov/datasets/usdot::north-american-roads/about

(13) https://www.arcgis.com/home/item.html?id=d4090758322c4d32a4cd002ffaa0aa12#overview

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