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Assessing Flood Risk to Critical Infrastructure of Ohio Valley Inland Airports

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Abstract: This paper uses a Geographic Information System (GIS)-based Flood Simulation Analysis in ESRI ArcGIS Pro (Version 3.4) to evaluate flood vulnerability of seven inland airports in the Ohio River Valley under two extreme precipitation scenarios: a short-duration flash flood (10 inches over 5 hours) and a longer duration regional event (16 inches over 24 hours). Recent increases in the frequency and intensity of heavy rainfall events have contributed to growing disruption risks for infrastructure, including airports and airport operations. While prior research has focused primarily on coastal airports exposed to storm surge and sea-level rise, inland airports are also vulnerable to flooding and require further study. Using the Flood Simulation Analysis Tool, planning-level analysis was conducted to assess inundation and potential impacts on critical infrastructure including runways, taxiways, access roads and ramps. Research findings show that all airports studied exhibit varying degrees of vulnerability, with smaller and lower-lying airports generally experiencing greater surface water accumulation on operational surfaces. Because this initial model does not incorporate drainage, infiltration or evaporation, results represent conservative, worst-case accumulation scenarios driven by precipitation and local topography. This research demonstrates the value of using widely available GIS tools for conducting screening-level assessments of airport flood vulnerability. This approach provides a consistent framework for identifying infrastructure most susceptible to inundation and can be used to support early-stage resilience planning for airports.

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Introduction

Airports are critical infrastructure, and any disruption to airport operations can have significant negative impacts on airport users and the communities they support. Weather is a leading cause of airport disruption, and airport resilience is increasingly recognized as an important area for investigation. One kind of weather disruption is flooding, and, unfortunately, airports may be increasingly vulnerable to this threat since the number, intensity, and magnitude of hazardous flooding events have been increasing exponentially in recent years. While the implications of climate change on flood magnitude and frequency remain controversial, research shows that flooding events now involve significantly higher rainfall intensities (the rate of rainfall in a period of time, such as two inches per hour) and volumes (the total amount of water in the storm event, such as five inches) (e.g., Meresa et al., 2022; Davenport et al., 2021; Quan et al., 2021; Yu et al., 2015; Kundzewicz et al., 2013). This increase in rainfall intensity and volume is linked to higher evaporation from ocean surfaces and the atmosphere holding more water vapor due to higher temperatures (Trenberth, 2011). These conditions are causing 100-year and 500-year flood events to occur more frequently, making the nominal probability assessments invalid (Mann, Peterson, & Hassol, 2017).

While industrialized countries experience lower death tolls from floods compared to developing countries, the cost of these events continues to rise (Bubeck et al., 2019; Brody et al., 2007). In developed nations such as Great Britain, flooding is the greatest risk to national infrastructure (Pant et al., 2018). The monetary damage relates to the amount and type of infrastructure impacted and the resilience of the infrastructure. Resilience can be enhanced by prevention measures like retention ponds, barriers, flood zoning, and building codes, all of which reduce damage costs (Mitsopoulos et al., 2022; Vousdoukas et al., 2020). Research shows every dollar spent on mitigation saves sixfold or more in future damages (United Nations, 2019; National Institute of Building Sciences, 2020). Damage and costs from storms and floods have significantly increased, contributing to a threefold rise in losses from 1980 to 2015 (Hoeppe, 2016).

Coastal infrastructure faces elevated vulnerability due to rising sea levels and storm surges driven by both tropical and mid-latitude cyclones. Recent literature models general flood risks (e.g., Mohseni et al., 2025; Abdo et al., 2025; Mahasneh et al., 2025) and coastal threats to existing infrastructure (e.g., Najafi et al., 2021; Lorie et al., 2020), including airports (e.g., Assab, 2023; Lindbergh et al., 2022; Yesudian and Dawson, 2021; Griggs, 2020). Airport resilience is important not only because airports are important infrastructure serving transportation and mobility, but also because many airports are located in low-lying and coastal areas that provide a wide expanse of flat land. These areas are ideal for long runways and supporting airfield infrastructure, and allow aircraft approach and landing trajectories over water, which reduces landside obstacles and mitigates the impact of aircraft noise. These locations also ensure airport infrastructure is close to the cities they serve since ten percent of the population lives in the Low Elevation Coastal Zone (LECZ) (Yesudian and Dawson, 2021). Ensuring the continuity of airport operations and assessing the resilience of airports is important since airports serve as critical hubs that move people and goods, support economic activities, and provide essential lifelines during emergency situations.

To evaluate how these vital airport assets withstand extreme weather, this paper introduces a planning-level framework to assess airport flood vulnerability of inland airports to extreme flooding events. Specifically, this research uses the Flood Simulation Analysis Tool in ESRI ArcGIS Pro (Version 3.4) to model operational resilience across two storm scenarios, using a diverse selection of airports in the Ohio River Valley as example case studies. The primary objectives are to simulate the impacts of both short-duration flash flood and longer-duration regional flood scenarios, assess how these events affect airport infrastructure and inferred operations, and illustrate how the use of flood simulation can provide a consistent, screening-level framework as a first step in resiliency planning and mitigation.

Background

Many airports have master plans to guide future development, and some have sustainability plans to balance operational needs with environmental, social, and economic considerations. Although airports are critical infrastructure, most do not have a resilience plan, particularly in the United States (U.S.). Large airports in coastal regions and airports that have experienced flooding may have undertaken activities to support resilience; however, there has been minimal assessment for airport resilience for inland and smaller airports. In 2021, FAA initiated a project to improve airport resilience, including a proposed Airport Resilience Assessment Framework (ARAF) (FAA, 2024a) although there are currently no published resources for all airports. While flooding can affect airports of all sizes, more general aviation (GA) airports are affected because there are more GA airports. There are 390 primary airports, which focus on passenger service and 2,897 nonprimary airports which primarily serve GA. It is easy to underestimate the importance of GA airports; however, their importance was highlighted when catastrophic flooding triggered by Hurricane Helene moved inland from the coast. The aftermath of this storm exposed the vulnerability of inland airports. The necessity of airport infrastructure for the movement of emergency relief supplies was critical when many roads and bridges were washed out, hampering relief efforts; unfortunately, many airports were also unusable due to flooding and storm damage. This demonstrates the critical need for the resilience of inland airports and the value of modeling the consequences of severe storms.

Vulnerability to hazard events such as significant rainfall, combined with the increasing frequency of catastrophic flood events, highlights the importance of evaluating airport resilience. It has been suggested that airport resilience can be addressed in a four-step process: 1) identify threats and hazards, 2) conduct an airport risk and vulnerability assessment, 3) select measures to mitigate the risk, and 4) identify delivery methods and financing options for the mitigation measures (Gale and Der Westhuizen, 2023). The research presented in this paper identifies tools that may be used to support this process and explore the vulnerability of inland airport locations through modeling and simulated flooding analysis.

FAA Advisory Circular 150/5320-5D Airport Drainage Design (FAA, 2013) provides extensive information about surface hydrology; pavement drainage; culvert, channel, and storm drain design; drainage structures, pipes, and storm water control features; and computer programs that may support design activities. This AC was developed with the Department of Defense (DOD) and incorporates the DOD draft document Surface Drainage Design, dated 2006. The Airport Drainage Design AC discusses over 20 computer programs and methods to support drainage design, however, there is not a prescriptive approach or required methodology. In many cases, airport drainage considerations are also affected by local ordinance, especially for airports in cities and developed areas; airport drainage design and resilience planning must meet FAA requirements as well as local code.

Research Question

This study investigates the following research question: How do extreme precipitation events of differing duration and intensity affect the operational resilience of inland airports of varying size and function in the Ohio River Valley, as approximated using a GIS-based flood simulator to provide estimates of water inundation that can be used to estimate operational impacts and airport resilience? To address this question, two objectives are identified:

1. Evaluate the application of a GIS-based flood simulation model to conduct a screening-level assessment of airport resilience under extreme, short-duration flash flood conditions.
2. Evaluate the same modeling approach for assessing airport resilience under a long-duration regional flood scenario.

The study focuses on seven inland airports in the Ohio River Valley representing a range of sizes and functional roles. For each airport, the analysis examines the impacts of both flash flood and regional flood scenarios on key infrastructure components, including airside infrastructure (e.g., runways, taxiways, and ramps) and landside infrastructure (e.g., access roads). Flood impacts are characterized using the Flood Simulation Tool in ArcGIS Pro to estimate inundation extent and its implications for operational disruption. This approach provides a consistent, screening-level methodology for comparing vulnerability across different airports and flood scenarios. In this study, operational resilience is not directly measured but is inferred from the presence and depth of water on critical infrastructure components.

The results of this research illustrate how widely available GIS tools can support airport planners and operators in assessing the resilience and vulnerability of an airport, or system of airports, to enable more informed decision-making and so that appropriate mitigation plans can be put in place. While the GIS-based flood simulation tool could potentially be used for a more detailed assessment which could potentially include the potential for structural damage, this application is beyond the scope of this research.

Methodology

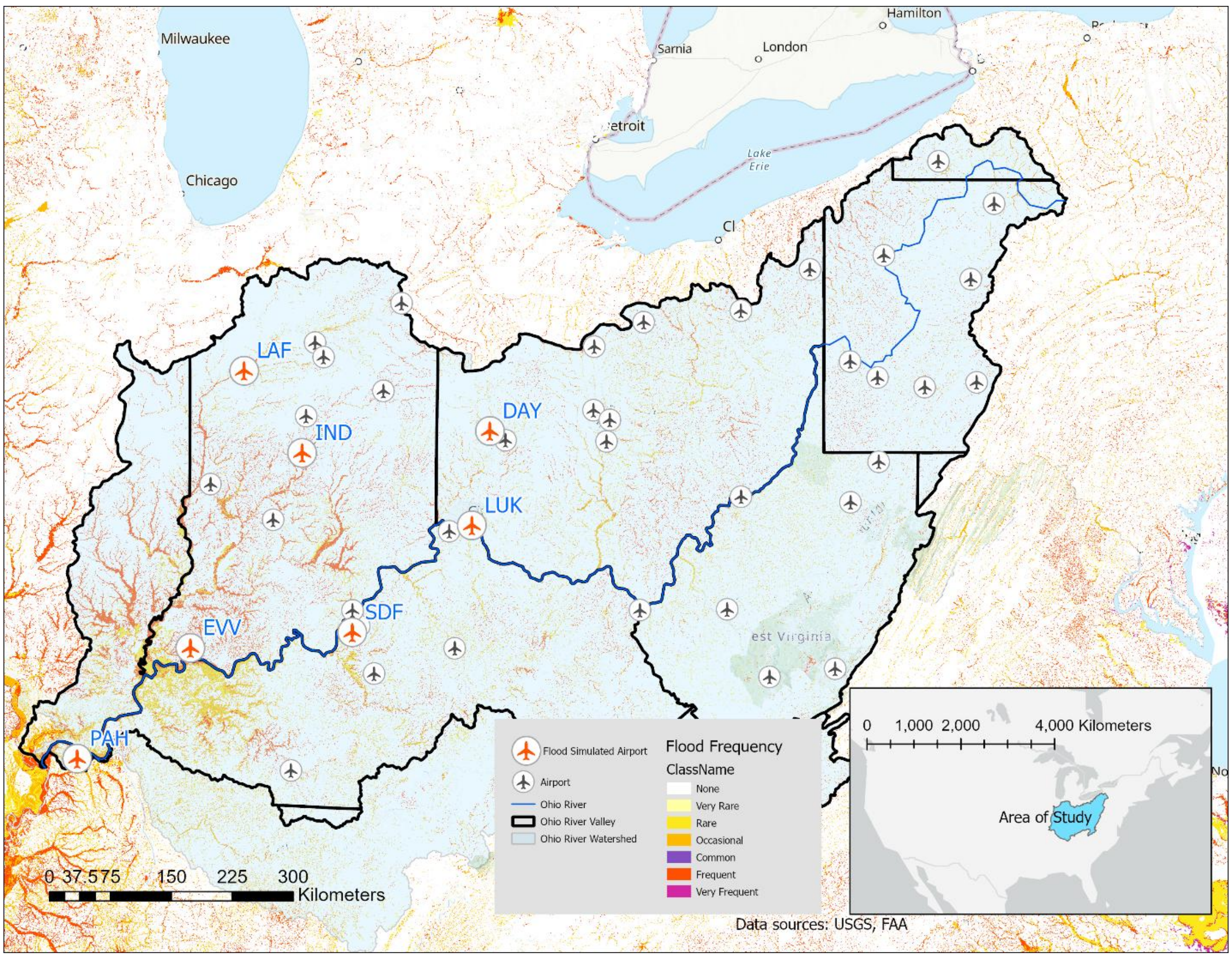
The methodology includes the study area, the selection of airports, the identification of appropriate data sources and processing methods, and the identification of appropriate parameters to use in the flood simulation modeling.

Study Area: The Ohio River Valley Watershed

The study area is the Ohio River Valley, situated south of the Great Lakes and north of the Appalachian Mountains, as shown in Figure 1. This area is known for both agriculture and industry. Agriculture thrives in the numerous river valleys on formerly forested Alfisol soil types and is more prevalent in the northern region (White et al., 2023). Light to heavy industrial land uses are located along numerous tributary rivers feeding the Ohio River, with more heavy industry along the Ohio River, which is 981 miles (1,579 km) in length and drains a watershed of 203,739 sq miles (528,200 sq km). The region has over 40 airports, including primary airports that serve commercial passenger service and general aviation (GA) airports that serve business and general aviation.

Figure 1

Location of Airports Chosen for Simulated Flood Analysis Shown and Other Airports within the Ohio River Valley



This area is dominated by majority tributaries including the Wabash within the Ohio River watershed. The region has experienced both widescale regional flooding in its lower reaches and rapid-onset, high-magnitude flash flooding events, which are especially prominent in the southern region (Atreya et al., 2024). Cities and industry are mainly concentrated along the Ohio River and the larger tributaries that feed into it (Adams and Dymond, 2019). These low-lying areas are attractive for development and are also susceptible to flooding, especially in the lower portions of the Ohio River valley. Airports in these low-lying areas may be particularly vulnerable to disruption from flooding.

Airports of all sizes are affected by flooding in the Ohio River Valley, and airports may experience flooding due to geologic features (e.g., karst drainage), elevation, local topography, and a lack of adequate drainage infrastructure. Karst drainage refers to a subsurface drainage system in which water rapidly infiltrates and flows through dissolved limestone features such as sinkholes, fractures, and underground channels, rather than remaining on the surface. Flooding of a runway or taxiway presents obvious problems and will disrupt operations; however, flooding of the ramp, fuel farm, storage buildings, navigational aids, access roads, and even grassy areas can also cause problems.

One national GA reliever airport (not in the sample for this study) is located in the floodplain near a river and experiences flooding of the access road that serves the navigational aids (navaids) and a building. This causes problems with the operation of the navaids, presents challenges for inspection and maintenance activities, and makes the building inaccessible. Given that national airports often have 100 to 300 based aircraft, an interruption of service due to flooding can have significant implications. At this airport, the runway safety area (RSA, which surrounds the runway on all sides) also experiences flooding, which is a safety issue since a flooded RSA may not be able to withstand the weight of an aircraft in the event of a runway excursion. High-velocity flows associated with flooding may result in conditions that compromise usability (washouts, sink holes, furrowing, and other damage). Although structural damage is not evaluated in this model, it is relevant to note the kinds of problems that flooding on airports can cause.

While wide open and flat spaces are ideal for landing aircraft, these flat spaces may cause airports, even airports at higher elevations, to experience localized flooding on some portions of the airfield. Discussions with airport managers and airport consultants in the Ohio River Valley indicate that standing water on the airfield and near the airfield (even outside the airport fence) may also contribute to problems with wildlife management, since standing water attracts birds, which pose a significant risk to aircraft operations. The safety risk associated with wildlife at airports was famously demonstrated by the dramatic landing of US Airways Flight 1549 in the Hudson River by Captain Sullenberger in 2009. Another problem for airports in the Ohio River Valley is drainage issues due to aging infrastructure, accumulated debris, and joint failure. Aging drainage pipes may require replacement or relining. Accumulated debris may include sediment and, in some cases, trash. Airports may also have flooding problems due to drainage issues on adjacent land or upstream.

Airport Selection

A sample of seven airports was selected from the Ohio River Valley, as shown in Figure 1. All airports in the sample are included in the National Plan of Integrated Airport Systems (NPIAS), which includes 3,247 airports that are vital to national interest (FAA, 2024b). Primary airports are categorized by the number of boarding passengers (aka enplanements) and include large hub (e.g., Chicago O'Hare), medium hub (e.g., Indianapolis), small hub (e.g., Dayton) and non-hub airports (e.g., Toledo). Non-primary airports do not serve large volumes of commercial passengers and include GA airports which serve smaller metropolitan and rural areas and support various activities like agriculture, medical services, emergency response, disaster recovery, flight training, recreation, tourism, and local economic development. GA airports are designated National, Regional, Local, and Basic based on their impact.

Selected airports for this research include primary airports (IND, SDF, DAY, EVV) as well as non-primary airports (PAH, LUK, LAF) and represent a variety of locations within the Ohio River valley and a range of airport characteristics, as shown in Table 1.

Table 1

Airports Selected for Flood Modeling within Ohio River Watershed

Airport	Code	Category Designation	Cargo airport (US rank)	Passenger Enplanements	Comments
Indianapolis Intl, IN	IND	Medium Hub	Yes 3580k short lbs[1] (8)	4,788,333	All major air carriers, and cargo operations for Fed Ex
Louisville Muhammad Ali Intl KY	SDF	Small hub	Yes 8753k short lbs[1] (3)	2,268,006 1,893,647[2]	All major air carriers, and cargo operations for UPS Worldport
Dayton Intl OH	DAY	Small hub		594,174	Major air carriers, and headquarters for PSA Airlines (American Eagle carrier)
Evansville Regional IN	EVV	Nonhub		165,186	Air service provided by Allegiant Air, American Eagle, Breeze and Delta Connection
Barkley Regional, West Paducah KY	PAH	Nonhub		13,057	Air service provided by Contour
Lunken Field, Cincinnati OH	LUK	GA – National		2,021[2]	Serves as reliever airport for CVG, Cincinnati/Northern Kentucky Airport
Purdue Univ, West Lafayette IN	LAF	GA – Regional		2,245	Supports flight training, serves Part 135 passenger service (Southern Airways) and cargo shipments to support local manufacturers (e.g., Caterpillar and Subaru)

[1] *landed weight, per (BTS, n.d.)*
[2] *in CY 2022, per (ACAIS, 2023).*

Some of these airports play an important role in cargo movement. IND and SDF both rank in the top ten in cargo served in the US due to FedEx and UPS operations, respectively.

Airports can serve an important role for cargo even if they serve a relatively small volume of cargo. For example, LAF is not a cargo airport, however, valuable cargo is often flown in to support local manufacturing activities at Caterpillar and Subaru; rapid delivery of parts for manufacturing is critical since downtime can cost hundreds of thousands of dollars per hour.

Data Tools: GIS

Geographic Information Systems (GIS) have long been used in flood simulation modeling. Traditionally, flood simulations for coastal locations were performed by simple raster math where sea level rise was modeled by adding height to a digital elevation model (DEM). Simulated flood research for inland fluvial drainage networks also leveraged hydrologic modeling, in which floodplain surfaces were added to an existing stream network to simulate how rising stream levels impacted floodplain surfaces. Early flood models were constrained by coarse ground sample distance (GSD), or pixel resolution, that hampered the accurate determination of flood surfaces at the macro scale level. Historically, simulating a precipitation event required the user to model flood surfaces based on the rise of the water body and predictions of how much precipitation would be needed to generate that rise. Recently, the widespread availability of LiDAR Digital Terrain Model Data at GSD values of a meter or less and computational abilities that allow for more robust modeling, make it possible to simulate flood events by modeling hourly precipitation rates over a set timed period. This allows simulation of both localized sudden onset flash flood events of high magnitude over several hours, and regional widespread flooding events over longer durations.

Data Sources and Processing Methods

Airport locations and attribute data were downloaded as shapefiles from the FAA spatial data portal (FAA, 2018). Flood frequency raster data layers based upon elevation information were obtained from the ESRI Online Living Atlas (ESRI, n.d.). Flood frequency data was not used in the flood modeling but was used to support airport selection. Airport size, use, and location in terms of flood frequency were used to identify sample airports to model.

To determine precipitation amounts for regional and flash flood scenario, meteorological and climatic records were analyzed for states within and in proximity to the Ohio River watershed (please see Table 2). Record 24-hour totals in these states range from 10.50 inches in Indiana in 1905 to 20.73 inches in Tennessee in 2021; most state records are between 11 and 14 inches (National Centers for Environmental Information, n.d.).

The flash flood scenario (Objective 1) reflected a rainfall of 10 inches (254 mm) over 5 hours, which is equivalent to a sustained rate of 2 inches per hour. While this magnitude over such a short duration has not been widely recorded within the specific study area, comparable events have occurred in the broader region — over 12 inches fell from a single storm event lasting several hours in the Ohio Valley in 1997, and more than 2.5 inches per hour were recorded during a 2006 storm in Southern Indiana (National Weather Service, n.d.a). The regional flood scenario (Objective 2) reflected a rainfall of 16 inches (406 mm) over 24 hours, a value consistent with the upper range of documented 24-hour precipitation records in the region and intended to simulate a high-end, regionally significant rainfall event.

Table 2

Record 24 Hour Precipitation of States Containing Streams within the Ohio River Watershed

State	Region/Area Impacted	Precipitation Amount (Inches)	Date
Illinois	Aurora	16.91	July 18, 1996
Indiana	Princeton	10.50	August 6, 1905
Kentucky	Mayfield	11.28	July 18-19, 2023
Ohio	Shelby County	10.75	August 7-8, 1995
Pennsylvania	York Pump Station	13.75	June 22, 1972
Tennessee	McEwen	20.73	August 21, 2021
Virginia	Williamsburg	14.28	September 16, 1999
West Virginia	Mellen	11.72	June 24, 1996

Source: National Centers for Environmental Information (n.d.)

These values were selected not to mirror any specific historical event, but to represent plausible stress-test scenarios for comparative resilience planning, in accordance with the study's goal of identifying which airport infrastructure elements are most vulnerable under extreme conditions (US EPA, 2025). Both scenarios are intended to bracket the range of extreme precipitation mechanisms that airports in the Ohio River Valley may face: short-duration flash flooding and longer duration regional inundation.

While receiving 10 inches of rain in 5 hours is extremely rare, this magnitude was chosen to simulate severe surface water accumulation on airfield infrastructure. Historical precedents in the region provide evidence that these high-volume events are possible. For example, over 12 inches of rain fell during March 1997 Ohio River flood, and more than 2.5 inches of rain fell in one hour at Leavenworth, Indiana, in September 2006 (National Weather Service, n.d.a; National Weather Service, n.d.b). Outcomes of flood events are related to a variety of other factors including surrounding land cover, existing river levels, water table heights, permeability rates, and soil saturation levels. The flood simulations performed with this model were intended to investigate airport resilience and model how high amounts of precipitation would affect existing airport infrastructure and were not intended to mirror or simulate conditions for any specific flooding event.

Flood Simulation Model Parameters

Flood simulations were conducted using the Flood Simulation Analysis Tool in ESRI ArcPro Version 3.4. The tool is available to advanced users and uses the highest resolution available base elevation data in the simulator analysis. In the United States, and within populated areas where airports are located, this resolution is often sub-meter or better. The simulator tool uses shallow water equations in an area defined by the user to model how water moves and accumulates within an ArcPro 3D scene. A 3D scene in ArcPro is one where Z elevation models provide for the ability to engage in 3D modeling analysis. The flood simulator tool is unique in the fact that precipitation amounts can be entered into the model as a rate per hour (e.g., inches/hour or mm/hour). The model also allows for adjusting the rainfall rate over a given period of time to model changing intensities in a storm event. Other model variances include the ability to change the model cell size, ground infiltration rates, evaporation rates, and starting water levels. Water is introduced into the model through setting rainfall amounts, or by a water source rate, such as where dam failure or a canal breach may have occurred. By default, the model utilizes the best available digital terrain data available for the given area; digital terrain raster cell values in this study were 3.3 feet (1.0 meter) or better. The model also provides the ability to model flow barriers and drainage channels, which offers promise for future modeling and analysis for airports.

In the ESRI ArcGIS Pro (Version 3.4) Flood Simulation Analysis Tool, infiltration rate, evaporation rate, starting water level, and drainage parameters are all user-defined, optional inputs (ESRI, 2025). When left unspecified, these parameters are not applied by the model — that is, no default drainage, infiltration, or evaporation value is automatically substituted. All rainfall input therefore accumulates on the surface and flows according to topography and shallow-water equations, without any subsurface absorption or evaporative loss (ESRI, 2025). As a result, modeled outcomes reflect surface accumulation driven solely by precipitation input and terrain, rather than drainage system performance. Because the airports selected for this study vary significantly in soil type, land cover, pavement condition, and drainage infrastructure, applying a uniform infiltration rate across all locations would introduce assumptions that cannot be supported by available data. Therefore, infiltration, evaporation, and starting water levels were intentionally left unspecified so that the differences in simulated flood accumulation would reflect the differences in surface topography and airport geometry rather than the assumed drainage parameters. This approach is consistent with the tool's design as a rapid, planning-level flood simulation tool intended for initial resilience screening and is not a replacement for site-specific engineering analysis (ESRI, 2025). Results should be interpreted as a conservative, worst-case scenario in which drainage infrastructure is absent or ineffective, resulting in the maximum plausible surface water accumulation under the simulated precipitation events. The approach used in this paper is consistent with ESRI Official Technical Paper (ArcGIS Pro 3.6, November 2025) which describes the model's continuity equation where infiltration (F) and evaporation (E) are externally supplied parameters. When not supplied, they are absent from the calculations. The ESRI paper characterizes the tool used in this way as a "rapid and approximate simulation tool" for "initial insight" and "initial geo-design and exploration," explicitly distinguishing it from engineering tools.

The flood simulator model requires the user to define an area of interest in a 3D scene. For each simulated area, the area was selected to include all existing airport infrastructure, including airfield, terminals, landside and support roads. After the area was selected, flash flood scenarios are simulated by introducing two inches (50.8 mm) every hour for 5 hours. The regional flood scenario was simulated by engaging 0.67 inches (38.1 mm) of rain per hour over 24 hours. The flood simulator provides real-time results of the flood occurrence, with the ability to rewatch the flood at up to 3X the actual speed. The results of the flood can also be exported as individual rasters that record actual flood levels, water depth, and flood velocities at determined time intervals. For this study, flood rasters were exported for each hour of the flood, and at 3.3 foot (1.0 meter) Ground Sample Distance (GSD) resolution for consistency.

While the model allows for increasing and decreasing precipitation over the duration of a rain event, it was determined that dividing precipitation evenly across the rainfall event was suitable for this study. Future research could simulate flooding at targeted locations for specific hazardous flood events, incorporating additional factors such as variable precipitation intensities, infiltration rates, evaporation, and pre-existing water levels. All reported flood depths represent maximum localized values derived from the raster outputs and do not imply uniform inundation across airport surfaces.

Assessment of Impact on Airport Infrastructure

There is no standard definition for airport resilience, and as previously mentioned, FAA is currently working toward developing additional guidance on this topic. In this paper, airport resilience is evaluated by estimating the extent to which airport infrastructure and operations would be impeded by the presence of water. This is not a straightforward assessment. Different aircraft have different capabilities to traverse water, and there is no standard reference for defining allowable water depths for landing or taxiing.

The Runway Condition Assessment Matrix (RCAM) is shown in Figure 2 and provides a useful reference for operational conditions. The RCAM specifies that a runway is reported as condition 6 (best braking action) when dry, condition 5 (associated braking action is good) when wet or damp with 1/8 inch or less of water, and condition 2 (associated braking action is medium to poor) when water depth exceeds 1/8 inch. Runway condition is reported as three values that correspond to each third of the runway, since conditions may vary over the runway length (e.g., a mile or more). For example, a dry runway is reported as 6/6/6, while a runway with 1/2 inch of water is reported as 2/2/2. A rating of 2/3/3 would be used if the first third of the runway has 1/8 inch (or more) of water, while the center and last third are wet. For comparison, more than 1/8 inch of dry or wet snow would result in a condition of 3 (medium braking action) for the affected segment. The RCAM does not distinguish between 1/4 inch and 6 inches (or more) of water on the runway, since anything greater than 1/8 inch can cause hydroplaning.

Although the Airport Snow and Ice Control Plan would include a defined threshold that would trigger runway closure, there is no analogous requirement for closure based on water depth. This may reflect the fact that runways are typically designed with drainage systems to prevent flooding. Airports that are prone to flooding may have established procedures as part of the Airport Emergency Plan; however, this is not a standard requirement per FAA. Ultimately, the decision to close a runway or taxiway due to unsafe conditions caused by flooding is based on the judgement of airport personnel. In some cases, portions of the airfield may remain operational while other portions are closed (e.g., flooded runways or taxiways).

Figure 2

Runway Condition Assessment Matrix

Assessment Criteria		Downgrade Assessment Criteria		
Runway Condition Description	**Code**	**Mu (μ) [1]**	**Vehicle Deceleration or Directional Control Observation**	**Pilot Reported Braking Action**
• Dry	6	40 or Higher	---	---
• Frost • Wet (Includes Damp and 1/8 inch depth or less of water) ***1/8 inch (3mm) depth or less of:*** • Slush • Dry Snow • Wet Snow	5	40 or Higher	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	Good
5° F (-15°C) and Colder outside air temperature: • Compacted Snow	4	39 to 30	Braking deceleration OR directional control is between Good and Medium.	Good to Medium
• Slippery When Wet (wet runway) • Dry Snow or Wet Snow (Any depth) over Compacted Snow ***Greater than 1/8 inch (3mm) depth of:*** • Dry Snow • Wet Snow ***Warmer than 5° F (-15°C) outside air temperature:*** • Compacted Snow	3	39 to 30	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	Medium
Greater than 1/8 (3mm) inch depth of: • Water • Slush	2	29 to 21	Braking deceleration OR directional control is between Medium and Poor.	Medium to Poor
• Ice [2]	1	29 to 21	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	Poor
• Wet Ice [2] • Slush over Ice • Water over Compacted Snow [2] • Dry Snow or Wet Snow over Ice [2]	0	20 or Lower	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	Nil

Given the lack of objective standards for airport resilience with respect to flooding, the objective of this research is not to define a threshold for resilience, but rather to demonstrate the value of a GIS based tool for planning-level assessment and to foster further dialogue regarding airport resilience. Accordingly, this research combines quantitative estimates of water presence and depth with qualitative interpretation of the operational implications.

Using the results of the flood simulator tool, impacts on runways, taxiways, access roads, and ramps were assessed and categorized into the following four categories: Unrestricted, Minor, Major and Severe. This qualitative assessment was informed by the extent and depth of the water, including edge impacts and ponding for runways and taxiways, as well as the extent and depth of water on access roads and ramps. The designated category reflects both the physical extent and depth of water and the expected operational impact. Example designations are provided below. In all cases, ponding and water accumulation in areas that are not critical for operations is not considered in the assessment.

- Unrestricted: No meaningful operational impact. Consistent with water depths less than 1/8 inch, clear to minor edge impacts.
- Minor: Minimal operational disruption. Consistent with edge impacts, limited standing water, localized shallow ponding.
- Major: May interfere with some operations. Consistent with more severe edge impacts and ponding across runways or taxiways, with access potentially limited; use of alternate facilities (e.g., different taxiways or access roads) may be appropriate.
- Severe: Significant disruption to operations, likely including closure and/or restricted operations. Consistent with flooding of a depth and extent that is likely to render a facility or facility segment unusable, including conditions described as inundated, widespread flooding, impassable, or with compromised access.

These categories are reasonable given that FAA does not provide specific standards for operational restrictions (e.g., closure of runways or taxiways) due to flooding; closure decisions are based on the judgement of airport management and/or operations personnel.

Results and Discussion

The results suggest that the Flood Simulation Analysis Tool in ESRI is effective for meeting the study objectives and supporting planning-level assessments of airport resilience, both at individual airports and across the resilience of a system of airports. Flood impacts varied by location and airport size, and by flood type. While the Objective 1 high impact flash flood scenario produced rapid surface water accumulation on taxiways and runways under the no-drainage modeling assumption, the longer duration Objective 2 regional flood scenario produced more extensive and deeper accumulation over time. Table 3 provides a summary of maximum flood depths for airports in the study. Runways at the larger airports, such as Indianapolis, were better protected from floodwaters covering the runways, but in most cases, water built up to cover taxiways, making runway access difficult. The discussion below is intended to illustrate the general capabilities of modeling and the general considerations for a planning-level assessment of airport resilience. A more detailed analysis that considers firsthand knowledge of the airport infrastructure and aeronautical operational considerations would be appropriate for a more detailed assessment of airport resilience. The implications of flooding are described in greatest detail for the first airport (IND) to illustrate impacts across different airfield areas. To avoid redundancy, subsequent airport scenarios summarize key operational implications rather than repeating the same level of detail provided for IND.

Table 3

Airport Flood Depth and Summary of Expected Impacts

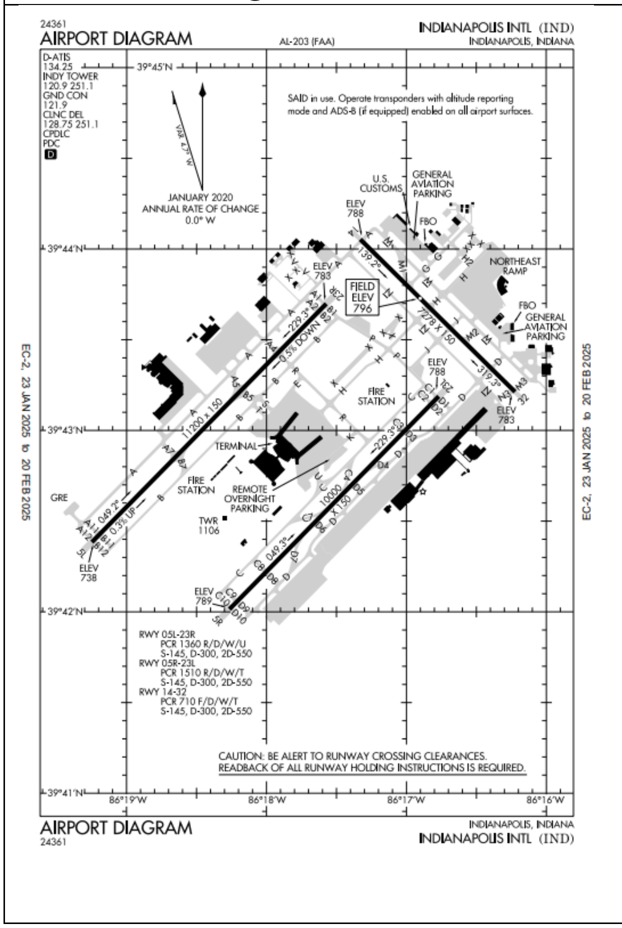
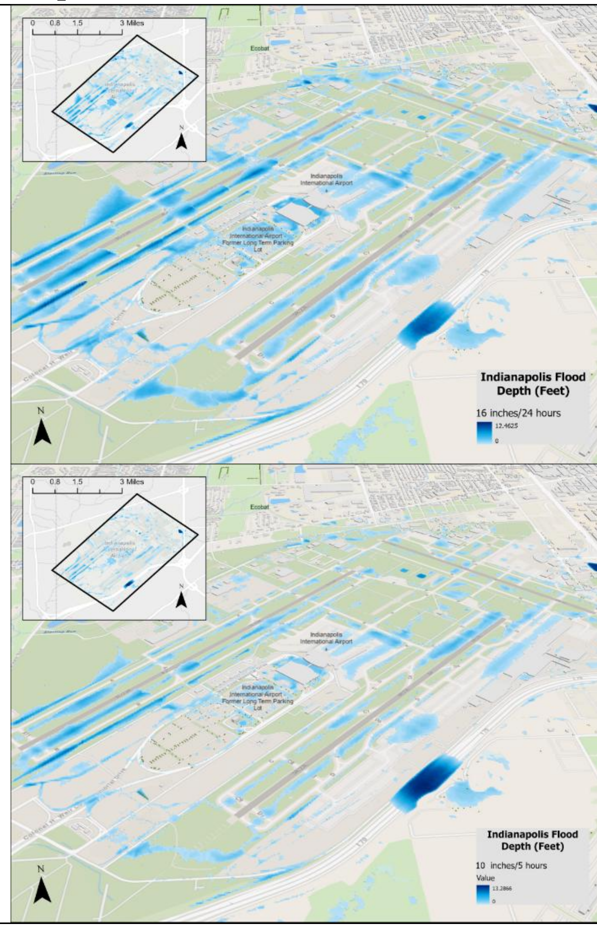
Airport Code	Flood Type	Max Flood Depth (in)	Facility			
			Runways	Taxiways	Access Roads	Ramps
IND	Regional	12.46	Severe	Severe	Severe	Major
	Flash	13.28	Major	Major	Severe	Minor
SDF	Regional	14.48	Minor	Minor	Minor	Minor
	Flash	13.16	Unrestricted	Minor	Minor	Unrestricted
DAY	Regional	12.55	Major	Major	Minor	Minor
	Flash	12.68	Major	Major	Minor	Major
EVV	Regional	10.37	Major	Major	Major	Major
	Flash	10.99	Severe	Severe	Severe	Severe
PAH	Regional	9.69	Major	Severe	Minor	Minor
	Flash	12.06	Major	Severe	Moderate	Minor
LUK	Regional	16.34	Severe	Minor	Unrestricted	Minor
	Flash	15.20	Major	Major	Unrestricted	Major
LAF	Regional	12.46	Major	Minor	Minor	Minor
	Flash	9.36	Severe	Major	Moderate	Severe

Indianapolis International Airport (IND)

The airport diagram and the results of the flood simulation analysis for Indianapolis, Indiana (IND) are shown in Figure 3. While many areas of the runways remained somewhat clear for both the flash flood and the regional flood scenarios, and no runway had water inundate it completely, there would likely be operational constraints because of the flooding. For the regional flood scenario, there are a few locations along runways 5L/23R with up to 4 inches of water, which would likely result in runway closure. Operational usability ultimately depends on aircraft type and the judgment of airport personnel.

Figure 3

IND Airfield Diagram and Map of IND after Rainfall Events

IND Airfield Diagram	**Map of IND after Rainfall Events**
	

Even if the runway does not have standing water on it, there may be operational limitations if the RSA is flooded. As mentioned previously, the RSA is designated on all sides of the runway and provides a safe refuge; it must be capable of supporting aircraft loads in the event of an aircraft excursion.

In the regional flood scenario, there are also problems since the taxiways serving the runway are compromised. All the taxiways serving runway 5L/23R appear to have some standing water, and taxiways B5, B7, B11 and B12 are especially prone to flooding. In some cases, aircraft may be routed via unaffected taxiways where available. The water encroaching on Runway 5L/12R not only presents a potential impediment to aircraft operations, but it also presents a threat to the airfield lighting.

Airfield lighting includes runway edge lights spaced at 200 ft intervals along the length of the runway; there are also centerline lights, touchdown lights, taxiway lights, land and hold short lights, and airfield signs and visual aids that could be impacted by flooding. Airfield lights may be elevated (e.g., some edge lights) or in-pavement (e.g., centerline lights). For testing in-pavement lights, the water test examines the light assembly submerged 0.5” of water (with a load); for elevated lights, the rain test evaluates performance for a rain rate of 5.2 in/hr for 30 min to confirm that the fixture does not leak; the leakage test examines an assembly submerged in at least 3” water for 10 minutes (AC 150/5345-46E; AC 150/5345-46E is cancelled and will be replaced by AC 150/5345-46F which is still designated a draft). The conditions presented by a flash flood event may exceed the design thresholds for lighting and visual aids. At Naples Airport, a full replacement of all airfield lighting, signs and navaids was required after Hurricane Ian (Sept 28, 2022) due to corrosion; the expected cost was $10 to $12 million dollars (Woolson, 2023). The damage at Naples was presumably exacerbated by exposure to saltwater, however, the flooding simulation suggests that the flooding that would be realized would exceed the design parameters of the airfield lighting in some locations.

Flooding on access roads is also an important consideration to ensure mobility for both passengers and freight and standing water on Col. H. Weir Cook Memorial Drive (connecting the airport to the interstate) and I-70 (connecting the airport to downtown Indianapolis) both have standing water for the regional flood scenario.

The parking areas on the west side of the main terminal, and the ramp next to the terminals have areas with standing water of depths of 12 inches. This presents potential concerns for the aircraft parked in the area, as well as for the ground service equipment (GSE) that may be parked on the ramp, and of course the area would not be useable by any personnel who may typically be working in the area.

At the northeast portion of the airfield, there is standing water on the ramp used by FedEx for cargo operations. As IND’s largest cargo provider and the second largest FedEx location in the nation, this could present significant challenges. The IND FedEx hub is FedEx’s second largest cargo facility and employs thousands of workers (Encyclopedia Indianapolis, 2021; Miller, 2018). The standing water on the vehicle service roads (e.g., the southeast and southwest portions) also presents a potential problem. These roads are used for service vehicles which perform important functions such as inspection and maintenance.

There is some standing water on the access road for the fire station, it would probably not present an issue since the airfield rescue and firefighting (ARFF) trucks are designed to traverse challenging terrain. One of the biggest concerns is water on I-70, south of the airfield. Water depths of up to 12 feet on I-70 would preclude all vehicle access and suggest that even smaller events could significantly disrupt access. I-70 connects the airport to downtown Indianapolis (including the convention center and field house), as well as I-465, the beltway around the city. Flooding on I-70 significantly compromises the mobility for the region and compromises the ability of the airport to support the city.

While the flash flood presents fewer issues, there is still water on vehicle service roads (e.g, on southeast and southwest portions of the airfield), standing water on taxiways (e.g., A11, A12, and C1, C2, C3 AND C7), standing water on the ramp, standing water on the access road near the terminal and on Col. H. Weir Cook Memorial Drive and on I-70. There is also water encroaching on the runway that may limit operations. A summary of the expected impacts at IND with supporting examples is shown in Table 4.

Table 4

Summary of Expected Impacts at IND

Flood Type	Max Flood Depth (in)	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	12.46	Severe (e.g., 5L/23R: partial flooding)	Severe (e.g., standing water in numerous places)	Severe (e.g., I-70 flooded limiting access)	Major (e.g., standing water in numerous places)
Flash	13.28	Major (e.g., 5L/23R: edge impacts)	Major (e.g., standing water in numerous places)	Severe (e.g., I-70 flooded limiting access)	Minor (e.g., localized areas: standing water)

Louisville, Kentucky (SDF)

The SDF airport diagram and the results of the flood simulation analysis for SDF are shown in Figure 4. The runways in both events are fairly clear, but flooding on the roads and on other paved areas is extensive. There are several areas with water exceeding 12 inches on I-65, which could present problems for access for passengers, air cargo, and for the military; the Louisville Air Guard base has water covering its access roads, which could be an issue. In the short term, if the lights are submerged then operational issues would be expected since visibility of the lights would be limited.

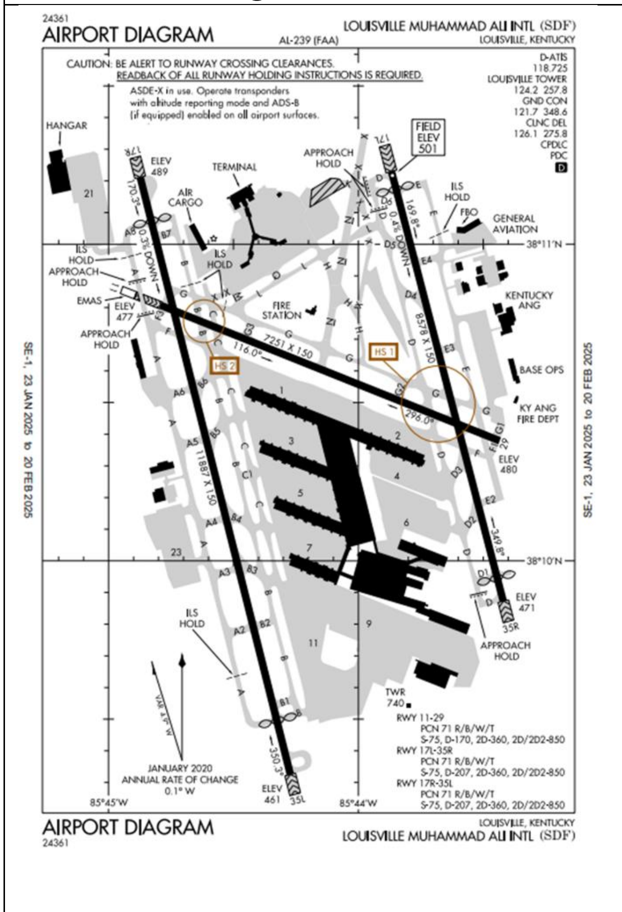
The extent and depth of flooding is greater with the 24-hour rain than the 5-hour rain at SDF, which differs from IND; at most other airports, the flash flood scenario produced greater impacts than the regional flood scenario. At SDF, there is some water encroachment on the edges of runway 17R/35L for the regional flood scenario, although it is not likely to limit operational capabilities.

At SDF, the passenger terminal is at the north end of the airfield; the larger terminal in the southern portion of the airfield is a cargo facility serving UPS Worldport (The Courier Journal, 2024). Worldhub is UPS's largest air cargo facility, employing over 20,000 people and processing over 2 million packages each day. The impact of operational disruptions at SDF will propagate throughout the nation. There is some flooding of the ramp serving the cargo facility, as well as near building 11, taxiways D1 (serves cargo), G (serves passenger terminal), B1 and B2. A summary of the expected impacts at SDF with supporting examples is shown in Table 5.

Figure 4

SDF Airfield Diagram Map of SDF after Rainfall Events

SDF Airfield Diagram



Map of SDF after Rainfall Events

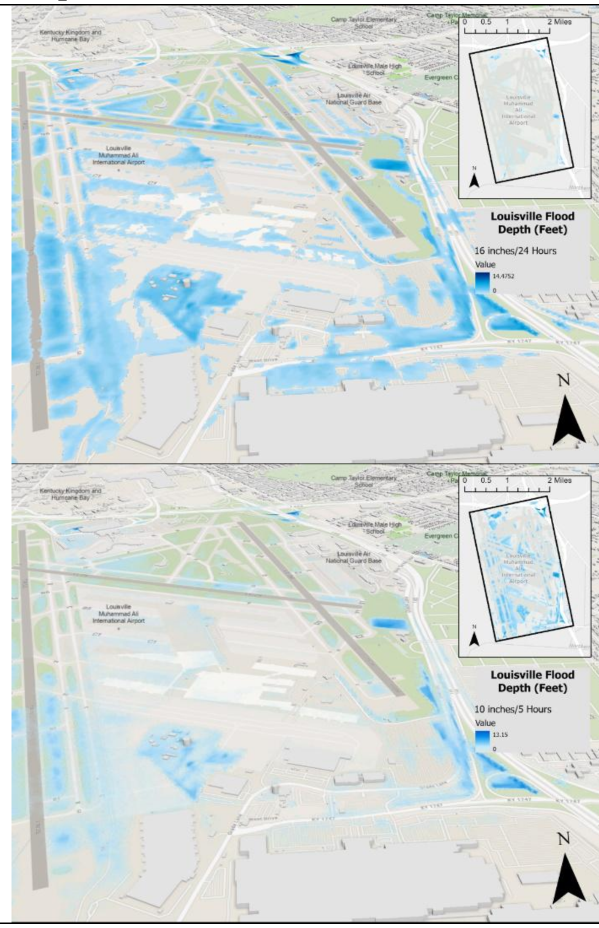


Table 5

Summary of Expected Impacts at SDF

Flood Type	Max Flood Depth (in)	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	14.48	Minor (e.g., 17R/35L south end: edge impacts; 11/29: edge impacts; likely manageable)	Minor (e.g., limited standing water; manageable)	Minor (e.g., I-65: localized standing water; likely passable)	Minor (e.g., localized standing water; manageable)
Flash	13.16	Unrestricted (e.g., all runways: clear to minor edge impact; no expected operational impact)	Minor (e.g., limited standing water; airfield accessible)	Minor (e.g., I-65: localized standing water; passable)	Unrestricted (e.g., localized areas: limited water; no expected impact)

Dayton, Ohio (DAY)

The airport diagram for Dayton Airport (DAY) and the results of the flood simulation analysis for DAY are shown in Figure 5. There is water encroachment on runway 6L-24R, which is the main runway, for both flood scenarios, and the flash flood scenario overwhelms all but the southern 6R/24L runway. Since this is the shortest runway, it would not accommodate larger commercial aircraft. Each of the other runways have water with depths of 2 to 5 inches crossing them in certain spots, which would likely make them inoperable. Taxiways K, S and T also have standing water, which would constrain operations for the passenger terminal, in the center of the airfield. The aviation businesses on the northwest portion of the airfield are not as affected by the flooding. There is significant aviation business activity at DAY, with 3,300 people working at airport business such as Procter & Gamble, Amazon, Chewy, Crocs, Sierra Nevada, PSA Airlines, Air Wisconsin, TJX Digital Inc. (owner of T.J. Maxx) and Joby Aviation (Hulsey, 2023). Access to the airport is compromised, with the road to the terminal and other access roads inundated with over 12 inches of water in certain locations, which would make the road impassable to general traffic. A summary of the expected impacts at DAY with supporting examples is shown in Table 6.

Table 6

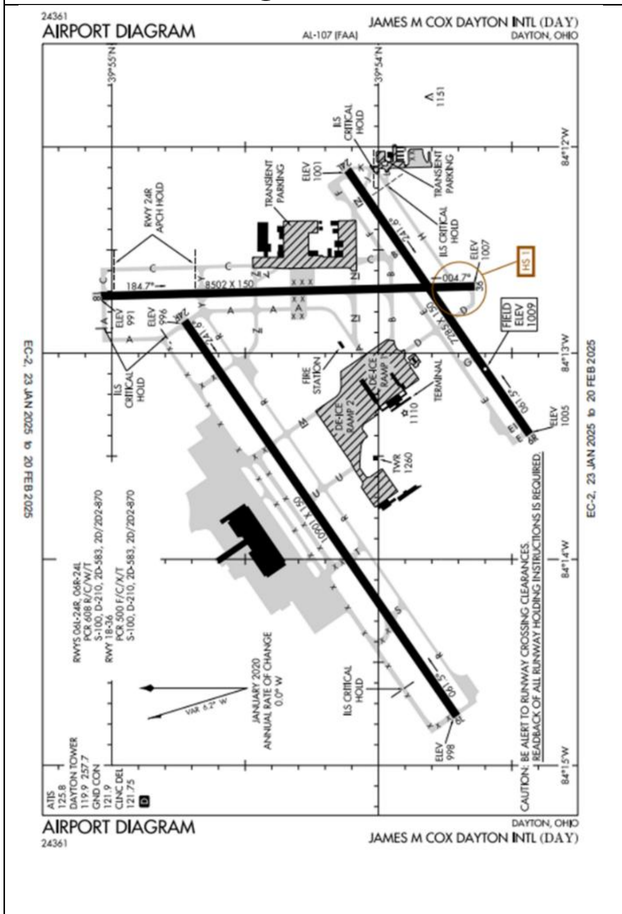
Summary of Expected Impacts at DAY

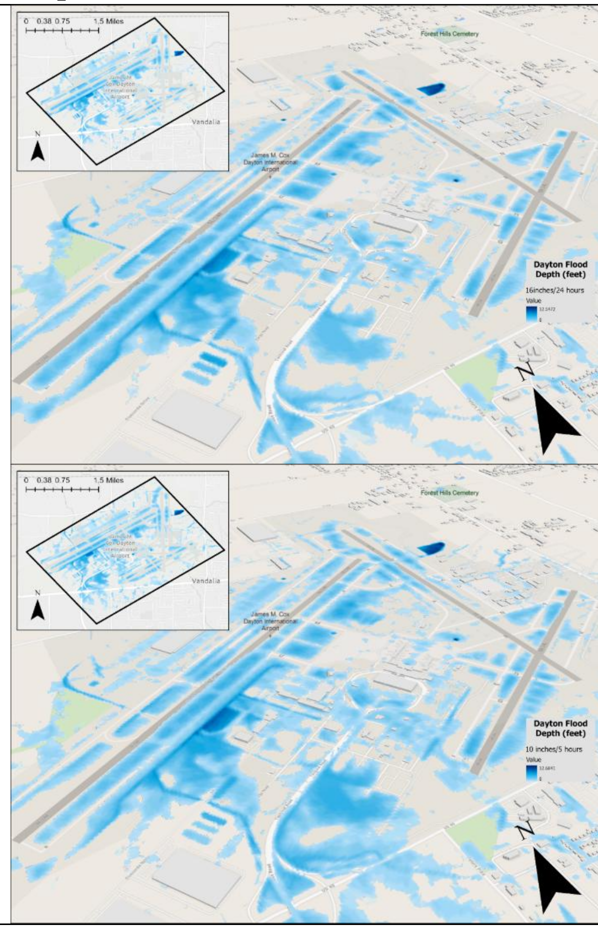
Flood Type	Max Flood Depth (in)	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	12.55	Major (e.g., 6L/24R: edge impacts; manageable)	Major (e.g., Taxiway R near Ramp 2: standing water; access limited)	Minor (e.g., Terminal Drive: standing water; passable)	Minor (e.g., Terminal ramp: standing water; manageable)
Flash	12.68	Major (e.g., 6L/24R & 18/36 west end: edge impacts; manageable)	Major (e.g., Taxiway R near Ramp 2: standing water; access limited)	Minor (e.g., Terminal Drive: standing water; passable)	Major (e.g., Terminal ramp: flooding may disrupt operations for some gates)

Figure 5

DAY Airfield Diagram Map of DAY after Rainfall Events

DAY Airfield Diagram	Map of DAY after Rainfall Events





Evansville, Indiana (EVV)

The airport diagram for the Evansville Airport (EVV) is shown in Figure 6, as are the results of the flood simulation analysis for EVV. The regional flood scenario inundates Runway 16/22 with 12 inches of water, but runway 4/22, the main runway, remains relatively clear, and access to the passenger terminal may be possible, although there is some flooding at the southeast portion of the ramp. There is, however, no access to the general aviation parking due to taxiway flooding (e.g., southwest portions of taxiway A). The flash flood scenario puts runway 16/22 under 24 inches of water in some places, and the southwest portion of runway 4/22 also becomes inundated, and none of the runways could be used. Runway 6/27 is flooded for both events. The waterbody to the west of the airport can be seen breaching its banks. This suggests that flow velocities could wash out US 41, creating problems for airport access; however, detailed analysis of flow-induced damage is beyond the scope of this planning-level study. A summary of the expected impacts at EVV with supporting examples is shown in Table 7.

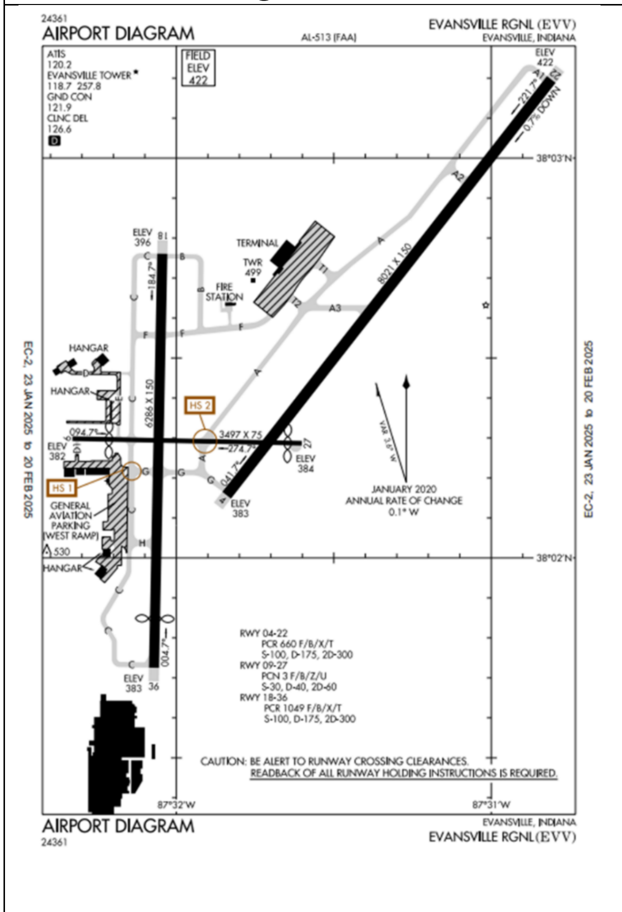
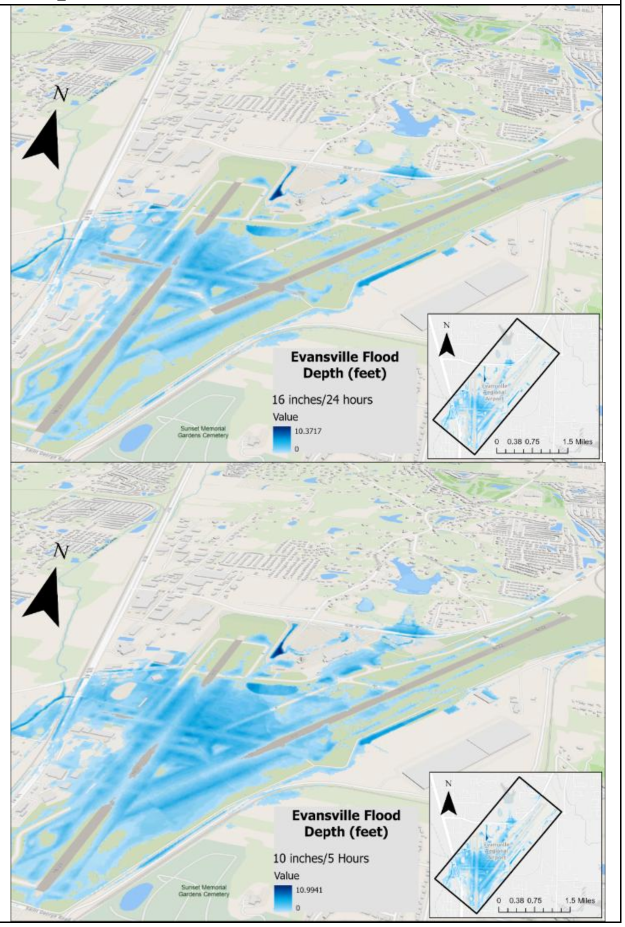
Table 7

Summary of Expected Impacts at EVV

Flood Type	Max Flood Depth (in)	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	10.37	Major (e.g., 9/27 & 16/22: significant flooding; closed)	Major (e.g., GA taxiway C: localized flooding)	Major (e.g., Petersburg Rd: localized flooding; detour required)	Major (e.g., GA & SE terminal ramps: widespread flooding)
Flash	10.99	Severe (e.g., all runways affected: widespread flooding; closed)	Severe (e.g., GA taxiway C: inundated)	Severe (US 41 & Petersburg Rd: widespread flooding; likely impassable)	Severe (e.g., GA & SE terminal ramps: inundated)

Figure 6

EVV Airfield Diagram Map of EVV after Rainfall Events

EVV Airfield Diagram	**Map of EVV after Rainfall Events**
	

Paducah, Kentucky (PAH)

The airport diagram for Barkley Regional in West Paducah (PAH) is shown in Figure 7, as are the results of the flood simulation analysis for PAH. Both the flash flood and regional flood scenarios produced similar results in terms of impacts. There are patches of water on runway 14/32, which extend into the runway intersection for the flash flood scenario. There is standing water on taxiway A in multiple places and on portions of Taxiway C (greater impact for the regional flood scenario), and on the east ramp. The water on the ramp near the fire station and on taxiway A is of particular concern, since the scheduled commercial passenger service cannot be provided if the aircraft rescue and fire fighting (ARFF) equipment cannot access the airfield in a timely manner. The water ponding on taxiway A2 is of concern and would likely make commercial operations impossible since it provides a connection to the terminal. The water near the terminal and air carrier ramp is also a concern, as is access to the air traffic control tower, which is located near the ARFF station. Access to the airport via Gholson Road (southeast of the southern part of runway 5/23) is impassable for both rainfall scenarios; however, other access routes may remain available. Access via Route 305 may be limited during the flash flood. A summary of the expected impacts at PAH with supporting examples is shown in Table 8.

Figure 7

PAH Airfield Diagram Map of PAH after Rainfall Events

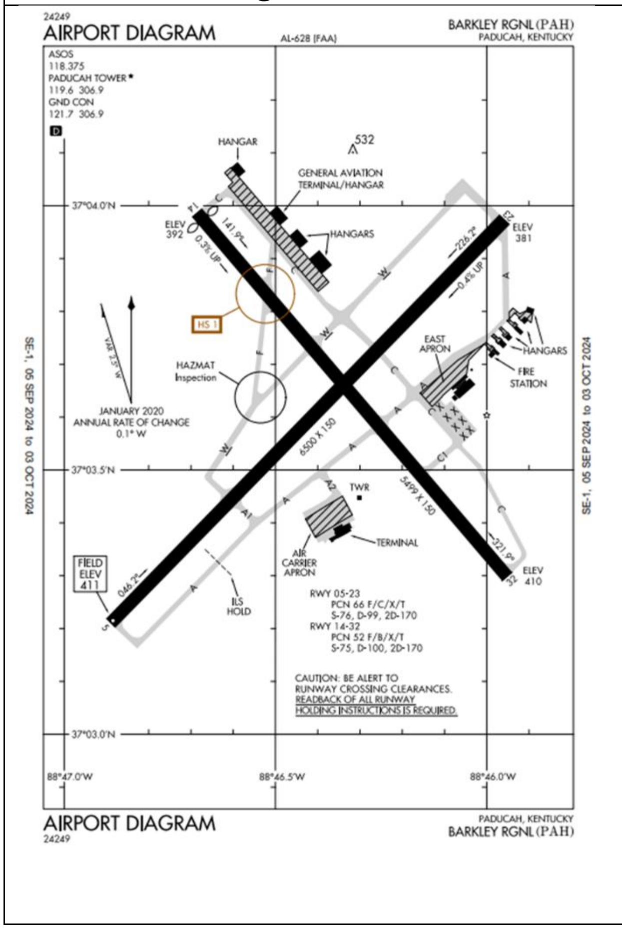
PAH Airfield Diagram	Airfield Diagram for PAH
	

Table 8

Summary of Expected Impacts at PAH

Flood Type	Max Flood Depth (in)	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	9.69	Major (e.g., 14/32 & 5/23 intersection: water patches; 14/32: edge impacts and ponding near intersection; 5/23 edge impacts)	Severe (e.g., Taxiway A: flooding)	Minor (e.g., limited water on Route 305 and Gholson Rd, may impact some access to airport)	Minor (e.g., east ramp: water patches; manageable)
Flash	12.06	Major (e.g., 14/32 & 5/23 intersection: water patches; 14/32: edge impacts and ponding near intersection; 5/23 edge impacts)	Severe (e.g., Taxiway A: flooding)	Moderate (e.g., water on Route 305 and Gholson Rd may impact access)	Minor (e.g., GA & east ramps: water patches; manageable)

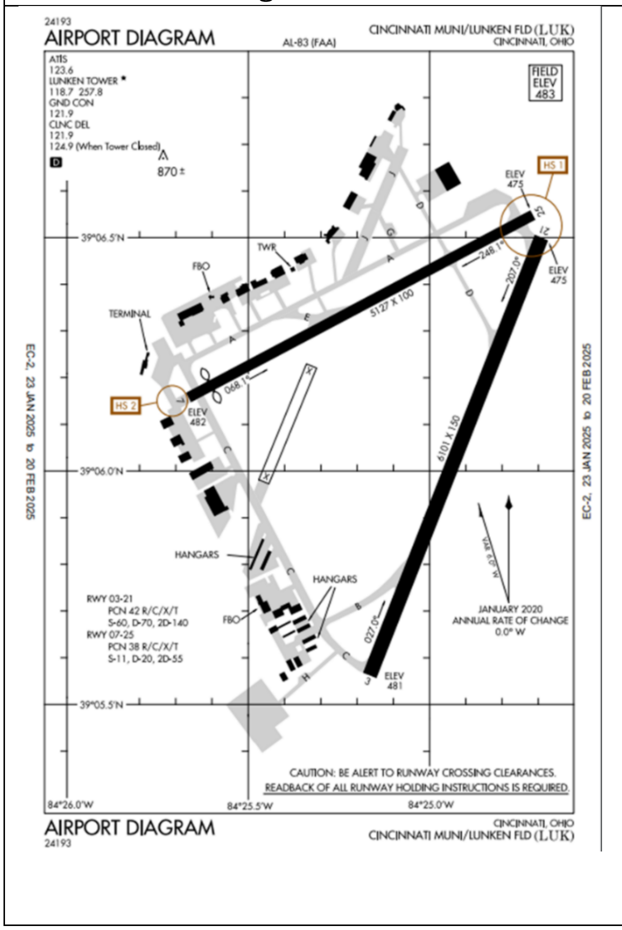
Lunken Airport in Cincinnati, Ohio (LUK)

The airport diagram and the results of the flood simulation analysis for Lunken Airport (LUK) in Cincinnati are shown in Figure 8. The regional flood scenario produces more widespread flooding than the flash flood scenario and in both cases, flood water crosses both runways at depths ranging from 3 to 6 inches. Runway 7/25 has standing water (greater depths for the flash flood) that would likely make the runway inoperable. Runway 3/21 has water encroachment on the runway, with more ponding for the regional flood scenario, which would likely result in runway closure. There is flooding northwest of runway 7/25 that may compromise operation of the air traffic control tower and the north fixed base operator (FBO) which is a primary service provider for GA aircraft, the primary aeronautical activity since this is a reliever airport for CVG. Access to the north FBO is problematic for both runways due to flooding on taxiway A and C. Access to the south FBO may be possible via taxiway B and C from runway 2-21, however, there is some flooding near many of the hangars on the airfield. The retention and detention ponds and drainage ditches are filled with water and the water spills over onto the runways. The airport is in proximity to the Little Miami River, which may flood during these events and contribute to the flooding. A summary of the expected impacts with supporting examples at LUK is shown in Table 9.

Figure 8

LUK Airfield Diagram Map of LUK (in Cincinnati) after Rainfall Events

LUK Airfield Diagram



LUK after Rainfall Events

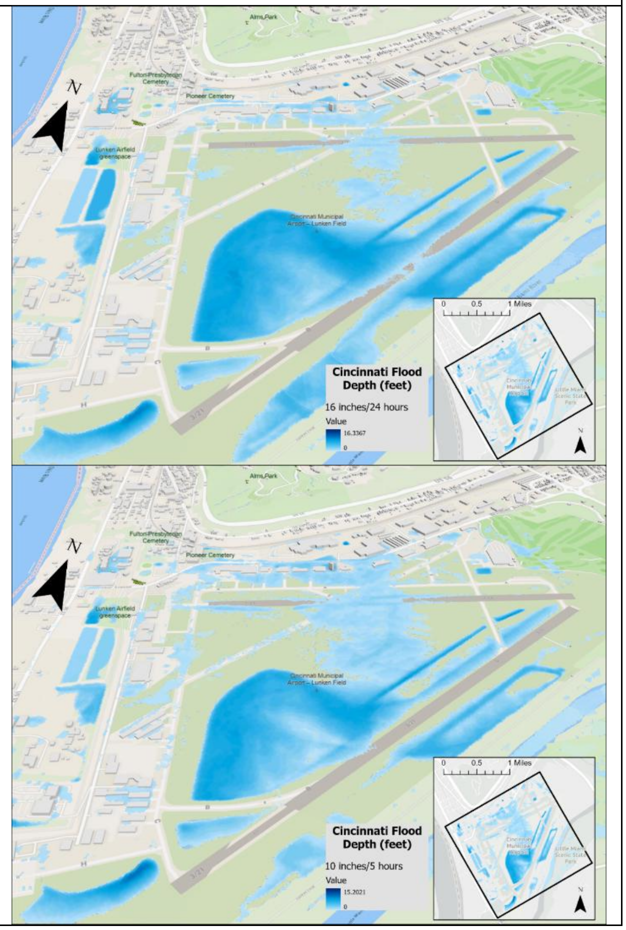


Table 9

Summary of Expected Impacts at LUK

Flood Type	Max Flood Depth	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	16.34	Severe (e.g., 7/25 & 3/21: edge impacts and ponding across runway in some locations)	Minor (e.g., Taxiway C: water patches; manageable)	Unrestricted (e.g., no visible impacts)	Minor (e.g., FBO ramp: water patches)
Flash	15.20	Major (e.g., 7/25 has significant ponding and 3/21 has edge impacts)	Major (e.g., Taxiway C: widespread flooding)	Unrestricted (e.g., no visible impacts)	Major (e.g., FBO ramp: widespread flooding)

Lafayette, Indiana (LAF)

The airport diagram for Purdue Airport (LAF) in West Lafayette, Indiana, is shown in Figure 9, as are the results of the flood simulation analysis for LAF. Both scenarios produce flooding on both runways, although the flooding on runway 5-23 is more severe. Edge impacts on the northwest portion of runway 10-28 are worse for the flash flood. Taxiways B and C (near taxiway B) have standing water for both scenarios, as do taxiways B4 and B5; there is also standing water on A2, although A1 can be used instead. The flash flood scenario results in water on both runways and would likely make runway 5/23 unusable with 4 to 13 inches of water in some locations. There is also some flooding landside on the access road in front of the terminal; this road also serves the FBO. A summary of the expected impacts with supporting examples at LAF is shown in Table 10.

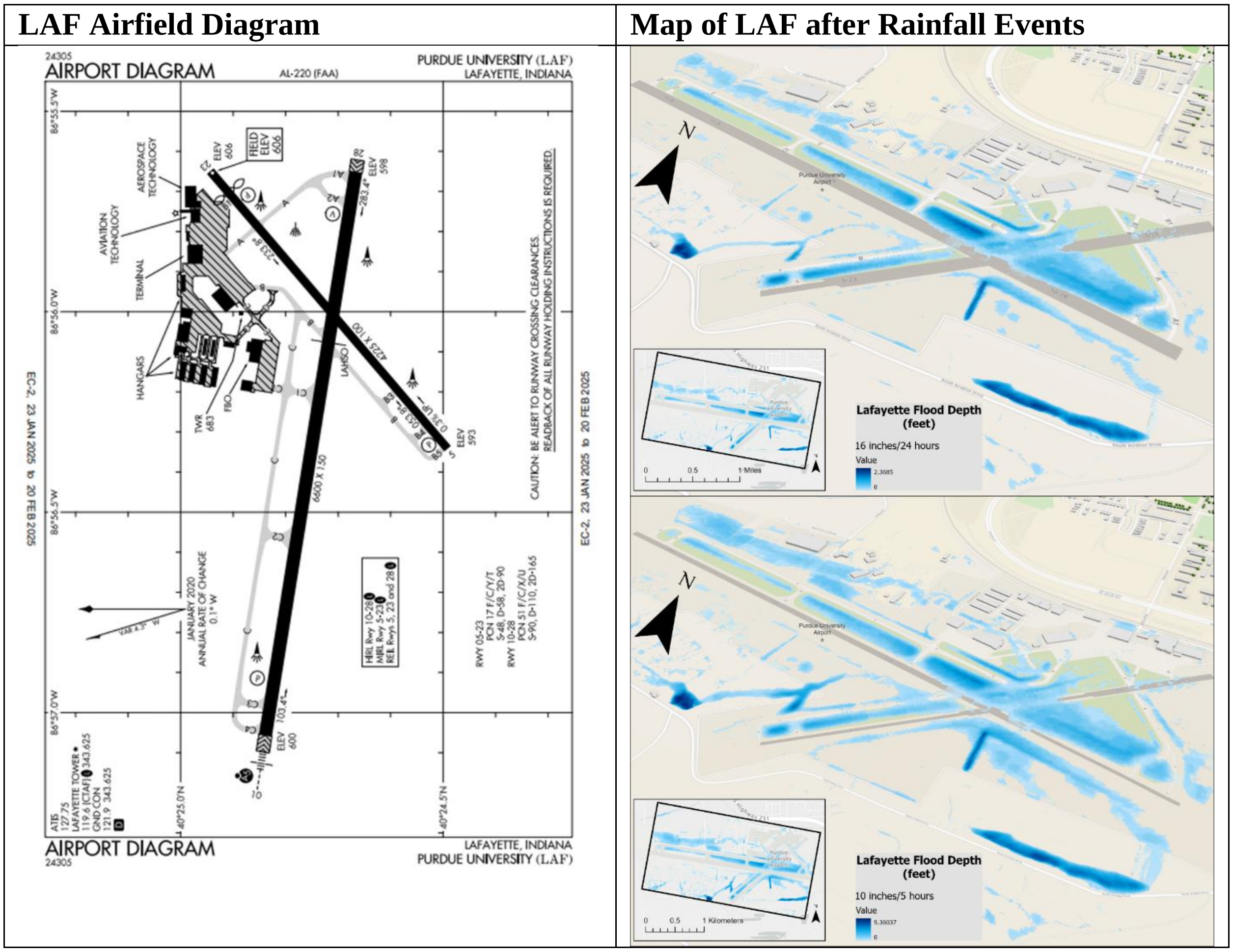
Table 10

Summary of Expected Impacts at LAF

Flood Type	Max Flood Depth	Facilities Affected			
		Runways	Taxiways	Access Roads	Ramps
Regional	12.46	Major (e.g., 5/23 has edge impacts and ponding near intersection; 10/28 has edge impacts)	Minor (e.g., Taxiways B, C & A2: standing water)	Minor (e.g., airport access road: standing water)	Minor (e.g., FBO & other ramps: water patches)
Flash	9.36	Severe (e.g., 5/23 & 10/28 have severe edge impacts: 5/23: flooding near intersection; 10/28: patches of water)	Major (e.g., Taxiways B, C & A2: standing water)	Moderate (e.g., airport access road: standing water)	Severe (e.g., FBO ramp: widespread flooding)

Figure 9

Airfield Diagram and Map of LAF and Map of LAF after Rainfall Events



Conclusion

With the increasing magnitude, duration, and intensity of rainfall events due to climatic changes, existing infrastructure is vulnerable to meteorological events not previously imagined. This research leveraged a flood simulator tool within a Geographic Information System to support resilience planning for airports of all sizes. Furthermore, this study provides a screening-level, reproducible workflow that any airport can use as a first-pass resilience assessment, thereby providing a foundation for a standardized GIS-based flood-simulation workflow for FAA resilience assessments. This flood simulation analysis illustrates future potential to utilize these workflows and methods to investigate the impacts of rain events on a single airport, or for multiple airports in a region to assess the overall resilience within the region.

Identification of areas that are prone to flooding can allow an airport to develop appropriate mitigation plans. In some cases, the mitigation plan may include development projects such as drainage facilities, detention facilities, and retention facilities to reduce the severity and/or impact of flooding. In some cases, the mitigation plan may be to utilize taxiways and runways that are not affected and temporarily close the flooded facilities. In some cases, it may be appropriate to utilize other airports in the area. The mitigation and response plans will vary depending on the resources available and the availability of alternate airports in the area.

The flood simulation methods presented in this paper are both cost effective and can be easily implemented with widely available online data sets. The widespread availability of the software and data makes resilience planning available and accessible to more airports. The results of the analysis, such as the flood depth results from the simulated models, can be analyzed alongside other simulated results, including flow velocities, to create maps to communicate possible scenarios with the public and decision makers. These findings also suggest that this analysis method may be useful for other purposes, including the assessment of airport resilience during airport and community emergencies, and as a tool to support the evaluation of airport resilience as part of airport master planning efforts. The methodology demonstrated in this paper supports FAA goals to include resilience in future airport planning activities (sustainability and master planning) by providing an accessible and uniform method to evaluate flood risk and inform mitigation activities. The results of this research use an innovative approach that leverages widely available tools and can be easily implemented to investigate resilience and vulnerability at airports of any size and across systems of airports to assess regional vulnerability. Future research may include the addition of using airport activity metrics (e.g., operations, enplanements, cargo tonnage), airport functional role (e.g., flight training, business aviation, emergency response) and other factors in the screening methodology.

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