Report on Slope Stability Related to the Jackson County Airport

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INTRODUCTION

The purpose of this report is to provide information to the North Carolina Division of Emergency Management (NCDEM) concerning past and potential future slope failures (landslides) related to the Jackson County Airport, upslope of private property that includes several homes. It also provides recommendations to the Jackson County Airport Authority (JCAA) to mitigate the potential for future slope failures.

The report includes observations made by the North Carolina Geological Survey (NCGS) staff on their site visits on August 30, 2005, December 20, 2005, and January 10, 2006 done in conjunction with the landslide hazard mapping program. This program, mandated by the Hurricane Recovery Act of 2005, involves documenting the locations of known landslide events to incorporate into landslide hazard maps to be provided to the 19 counties listed in the bill. The NCGS also documents landslides and responds to requests by NCDEM to evaluate slope stability at locations where public safety might be endangered as part of a hazard mitigation grant agreement (FEMA-DR-1490-006) with NCDEM.

BACKGROUND

Mr. Dewayne Pruett contacted the NCGS on August 29, 2005 with concerns about the stability of slopes above, and adjacent to, his property below the Jackson County airport (figs.1 and 2). NCGS staff members Richard Wooten, Rebecca Latham and Anne Witt met with Mr. Pruett at his property on Ben Cook Road on August 30. Mr. Pruett reported that some ground failed from an area immediately above his property (Site 1). Mr. Brian Ammons, a neighbor of Mr. Pruett, also present, reported a mudslide on his property that originated just downslope from airport property (Site 2). He also relayed concerns about significant seepage from a rock slope just upslope from his property (Site 3). The Pruett and Ammons properties are located on northeast-facing slopes below the northwest end of property developed for the Jackson County airport (figs. 1 and 2). Both of the slope failures occurred on Monday, August 22, 2005 during a localized rainstorm that, according to local residents, may have dropped as much as four inches of rain within one hour. Rain gage data for the area are limited, and the maximum 24-hour rainfall recorded for this time period in Jackson County was 0.99 inches (IFLOWS, 2005). The stream gage for the Tuckasegee River (fig. 3) located about 3.75 miles southeast of the airport shows an increase in stream flow for that time period.

The Jackson County Airport was built in 1976 using cut and fill construction to level Berry Mountain to an elevation of about 2857 feet (fig. 2). Evaluation of aerial photographs and the *Jackson County Airport: Airport Master Plan Update* report by Talbert & Bright (2004) indicate that a number of slope failures related to the airport have occurred in the past. Local residents report damage to the Stack property (fig. 1) in 1977 from a slope failure or high runoff originating on airport property. Personnel from the North Carolina Department of Environment and Natural Resources, Land Quality Section, also reported sedimentation enforcement problems associated with slope failures related to runway construction. Some monitoring of slope stability may have occurred at that time as a result of the slope failures.

The past slope failures appear to be related to soil and rock material used to fill in drainages and low areas during airport construction. Figures 1 and 2 show two major scarps (A and B) that developed into embankment failures near the southeast end of the airport. Scarp A, southwest of the terminal, is about 400 ft wide at the top. Scarp B, south of the terminal, is about 300 ft wide. Scarp A began to develop approximately 8 months after airport construction was completed in 1976. It continued to progress upslope until it affected the runway pavement in 1987 shortening the runway by 500 feet and, in 1994, removed part of the taxiway (Talbert & Bright, Inc., 2004). According to the GeoTechnologies report (Appendix C, Talbert & Bright, 2004), the major failure at scarp A occurred in a soil fill that was originally designated as a rock fill. Because of the large volume of excavation waste material after site grading, concessions were made to allow the waste material with soil to be used as fill at this location. The time of initial slope movement related to scarp B is not known. A review of 1993 and 1998 aerial photographs indicates that approximately 50 feet of downslope movement occurred in the vicinity of scarp B between 1993 and 1998, as evidenced by displaced trees visible in the aerial photography.

Ground reconnaissance by NCGS staff on December 20, 2005 indicates the failed embankment material below scarps A and B shows signs of continued, slow movement as evidenced by numerous curved trees and saplings, and unvegetated intermediate scarps in both areas. An unvegetated, scoured channel originating in soil beneath rock boulders on the ground surface indicates recent erosion and slope movement below scarp B.

Discussions with Mr. Thomas McClure, JCAA, indicate that in recent years there have not been any slope failures associated with the airport. This time frame includes the period of heavy rains when the remnants of Hurricanes Frances and Ivan passed over western North Carolina in September 2004.

Construction of the airport required large volumes of fill material to obtain the current airport elevation (2857 ft). The NCGS's analysis of topographic maps and aerial photographs confirms that areas of thick soil and/or rock fills are present at several locations. Figure 4A is a geographic information system (GIS) map that shows the pre-airport topography overlain with the airport boundary and the approximate areas with fill. The approximate areas of extensive fill were estimated by identifying those areas in the airport vicinity that were below the current airport elevation as determined from topographic maps made prior to airport construction. Field observations and aerial photographs were also used to refine the estimates of the areal extent of fill.

Fills can be less stable than natural ground if they are not composed of suitable material that is properly placed on a stable foundation and compacted. Boring logs from the airport included in the GeoTechnologies report indicate that some fill contains woody and organic debris. This organic material eventually decomposes leaving void spaces in the fill that can channel water and destabilize the slope. The steepness of the slope also affects its stability. Figure 4B is a GIS map showing general areas where slopes greater than 30 degrees (58%) occurred in the vicinity of the Jackson County Airport prior to airport construction. Unless adequately designed and constructed, fill placed on slopes steeper than 30 degrees can be less stable and more failure prone than unmodified slopes at the same slope angle. Figure 4B shows areas where fill appears to have been placed on slopes greater than 30 degrees.

GENERAL OBSERVATIONS

NCGS staff made the following observations at the three sites visited on August 30, 2005.

SITE 1. Site 1 is the head scarp area of the August 22, 2005 slope failure above Mr. Pruett's residence. The slope failure appears to have originated within material previously transported during a 1977 landslide that reportedly involved material from airport construction. The scarp exposed on August 22, 2005 (fig. 5) marks the location where material detached from the pre-existing slope either by water erosion and/or slope movement. Tension cracks were observed near the top edge of this oversteepened slope. Some gullying above the scarp indicated runoff was directed toward the slope that failed. The bulk of the slope failure material was transported by water onto the Pruett property for a distance of approximately 500 feet.

The steep scarp area exposed by the slope failure is shown in figure 5. The sequence of main deposits exposed in the scarp is described below, starting with the uppermost (youngest) deposit:

Deposit 1. Boulders on the ground surface from a rock slope placed during airport construction and possibly transported by a 1977 landslide. Numerous curved and tilted trees indicating soil creep are growing near the boulder deposit in the vicinity of the head scarp. The rock slope appears to thicken upslope toward airport property.

Deposit 2. Clay-silt-sand mixture with large fragments of decayed organic debris possibly transported during the 1977 landslide. Scattered gravel- and cobble-sized rock fragments are also in this horizon. The base of this unit may approximate the original ground surface prior to airport construction.

Deposit 3. Sandy, silty clay with subrounded gravel- and cobble-sized rock fragments. This deposit appears to be a colluvial hillslope deposit present well before airport construction.

Also exposed at Site 1 are what appear to be remnants of an older scarp from a previous slope movement (fig. 6). This older scarp predates the August 22, 2005 slope failure, and may postdate the 1977 landslide event reported at this location.

SITE 2. Site 2 is the head scarp of an August 22, 2005 debris flow that traveled about 1,500 feet downslope onto the Ammons property (figs. 1 and 2). Figure 7 shows a sequence of deposits at Site 2 similar to those exposed in the scarp at Site 1 (fig. 5). If present, any original colluvial deposit predating airport construction was not clearly exposed at this scarp location. Figure 8 shows decayed woody debris in the layer beneath the man-made rock slope most likely placed during airport construction. Gullying above the scarp indicates that some runoff was directed toward the slope that failed.

Figure 9 shows a sequence of images along the debris flow track downslope from Site 2. Older colluvial and/or debris flow deposits were observed in some of the incised sections of the debris flow track. Not shown in the photographs is a diversion ditch being constructed near the midpoint of the track to divert water and sediment away from the Ammons' property.

SITE 3. Figure 10 shows seepage (~10 gallons per minute) from the base of a rock slope constructed below the airport. Mr. Ammons reported that shortly after the August 22, 2005 slope failure events, the volume of water flowing from this location was considerably greater than at the time of the August 30, 2005 site visit, and was murky with sediment. If suspended sediment in the water occurs, it indicates that subsurface erosion (piping) beneath the rock slope may be occurring during high rainfall events. Clear water discharge may indicate a spring or some other form of groundwater discharge from the area beneath the rock slope. No culverts or other drainage structures that could be the immediate source of this water were observed in the man-made rock slope at this location.

Runoff from this area flows over a steep embankment along an old roadbed. The old roadbed may be an abandoned logging road, or an access road built during airport construction. This runoff could have a destabilizing affect on the old roadbed, and trigger a future slope failure.

CONCLUSIONS

The slopes exposed in the scarps at Sites 1 and 2 are oversteepened and are subject to further erosion and slope failure. Heavy rainfall triggered the slope failures that involved material that was emplaced or disturbed in connection with airport construction. Observations made during the site visit on the loose rock slopes above Sites 1 and 2 did not reveal any obvious signs of impending catastrophic failure. Exposures in the scarps at Sites 1 and 2 indicate that the sand-silt-clay deposits containing decayed organic debris may underlie the rock slopes at this and other locations below the airport.

The seepage and runoff at Site 3 will likely have a destabilizing affect on the old roadbed, and could trigger a future slope failure. Continued seepage and piping could also destabilize the rock slope at Site 3.

If the large man-made rock covered slopes below the airport are underlain by end-dumped, or otherwise improperly placed soil and organic debris, they may be susceptible to future slope failures that could endanger public safety. Dryer than average conditions in the region persisted from 1998 until 2003 (NCDC, 2005). If the current cycle of wet weather continues, additional slope failures along the slopes in the vicinity of the airport could occur. Although slope failures occur on a widespread basis more often during wet weather cycles due to overall increased precipitation, they also occur during isolated, intense storms that locally produce large amounts of rainfall. Any relationships between slope movements and long- or short-term precipitation events in the airport area are not well understood at this time.

RECOMMENDATIONS

NCGS staff recommends the following actions be taken by the JCAA as soon as possible to ensure the future stability of the slopes adjacent to the airport, and to protect residents and private property below the airport from future slope failures.

1) Perform a slope stability assessment of the slopes affected by airport construction or runoff from airport property. Particular attention should be placed on locations of thick fill deposits and on areas immediately above residences or private property. The assessment should include a determination of factors of safety and documentation of the parameters and assumptions that go into the factor of safety calculations. Further drilling, installation of groundwater monitoring wells, and material testing may be necessary to collect sufficient, reliable data for the slope stability analyses. Qualified geologists and geotechnical engineers with experience in evaluating the stability of slopes should perform the assessment and certify their findings.

2) Stabilize or mitigate the slope failure hazard (e.g., construct diversion structures or debris dams) for any slopes deemed unstable or marginally stable in the slope stability assessment that could have adverse impacts on public safety or private property below. Geotechnologies and Talbert & Bright (2004) both recommend stabilizing the slope failure at scarp A as the initial phase of any rehabilitation work. Qualified geologists and geotechnical engineers with experience in slope stability should recommend the corrective action for slope stabilization. Proper drainage and runoff control on airport property will be necessary to maintain the stability of areas downslope.

3) Establish a slope stability monitoring plan for steep slopes affected by airport construction or runoff from airport property. The monitoring plan should include provisions for monitoring deep slope movements (inclinometers) and groundwater (piezometers). Onsite, ground observations should be made on a regular basis to check for surface evidence of ground movement (e.g., tension cracks, scarps, etc.) and groundwater discharge (e.g., Site 3). Special attention should be paid to areas of known past slope failures and potentially unstable areas upslope from residential

homes. A qualified geologist or geotechnical engineer with experience in slope monitoring should develop and oversee the monitoring plan.

4) Develop a citizen alert plan to notify residents and land owners below the airport when precipitation or other conditions (e.g., ground disturbance) warrant that a precautionary landslide advisory be issued. This plan should be coordinated with NCDEM and Jackson County Emergency Management officials. This plan may no longer be necessary once unstable slopes are stabilized or the slope failure hazard is mitigated by some other means.

5) Future development to expand airport facilities that involve large cut and fill slopes should be undertaken with caution. Cut and fill construction methods, unless carefully done, may destabilize already marginally stable slopes, particularly in soil fills as noted by Geotechnologies in Talbert and Bright (2004). Qualified geologists and geotechnical engineers should perform detailed studies prior to development that would involve significant earthwork or drainage measures. These studies would be needed to determine the affects such expansion would have on property and people in the downslope area.

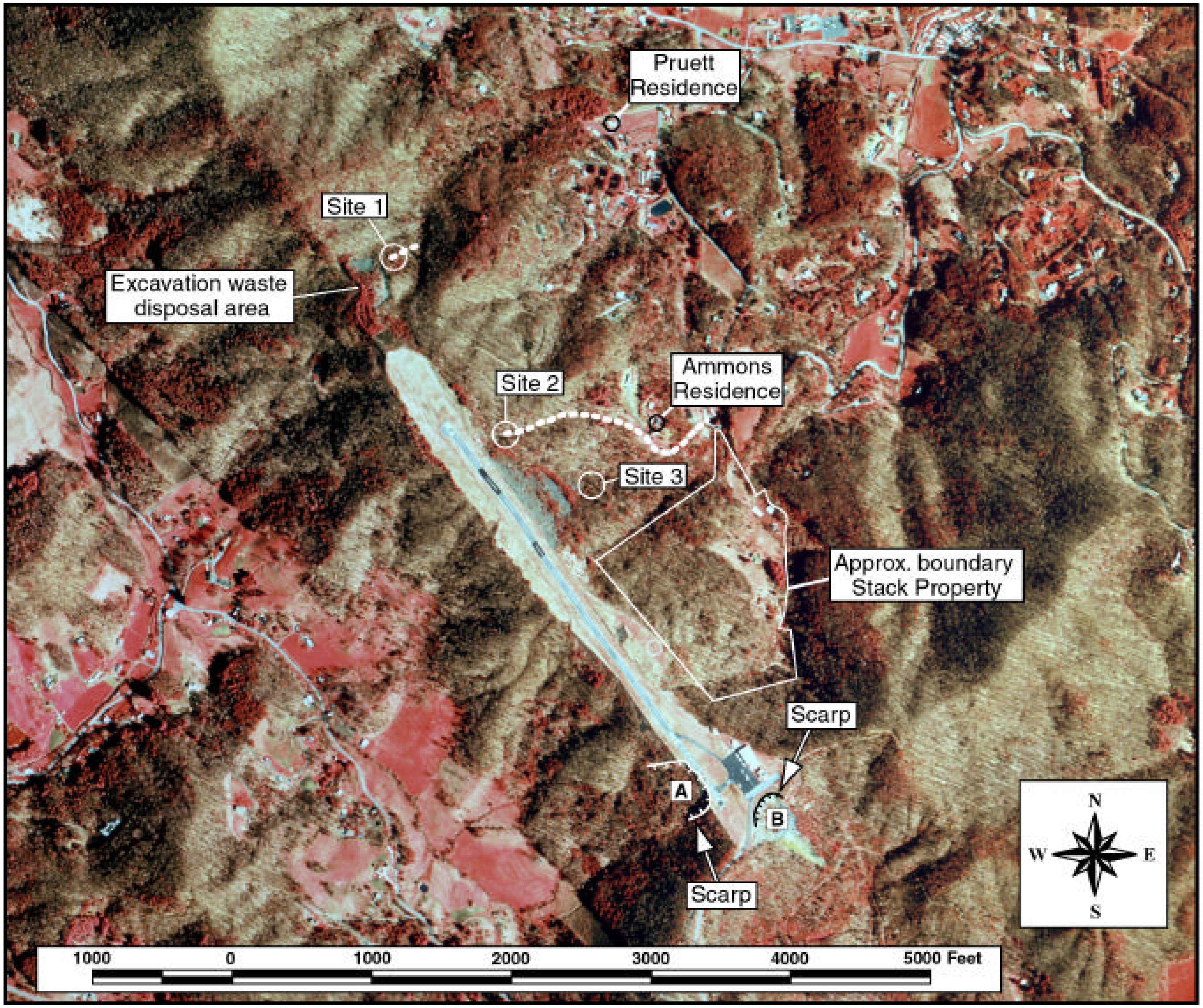

Figure 1. Excerpt from 1998 color-infrared digital orthophoto quarter-quadrangle (DOQQ) showing the locations of the Jackson County airport, sites visited on August 30, 2005, and other features. Dashed white lines show the approximate tracks of the August 22, 2005 slope failures. A white hachured line delineates scarp 'A,' and a black hachured line delineates scarp 'B,' showing the locations of known pre-existing embankment failures.

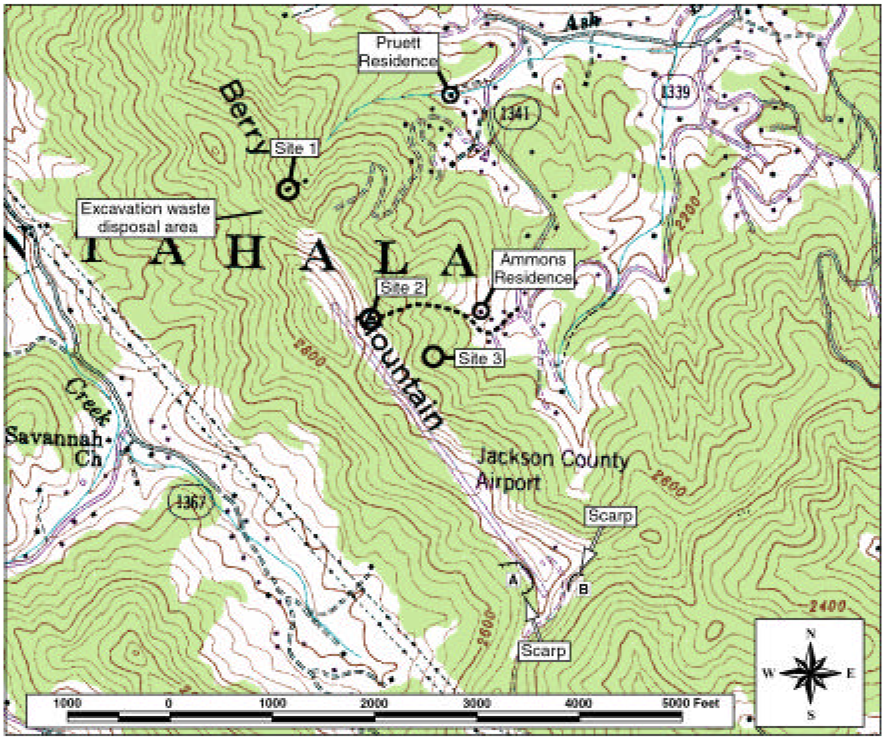

Figure 2. Excerpt from USGS 7.5-minute topographic map showing the locations of the Jackson County airport and sites visited on August 30, 2005. Dashed black lines show the approximate tracks of the August 22, 2005 slope failures originating at Sites 1 and 2 respectively. Black hachured lines delineate scarps labeled 'A' and 'B' located above pre-existing embankment failures.

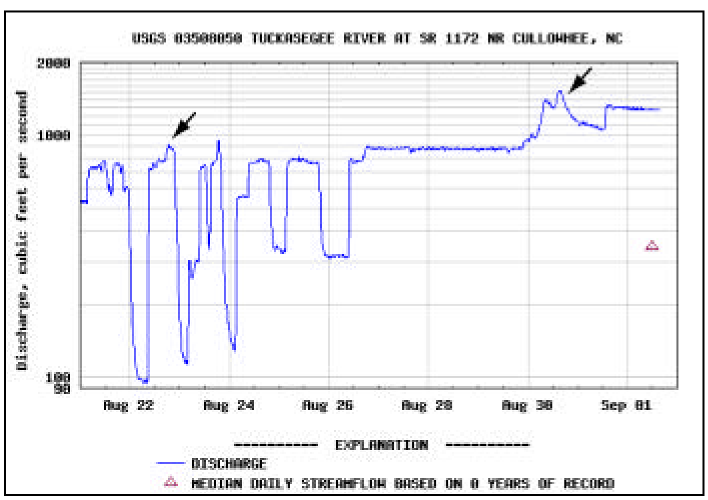

Figure 3. Stream flow hydrograph for the Tuckasegee River near Cullowhee. August 22, 2005 peak discharge (arrow left) indicates an increase in stream flow attributed to the storm event that day. Major fluctuations in discharge between August 22 and August 26 resulted from lowering of lake levels above the dam upstream in preparation for the remnants of Hurricane Katrina on August 30 (arrow right) (USGS, 2005).

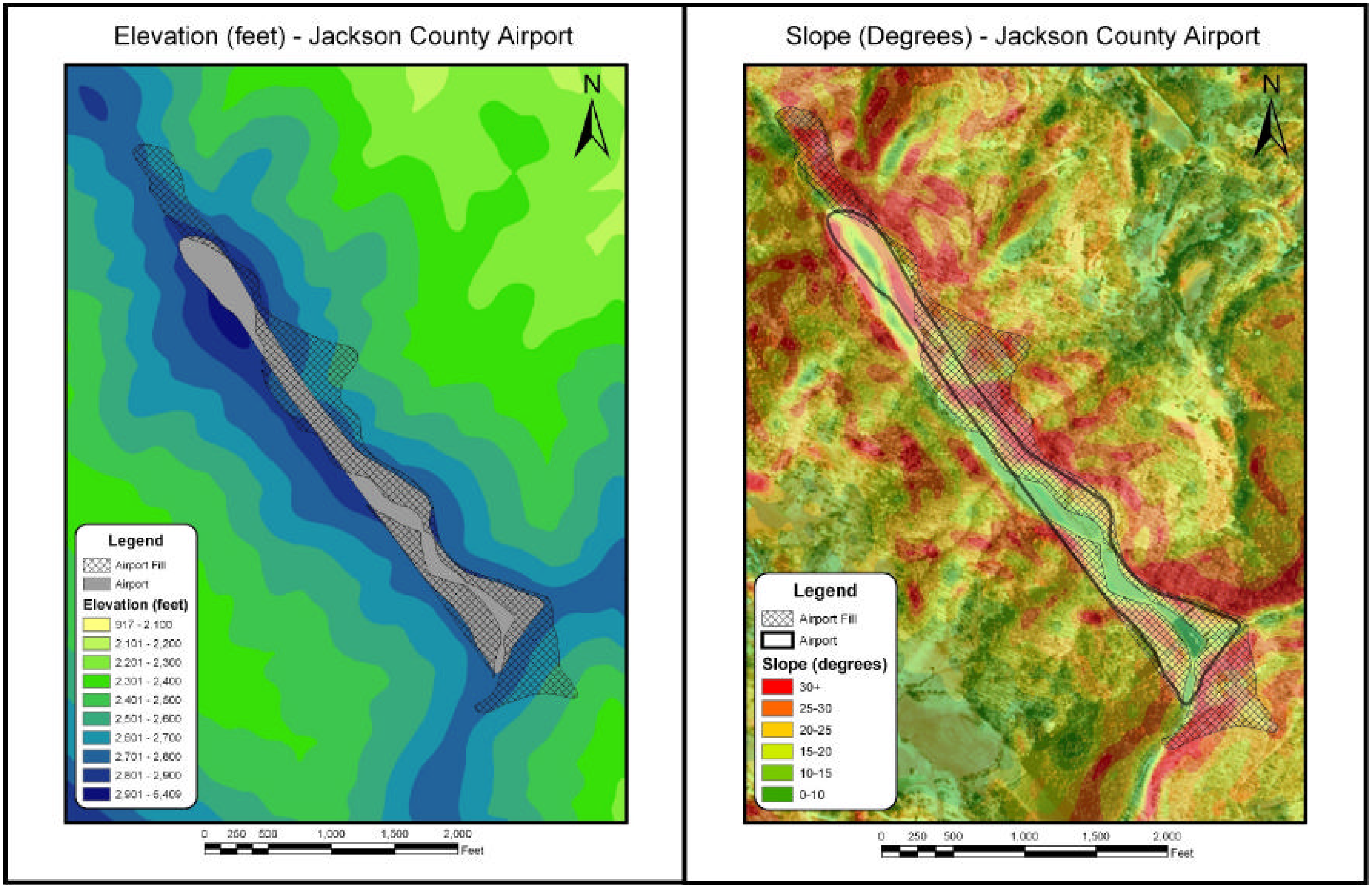

Figure 4. GIS maps of the Jackson County Airport and vicinity. **A.** Elevation map of the Jackson County Airport. Grey area delineates airport. Hatched area shows assumed locations of constructed fills based on elevation. Some fills may be at least 75 ft thick based on differences in elevation. **B.** Slope map of the Jackson County Airport. Areas in red indicate slopes greater than 30 degrees (58%). Hatched area shows assumed locations of constructed fills. Slopes greater than 30 degrees (58%) can be marginally stable, particularly where overlain by fill.

Figure 5. Head scarp of slope failure at Site 1. **Deposit 1** – Rock boulders from airport construction on ground surface. **Deposit 2** – Sand-silt-clay mixture with large fragments of organic debris. **Deposit 3** – Colluvial hillslope deposit consisting of sandy, silty clay with gravel and cobbles. Portions of layers 1 and 2 may have been transported during the reported 1977 landslide.

Figure 6. Top of older scarp (white dashed line) exposed at Site 1. Geologist is standing on down-dropped surface. This partially vegetated older scarp predates the new scarp formed by the August 22, 2005 slope failure (just southeast of this location shown in figure 5). The older scarp may have developed in the reported 1977 landslide deposits.

Figure 7. Debris flow head scarp exposed at Site 2. White arrow points to rock boulder from airport construction on ground surface.

Figure 8. Close up view of decayed woody debris (dark areas) exposed in the August 22, 2005 debris flow head scarp at Site 2 (fig. 7). Hammer head is about 7 inches across.

Figure 9. Photographs of debris flow that originated at Site 2. **A.** Mudline on tree (white arrow) along middle of track. Flow was downslope toward the left. **B.** Lower part of debris flow deposit with imbricated boulders and cinder block from destroyed springhouse. Flow direction was to right. **C.** Run out zone of debris flow deposit on yard of Ammons property. Flow direction was toward lower left of photograph.

Figure 10. Seepage (~10 gallons per minute) from base of man-made rock slope (bottom right of photo) at Site 3. Downslope is toward bottom right.

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