Natural Bridge, Virginia: UAV and Terrestrial Optical Data Collection

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MARSHALL UNIVERSITY

Dr. Anthony Szwilski, Chair (Civil)

KENT STATE UNIVERSITY

Dr. Abdul Shakoor, Prof. Em. (Eng. Geol.)

VTRC Virginia Transportation Research Council

Dr. Edward Hoppe, Research Scientist

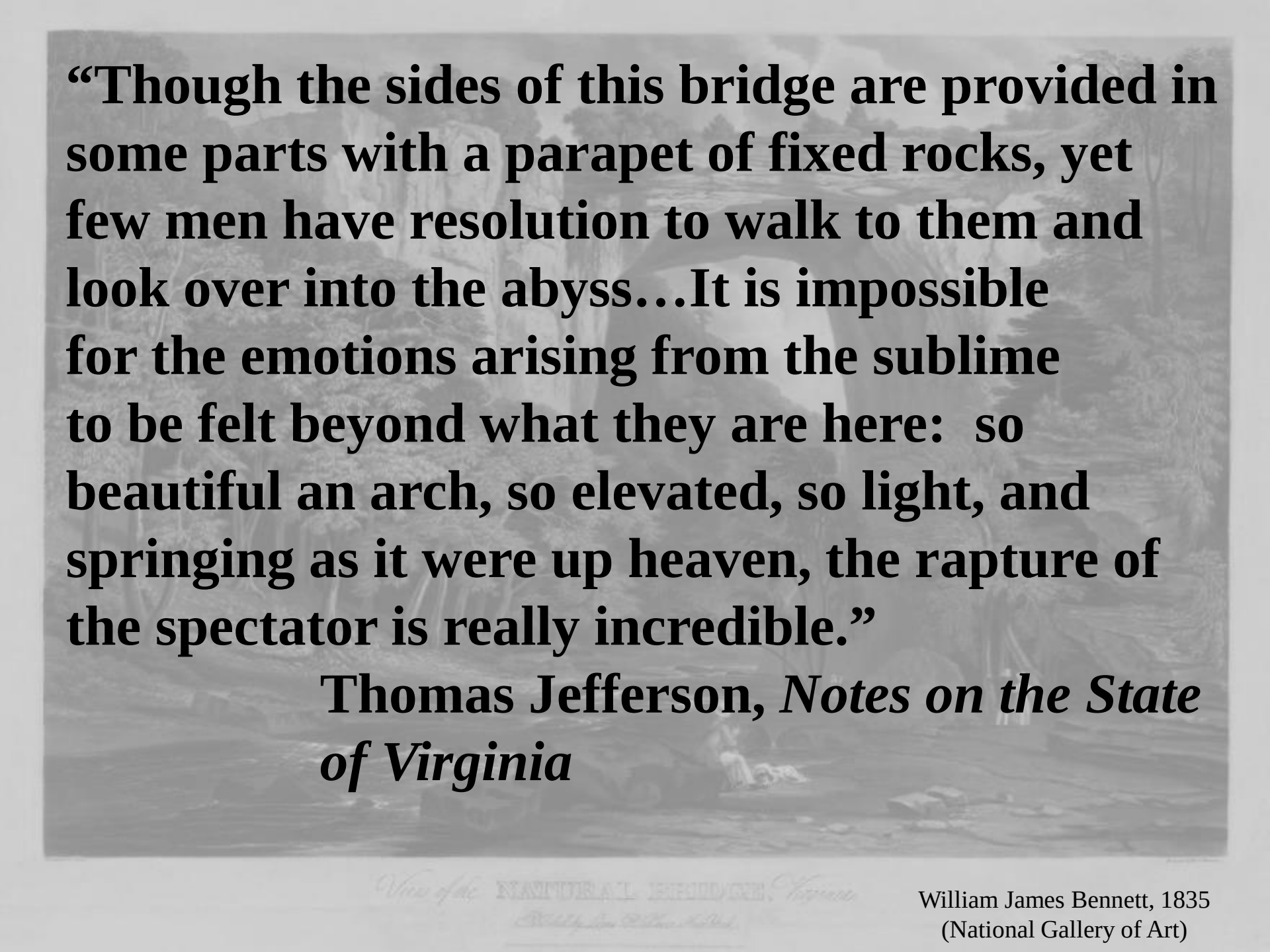
DMME Virginia Department of Mines Minerals and Energy

Mr. David Spears, CoVA State Geologist

William James Bennett, 1835
(National Gallery of Art)

“Though the sides of this bridge are provided in some parts with a parapet of fixed rocks, yet few men have resolution to walk to them and look over into the abyss…It is impossible for the emotions arising from the sublime to be felt beyond what they are here: so beautiful an arch, so elevated, so light, and springing as it were up heaven, the rapture of the spectator is really incredible.”

Thomas Jefferson, *Notes on the State of Virginia*



William James Bennett, 1835
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Natural Bridge Investigation
Investigation Methods

- Electrical Resistivity Imaging (Radford)
- Seismic Refraction (Radford)
- Multichannel Analysis of Surface Waves (MASW) (Radford)
- Ground Penetrating Radar (VDOT, Radford)
- Unmanned Aerial Systems (UAS) Photography and Videography (Radford)
- Terrestrial LiDAR (VDOT, Radford)
- Manual Discontinuity Mapping (VDOT, Radford)
- Vibration Monitoring (Radford)
- Unmanned Aerial Systems Remote Discontinuity Mapping (Radford)
- GigaPan Imaging (Radford)

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Natural Bridge Investigation

- Voids at both northern and southern end of the arch.
- Well-developed joint system.
- Blocks/masses sensitive to natural and human-induced weathering.
- Water migration throughout the mass.
- Traffic and light-show vibrations detected in the rock mass.
- Areas susceptible to rockfall.

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Natural Bridge Investigation
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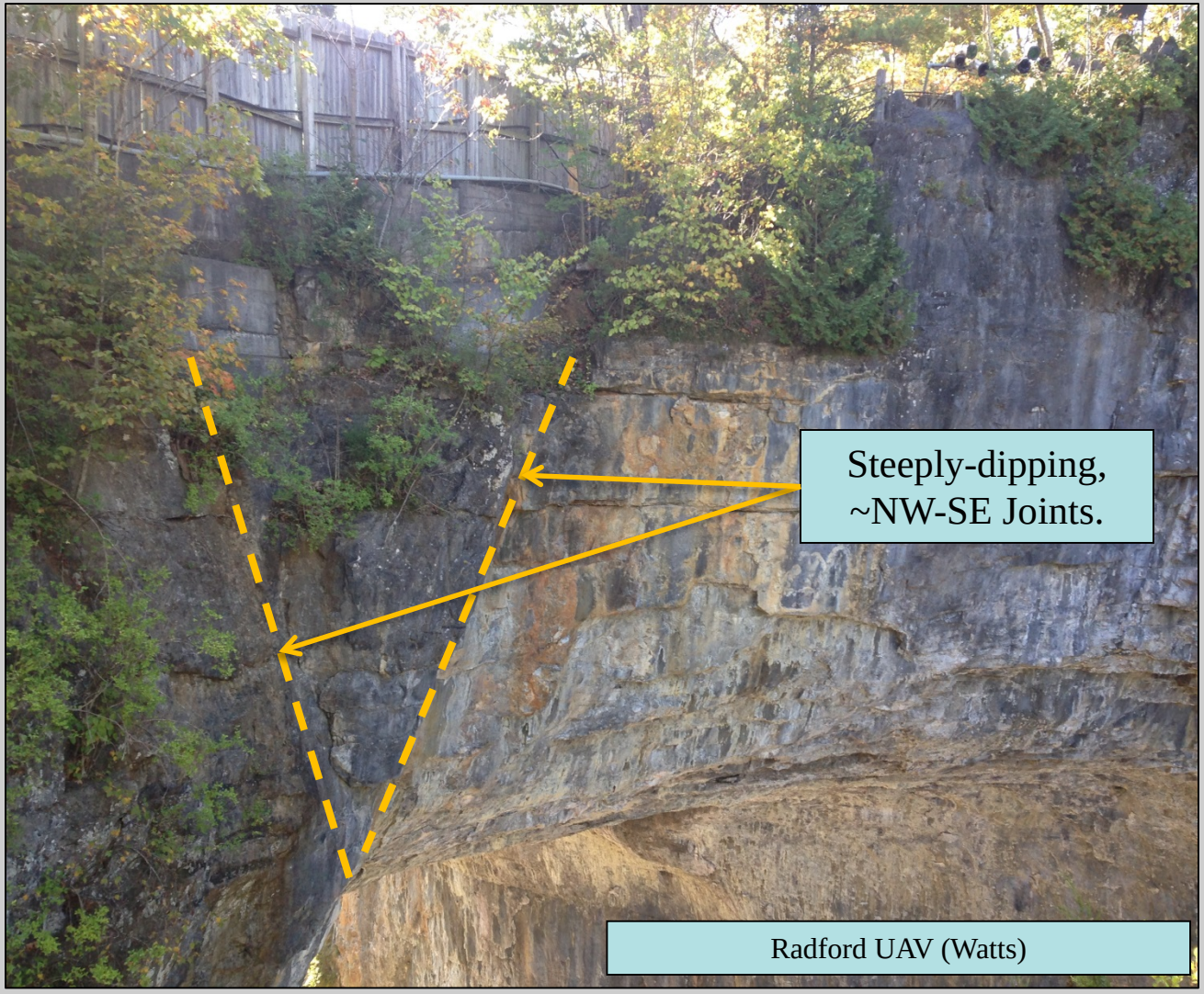
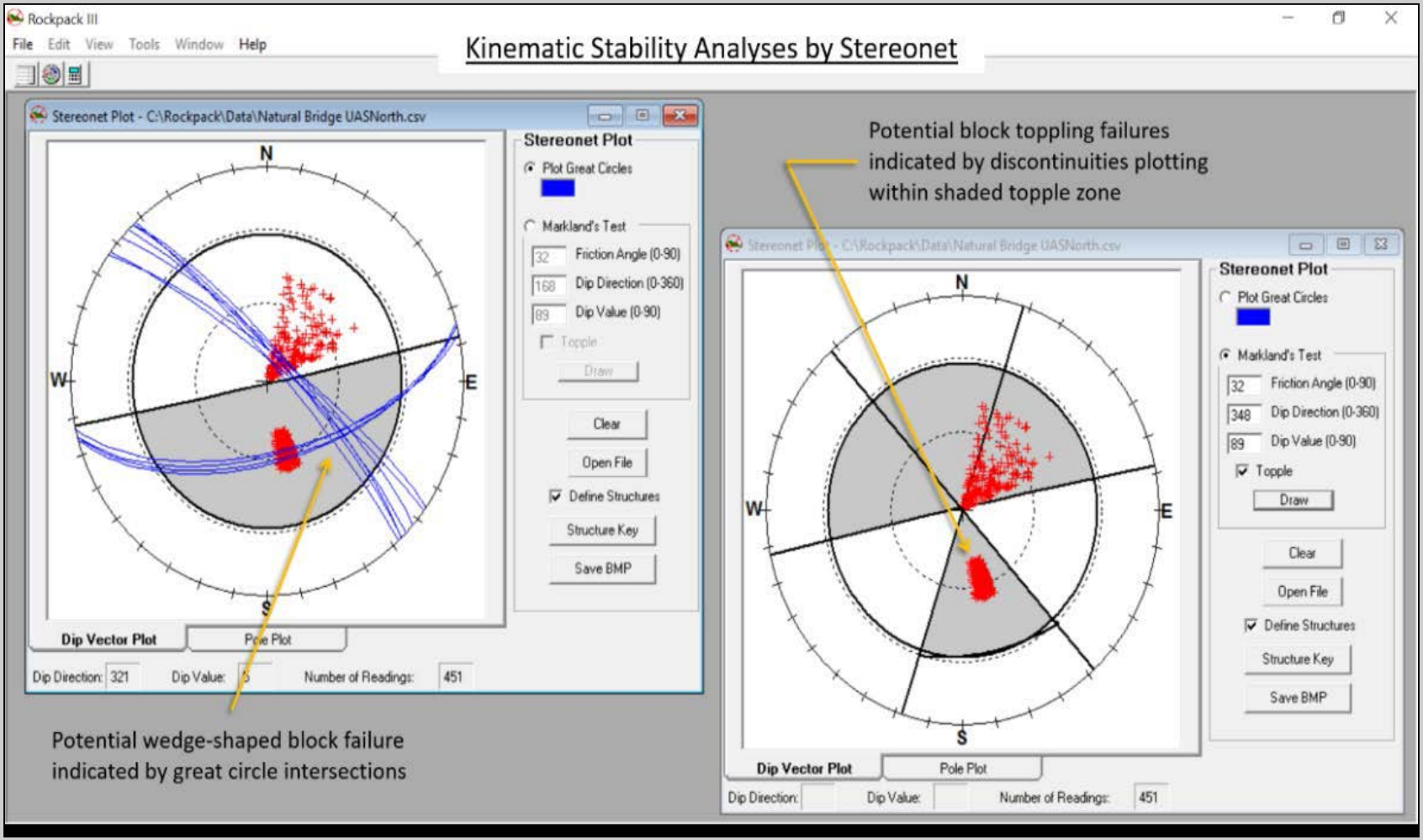
Joints



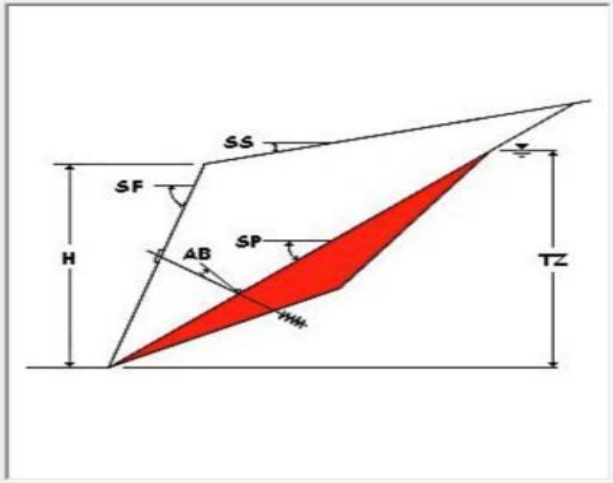
Natural Bridge Investigation
Weak Planes/Masses



Natural Bridge Investigation
Weak Planes/Masses

Plane Failure Analysis Input Screen - C:\Documents CFW\Projects\Tourist Sites\Natural Bridge\01 RU Report\Safety Factor RKPK\Typic...

File View Units Reset Help



Status: READY

CALCULATE FACTOR OF SAFETY

Optional Input Data

(AC) Horizontal Acceleration	0.008	G
(TZ) Amount of Discontinuity Saturated	0.6	decimal%
(VSUR) Vertical Surcharge	0	lb(f)
(HSUR) Horizontal Surcharge	0	lb(f)

Standard Input Data

(H) Height	18	ft
(SF) Inclination of Slope Face	90	°
(SS) Inclination of Upper Slope	0	°
(SP) Inclination of Failure Plane	69	°
(CO) Cohesive Strength of Failure Surface	400	lb(f)
(PH) Friction Angle of Failure Surface	29	°
(GR) Density of Rock	150	lb(f)/ft³
(GW) Density of Water	62.4	lb(f)/ft³

Bolt Data

(AB) Starting Rock Bolt Angle	0	°	(T1) Starting Bolt Tension	0	lb(f)
(AR) Ending Rock Bolt Angle	0	°	(T2) Ending Bolt Tension	0	lb(f)
(AA) Bolt Angle Increment	0	°	(T3) Bolt Tension Increment	0	lb(f)

Tension Crack Data

No
Ten
Ten
(B) Ho
(DZ) F
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Plane Failure Analysis Output Screen

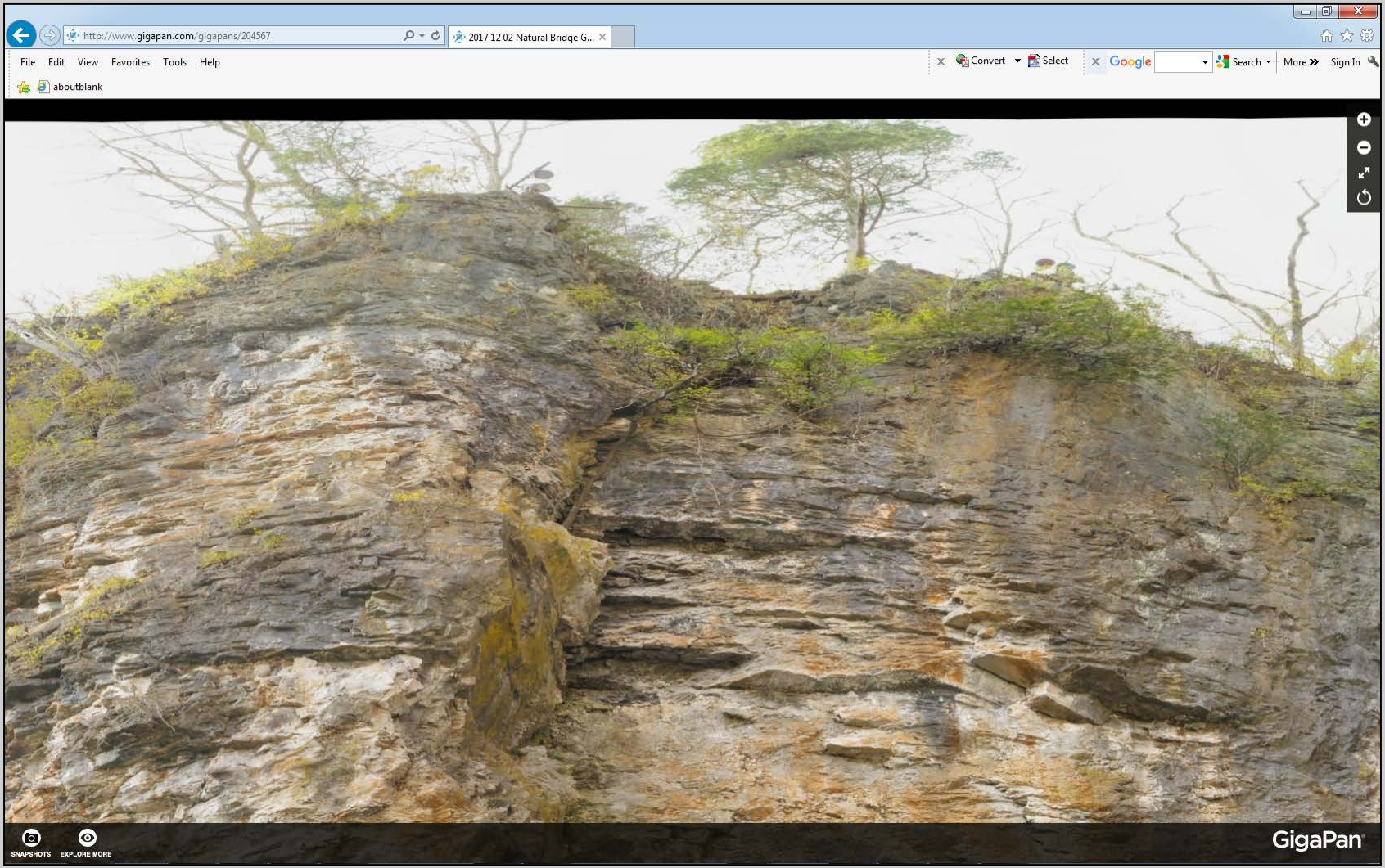
Print Units Graph Mode Help

Results

(F) Factor of Safety =	**0.97**	
(A) Contact Area =	19.28	ft²
(W) Weight of Slice =	9327.9	lb(f)
(U) Water Force Normal to Failure Plane =	1949.04	lb(f)
(V) Horizontal Water Force on Tension Crack =	0	lb(f)
(B) Horizontal Distance of Tension Crack from Crest =	6.91	ft

Radford GigaPan (Gigapan)

Natural Bridge Investigation
Water Migration



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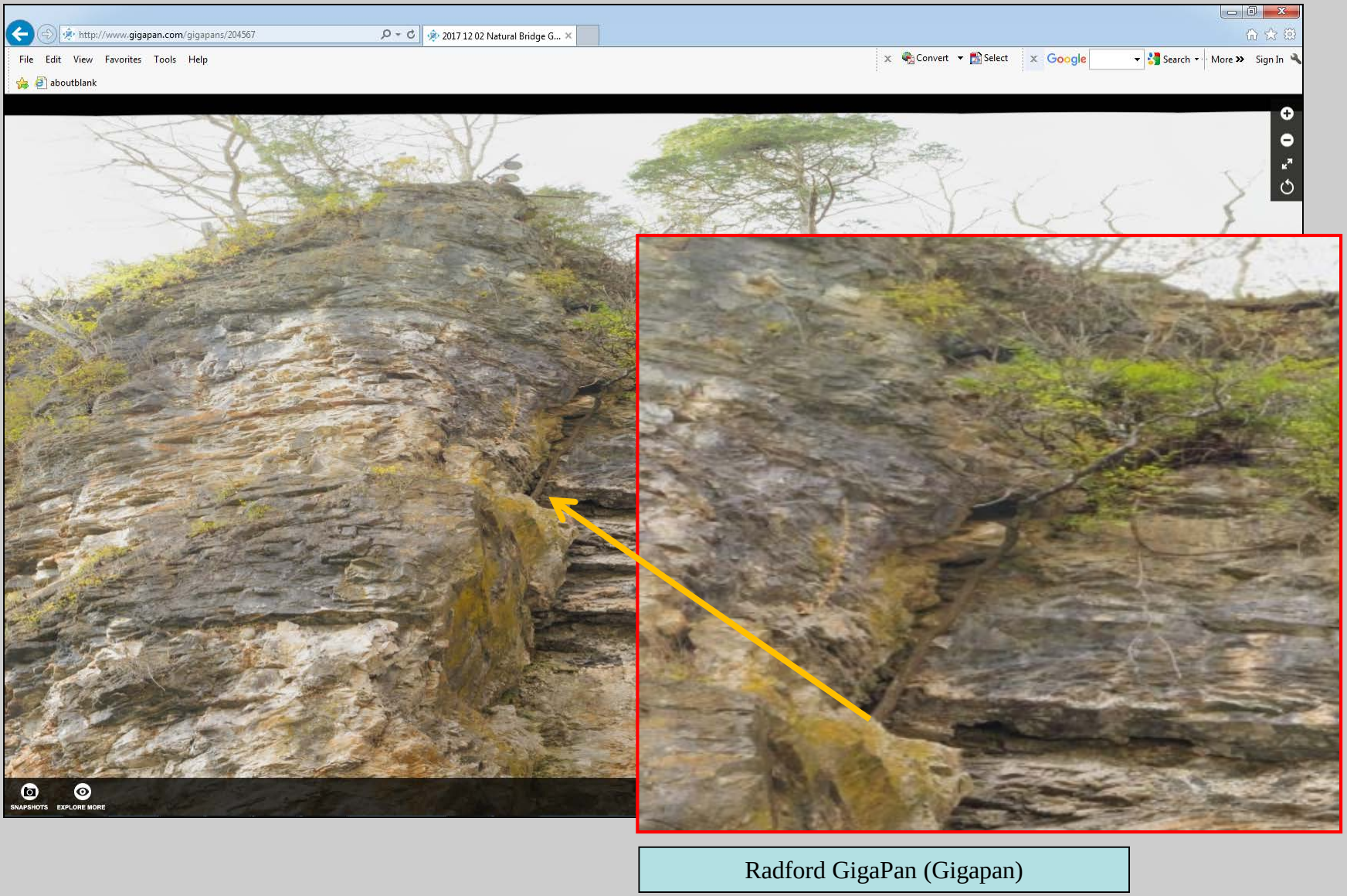

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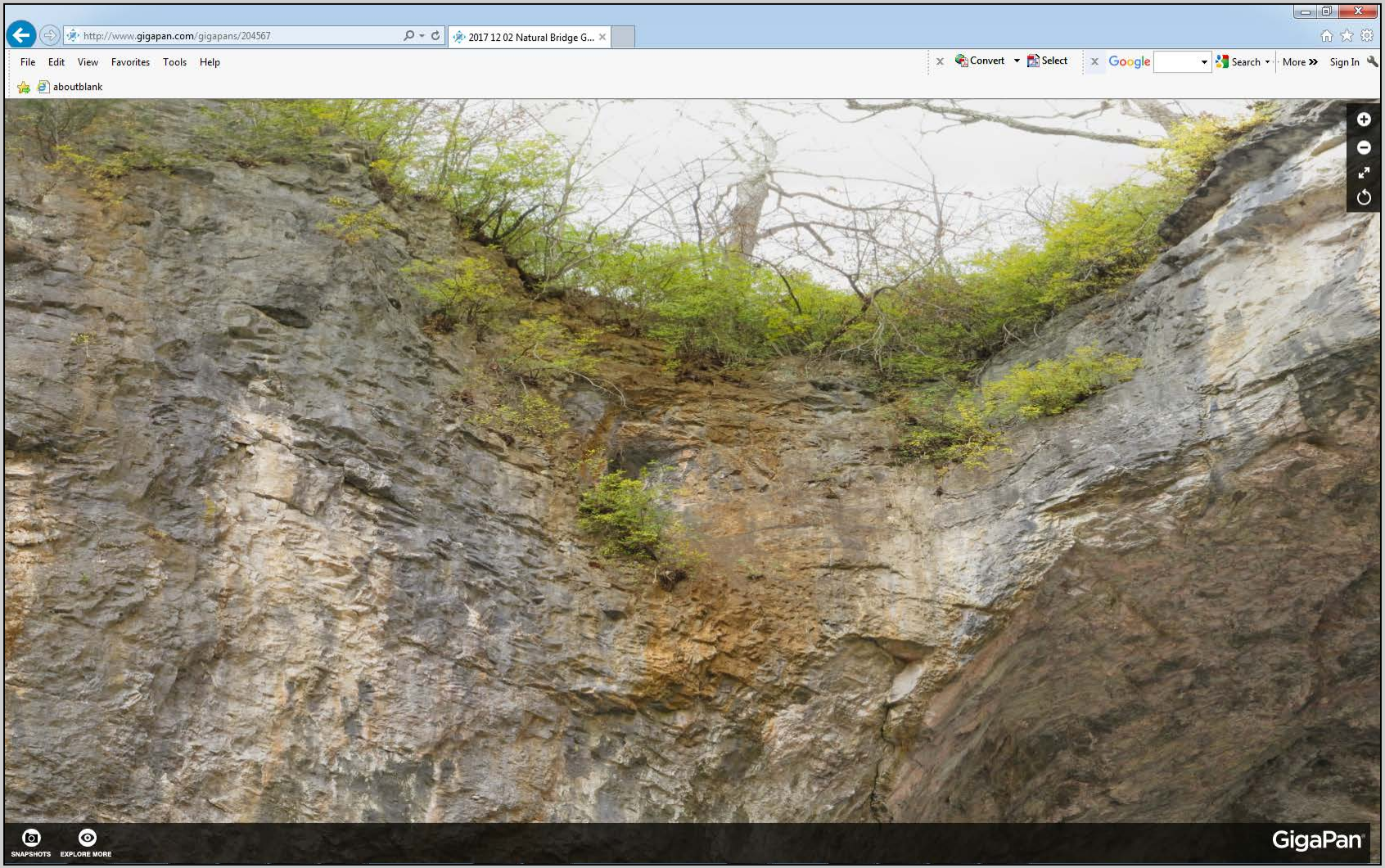

Radford GigaPan (Gigapan)

Natural Bridge Investigation
Rockfall

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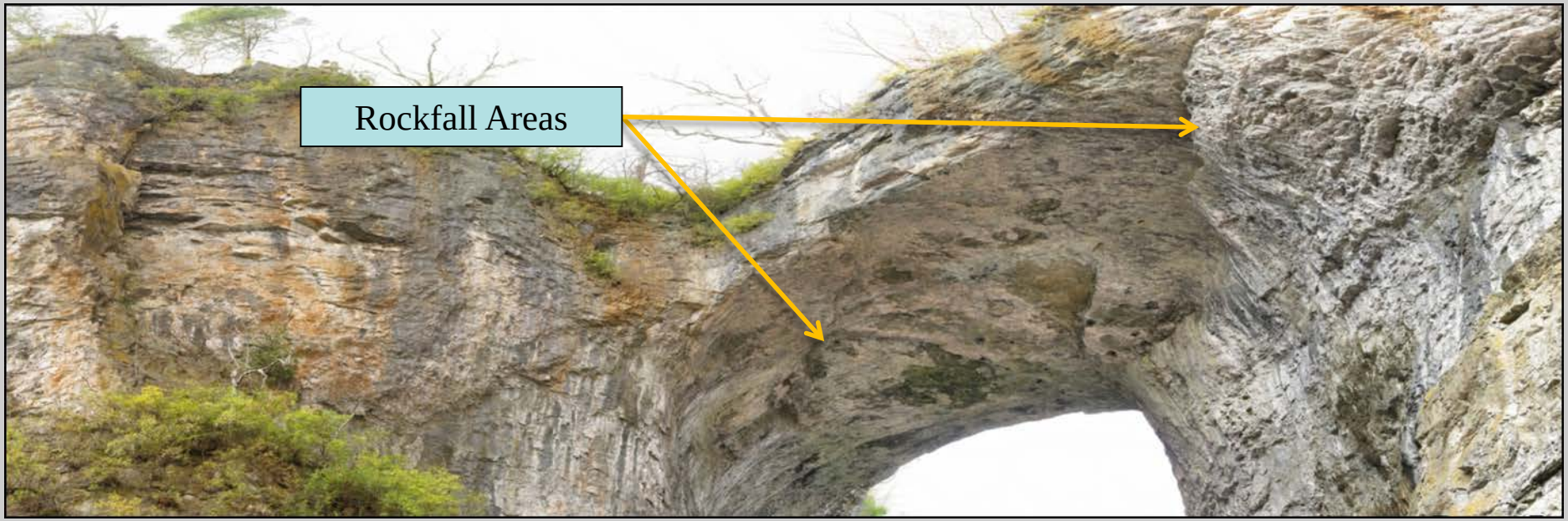

http://www.gigapan.com/gigapans/204567

Radford GigaPan (Gigapan)

Natural Bridge Investigation
Rockfall

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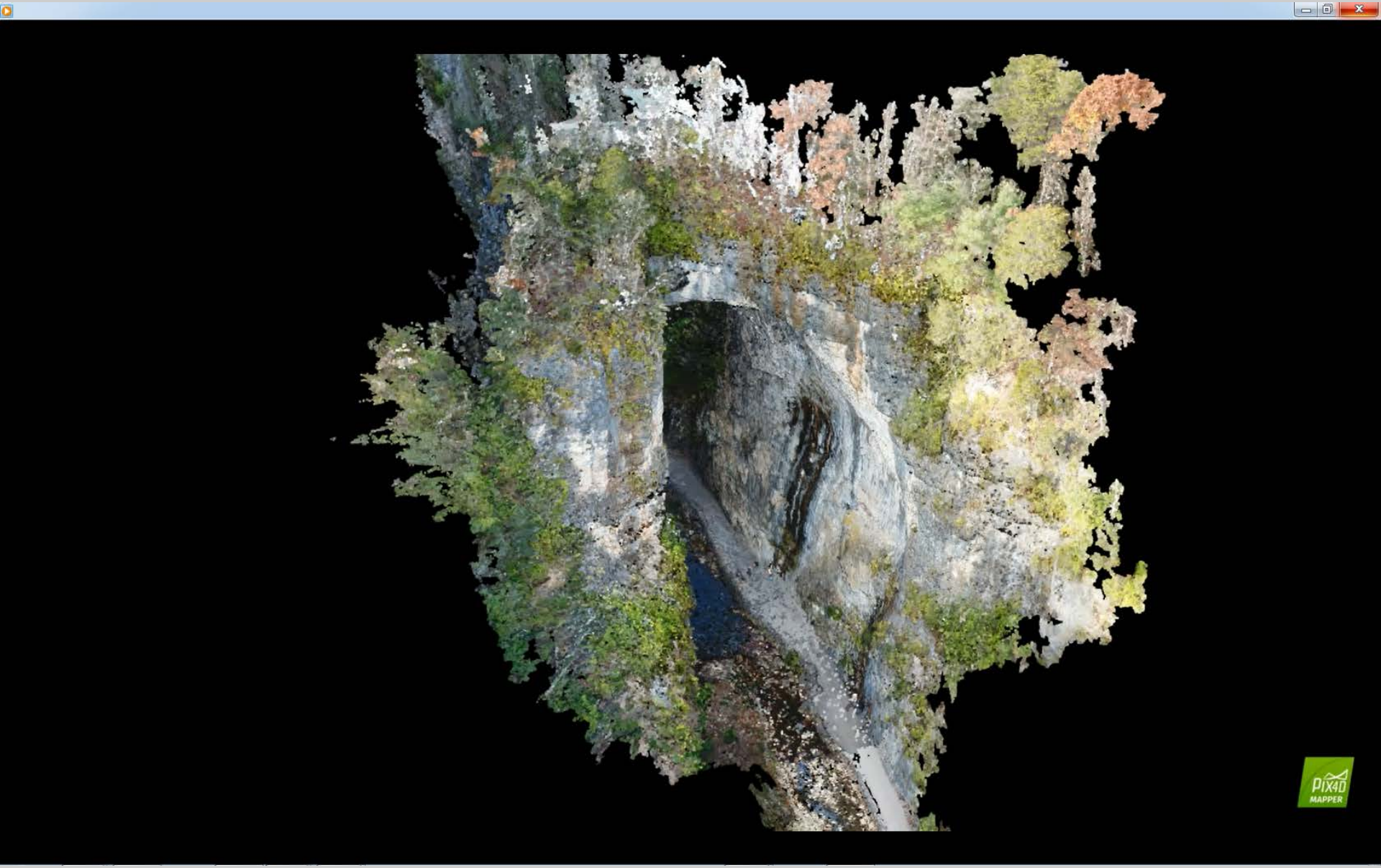
Natural Bridge Investigation Rockfall

- Vid DJI_0379us - AweBr.mp4
- UAS PtCloud from downstream vid.mp4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Natural Bridge Investigation

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- Well-developed joint system.
  - Confirmed by GigaPan; allowed calculation of FOS.
- Blocks/masses sensitive to natural and human-induced weathering.

- Water migration throughout the mass.
  - Confirmed by GigaPan and false-color UAV-derived imagery.
- Traffic and light-show vibrations detected in the rock mass.

- Areas susceptible to rockfall.
  - Confirmed and risk-indexed by GigaPan.

The News-Gazette.

April 17, 2018

NB Study: Road Should Go

However, Bridge May Not Fail Until 7018 Or So

By Lisa Perry

A Radford University study recommended that Lee Highway should be moved from the top of local limestone icon Natural Bridge "as soon as it is practical for the agencies involved, sooner better than later."

While the state highway will not cause the global, or complete, failure of the bridge, vibrations from the highway are impacting the bridge, said Dr. Skip Watts, director of the Radford University Geohazards Research Center that recently concluded a second months-long geological study of the state park centerpiece.

"We threw everything at the bridge that you can imagine in terms of technology," Watts announced at a press conference at the Virginia Department of Transportation offices in Lexington Friday. Exhibiting a seismographic printout showing vibrations as traffic crossed the bridge, Watts noted, "We can think of these as miniature earthquakes."

THE CIRCLE on this aerial image of the eastern side of Natural Bridge shows sensitive areas on the limestone arch, according to a report from Radford University Geohazards Research Center. The arrows point to concrete buttresses placed in 2000 by VDOT. U.S. 11 currently crosses the bridge above the buttresses. (Radford University Geohazards Research Center photo)

Testing concluded that there are some fractures and hollow spots within the bridge, and some sediment-filled cavities.

Even so, Watts said the earliest predicted potential global failure, or collapse, of the bridge will not occur until somewhere between 5,000 and 14,400 years from now.

The current highway lies very close to sensitive rock masses on an upper corner of the bridge. Regarding more localized stability, as opposed to global stability, nature does what nature does, Watts projected.

"The sensitive rock masses have potential to fall and could impact the trail below," Watts said. The sensitive rock areas are currently buttressed by Virginia Department of Transportation guards put in place in 2000.

Watts also conducted a similar study in 1999 after a piece of rock fell from the tourist attraction and caused a fatality. Having the surveys allowed his team to compare the bridge's condition now to that when the study was completed 18 years ago.

See **NB**, *page 16*

The News-Gazette.

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Study: Road over Natural Bridge should be rerouted

ASSOCIATED PRESS

ROCKBRIDGE, Va. – A study commissioned by Virginia transportation officials recommends eventually rerouting part of a road that crosses Natural Bridge, the landmark limestone arch.

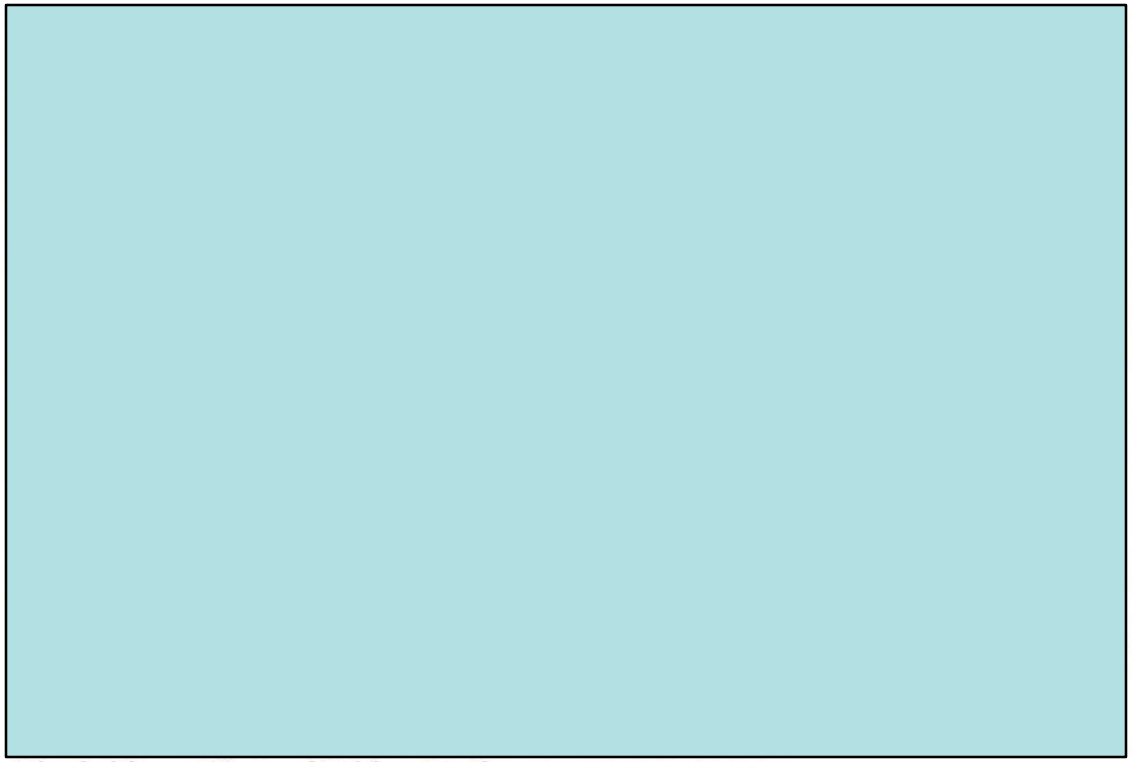
The findings of the study led by a Radford University geologist were released this week.

It found that the formation remains safe for the traveling public. But it says weak areas of the sides and beneath the rock formation and gorge will result in occasional local rock fall events.

It also says vehicular traffic should eventually be removed.

Virginia Department of Transportation spokesman Ken Slack says work on find other alignments for U.S. Route 11 is already underway.

He says preliminary possibilities could be made public this summer.



The bridge at Natural Bridge Station BILL CHRIST/SUBMITTED

Sunday, 04/15/2018 Pag.B01

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