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Ranking trails based on natural hazards instead of difficulty: A case study on Starved Rock State Park

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RANKING TRAILS BASED ON NATURAL HAZARDS INSTEAD OF DIFFICULTY

A CASE STUDY ON STARVED ROCK STATE PARK

By

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TABLE OF CONTENTS

To Dr. Max W. Reams, my fantastic mentor:

The life-blood of the department and an inspiration to us all.

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ABSTRACT

Starved Rock State Park in North-Central Illinois is not topographically flat as are many glaciated areas of Illinois. Its deep canyons and steep valley walls provide the backdrop for a diverse variety of natural hazards. Geologic hazards include steep canyon walls, flooding with erosion events, high elevation vantage points, and rock falls. Other natural hazards include falling tree branches and steep staircases. ArcGIS was used to record locations of both hazards and injuries along the trails and feature classes were made for each hazard. These feature classes were spatially joined and a weighted sum computed to create a hazard rating for each trail; the values ranged from 0 to 151. These hazard ratings were divided into three categories: least, somewhat, and most hazardous. This is a new way to rate trails, not by difficulty, but by how hazardous they are. The Illinois Canyon Trail was the most hazardous with a rating of 151. The high rating is due to its large number of rockfalls. My next step is to partner with the park to increase visitor awareness of hazards and encourage the public to be more careful where and when they hike. A Trails Hazard Rating map might be available to visitors in the future.

Keyword list:

- Starved Rock State Park
- Natural Hazards
- Geologic Hazards
- Case Study
- Rating trails
- Hazard-assessment
- Hiking trails

Introduction

One would not expect the need for a hazard-assessment case study in flat Illinois, but Starved Rock State Park in North-Central Illinois defies this misconception. Set along the scenic Illinois River in LaSalle County, it boasts 18 sandstone canyons and as many waterfalls that flow with water in the spring and fall and with ice in the winter. But as beautiful as this scene is, there are many natural hazards throughout the park's area and a number of people are injured each year in the park due to these hazards. Geologic hazards include steep canyon walls, flooding with erosion events, high elevation vantage points, and rock falls. Other natural hazards include falling tree branches and steep staircases. The purpose of this research is to create a new method of rating trails; they are rated by how hazardous they are, instead of by degree of difficulty. Data collected was entered into ArcGIS for analysis. The next step is to partner with the park to increase visitor awareness of these areas and their hazards. This is not a stay-away-from-this-place project, but a be-more-aware-so-you-can-be-safe project. The ultimate goal is for visitors to enjoy the majestic beauty of Starved Rock State Park with a minimal likelihood of injury.

Literature Review

Ranking and rating trails based on their hazards is a new concept that could be implemented state-wide, if this method is found to be accurate and useful. There have been similar studies, called hazard-assessment studies, that have been conducted for many years. The purpose of a hazard-assessment study is to understand the cause of the hazards, the probability of their reoccurrence, and the consequences of their occurrence on the general public in the study area (Walder & Driedger 1994). Historically, hazard assessments have been used for debris flows, landslides, floods, and hurricanes (Walder & Driedger 1994; Lui et al. 2004; Islam & Sado

2000; Nott 2004). This investigation is somewhat of a hazard-assessment study, but it focuses mainly on the consequences of the hazards on the general public visiting Starved Rock State Park. It does not focus on the causes of the hazards. The probability of reoccurrence is a factor in the hazard ratings, but that is not a product of this study. Since my research involves testing a new method of rating trails, it is a case study as well.

Hiking trails have been rated by difficulty for many years. Larger national parks like Yosemite that contain substantial peaks have a rating system comprised of classes (*Difficulty Rating System* 2014). These classes do not apply to smaller parks without mountains, however. State parks like Starved Rock may use specific criteria for rating their trails, but none have been published online specifically for Starved Rock State Park.

The Study Area

A Brief Geologic Background

At the time of the last ice age, approximately 15,000 years ago, an event called the Kankakee Torrent scoured much of Northern Illinois (Wiggers 1997). These glacial meltwaters were dammed by ridges of sediment (moraines) deposited by the retreating glaciers. The meltwaters broke through the moraines in multiple places and proceeded to sweep away rock and soil from large areas. The Illinois River valley, along which the park is situated, was gouged out by these floods (Wiggers 1997). The powerful torrent cut into the uplifted Ordovician St. Peter Sandstone and into the Shakopee dolostone bedrock below (Illinois State Geological Survey [ISGS] 2005).

It is hypothesized that the canyons of Starved Rock State Park formed from streams tributary to (draining into) the newly formed Illinois River; the streams would have been left

hanging by the rapid incision of the river valley due to the Torrent and were quickly eroded into the sandstone to reach the new base level (ISGS 2005; Wiggers 1997). Other flood events occurred after the torrent and further eroded the Illinois River (Wiggers 1997). Continued erosion along joints (weak planes in the rock) deepened these canyons into the 50-80 feet deep, box-canyons that we see today (ISGS 2005).

The canyon walls are made up of St. Peter Sandstone, a pure quartz arenite that has been extensively weathered (Kolata & Nimz 2010). The creation of the sandstone was likely a combination of wind and water processes; cross-bedding in some layers suggest near-shore sand dunes while fossils found in other layers suggest that the sand was most likely deposited in a marine environment and re-worked by waves (Reams 2013). Alternating Pennsylvanian shales, sandstone, and coal were deposited on top of the sandstone (ISGS 2005). The coal beds were eventually mined by the Starved Rock Coal and Mining Company in areas of where the park stands today (Willman & Payne 1942).

Where is Starved Rock State Park?

The park is in LaSalle County, Illinois, which is highlighted in blue in Figure 1. Starved Rock State Park lies along the southern bank of the Illinois River just south of I-80. It is nestled between LaSalle, IL on the west and Ottawa, IL on the east. A more detailed map of LaSalle County is shown in Figure 2.

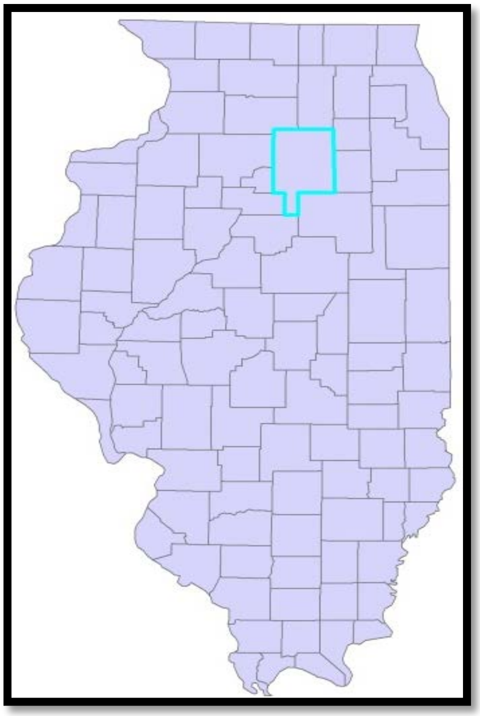

Figure 1. LaSalle County is highlighted in blue.

Figure 2. The arrow points to the location of Starved Rock State Park in LaSalle County.

More about Starved Rock State Park

Figure 3 shows a relief map of the park, a zoomed in look from where the arrow pointed in Figure 2. Red indicates a higher elevation and green indicates a lower elevation. The trails are represented by the black lines close to the river. The visitor’s center is represented by the red dot and the lodge by the yellow dot.

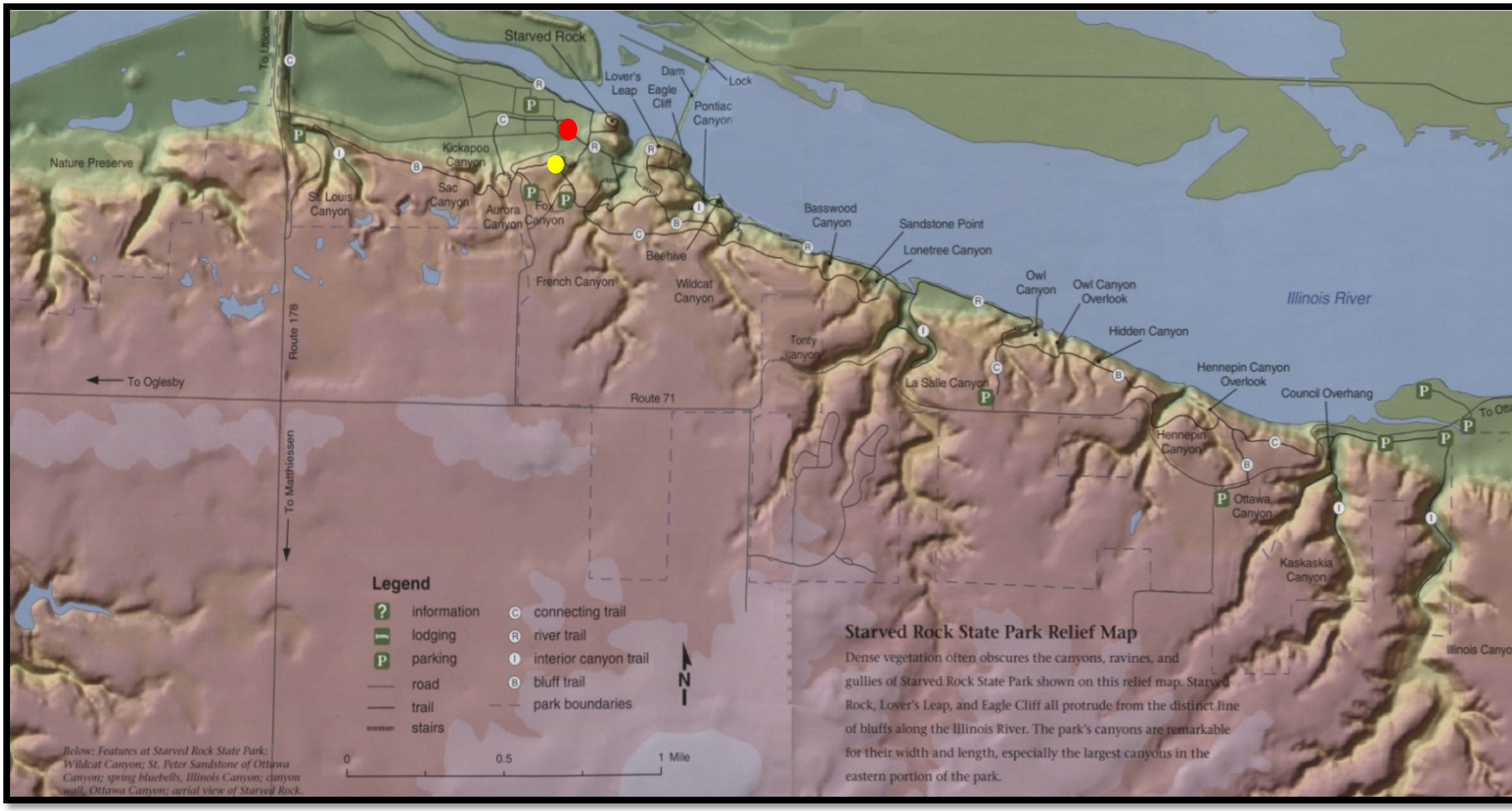

Figure 3. A relief map of Starved Rock State Park. Red is high elevation and green is low elevation (ISGS 2005).

It is difficult to see from Figure 3, but the park is built on two levels—along the Illinois River bank and on the vertical sandstone bluffs about 50 to 80 feet above the river bank. The park's visitor center (red dot in Figure 3) is built on the floodplain of the river and the Lodge, the only hotel in the park, sits on the sandstone bluff overlooking the visitor's center (yellow dot in Figure 3).

The park has about 2 million visitors annually, according to Stacy Solano, spokeswoman for the Illinois Department of Natural Resources (Grimm and Bowean 2011). In 2014, however, an unprecedented 1 million visitors came to the park between March 31, and August 6, 2014 with 300,000 visitors in July alone (Collins 2014). The park has an impeccable safety record: in the years 2008-2011, only four serious accidents occurred when roughly 6 million visitors visited the park (Grimm and Bowean 2011). For visitors' safety, park authorities stress staying on the trail and prohibit climbing the crumbly canyon walls (Illinois Department of Natural Resources [IDNR] 2014).

The Hazards

The natural hazards identified by this study are as follows: flooding/erosion, major (steep) staircases, high elevation vantage points of the Illinois River, canyons, falling trees/tree branches, and rockfalls.

Flooding occurs often along many trails in the park. There is evidence of rapid erosion of the trails along the Illinois River. Trails have been closed before due to flooding because swiftly moving water causes a drowning risk and washes out trails and bridges (Sterrett 2013; Dziedzina 2011). Figure 4 shows the erosion of one of the river trails.

Figure 4: Erosion of a river trail.

Steep staircases are also a hazard. The sheer 50-80 foot drop from the sandstone bluffs to the river trails below necessitates staircases. The park has built them to ease access to and from these trails. However, the stairs produce a hazard for all ages and fitness levels. Many hikers have injured themselves by tripping or falling on the stairs. Figure 5 shows one of the many major staircases in the park.

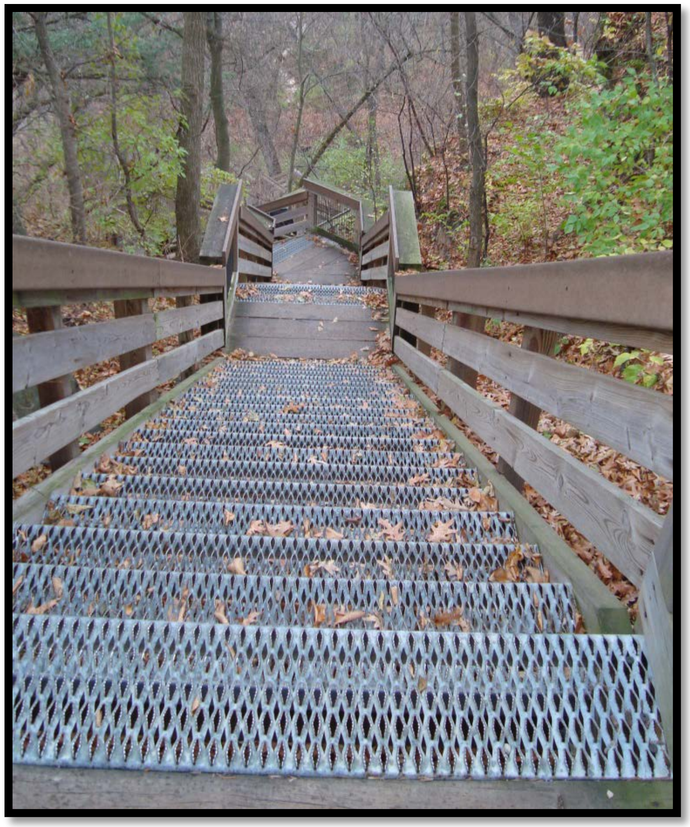

Figure 5: One of the major staircases in the park connecting the bluff trails above to the river trails below.

High elevation vantage points are a third hazard. These are places high above the floodplain where people can gain a great view of the beautiful Illinois River. Sometimes these views are enclosed by barricades, other times not. The steep drop to the river or to the trails below creates a risk for any who venture too close to the edge. In December 2011, one man fell to his death in the river when he stepped over the safety fences near Eagle Cliff Overlook, a high elevation vantage point (Meyers 2011). Figure 6 shows an example of a high elevation vantage point that is barricaded.

Figure 6: Eagle Cliff Overlook complete with a barricade to prevent falls.

Canyons are a fourth hazard. While stunning to look at, many visitors want to get too close. Numerous injuries and one death have occurred from January 2008 to August 2013 when people either got too close to the edge and fell in, or climbed up the friable canyon walls and then fell down. These dates are explained in the Methods section. Figure 7 shows the friability of the sandstone that makes up the canyons. Figure 8 is a picture of Wildcat Canyon, an 80 foot deep canyon where some have fallen to their deaths (GoWaterfalling.com 2011).

Figure 7: The sandstone crumbles at the slightest touch, if not covered in weathered silica residue.

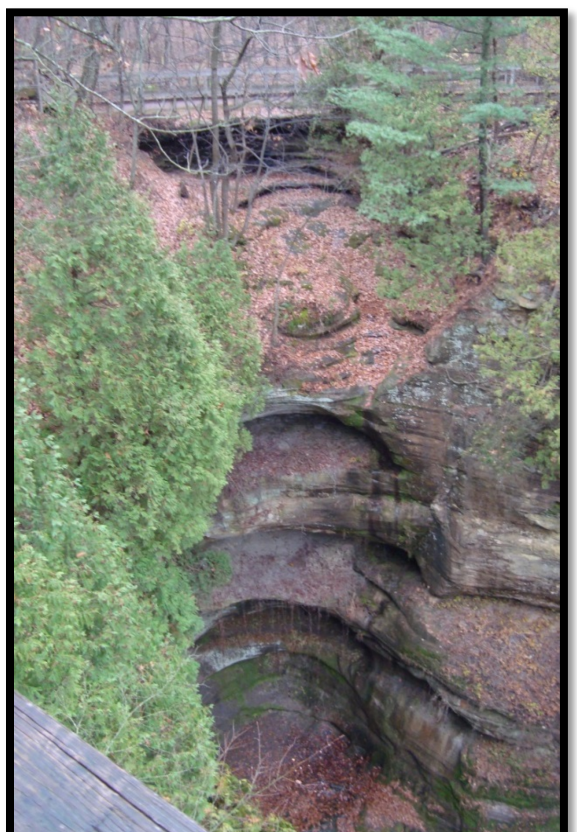

Figure 8: A view of the 80-foot drop of Wildcat Canyon.

Falling trees and tree branches are another natural hazard; the park is densely forested and the tree roots are wide and shallow, unable to deeply penetrate the bedrock beneath. If the roots do penetrate the bedrock, it erodes easily and can cause trees to fall. Flooding can erode away the thin topsoil, also causing trees to fall. Strong winds can knock the trees together and snap branches off. Sometimes the trees and tree branches fall onto the trails; two hikers were injured by falling tree branches during the five and one-half year study period. One branch struck a visitor's hand, but another fell on a visitor's head (IDNR 2013).

In the summer of 2014, two storms struck the park and felled so many trees that all of the trails had to be closed (McConnaughhay 2014). Dangling branches and felled trees made hiking the trails unsafe (McConnaughhay 2014; Dankert 2014); McConnaughhay called them "widow-makers" (2014). Figure 9 shows an example of a fallen tree.

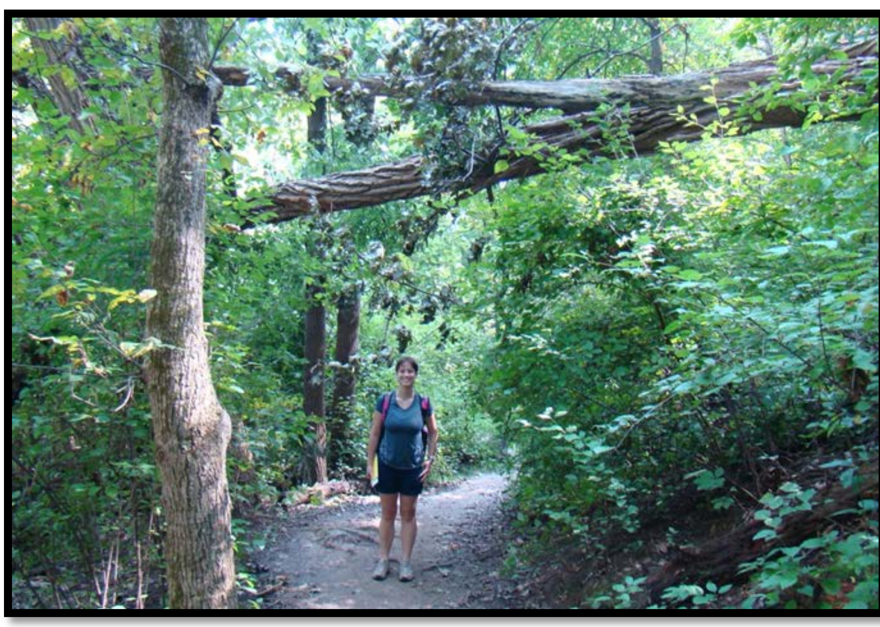

Figure 9: An example of a fallen tree above the trail leading to Council Overhang near Kaskaskia Canyon.

The final natural hazard found in the park is rockfalls. There are numerous rockfalls along the trails, especially trails on the far eastern edge of the park. While many possibly occurred in the Pleistocene, some are quite recent. Evidence for older rock falls is tree growth around or on top of the rockfalls and sand accumulation underneath due to weathering. More recent rockfall sites have not been as severely weathered; some have fresh surfaces exposed.

A particularly notable canyon for rockfalls is Illinois Canyon; it has been unstable for many years. In the early 1930s, a massive landslide occurred in Illinois Canyon and the Civilian Conservation Corps stationed at Starved Rock had to remove the debris (Buckman 2014). More recently, a visitor was struck on the head by a falling rock in Tonty Canyon in 2013 (IDNR 2013). Most of the recent collapse of sandstone, however, comes from sheeting— sandstone peeling off the canyon walls in layers.

Rockfalls occur because the St. Peter Sandstone is jointed and friable. Weathering along the joints, in tandem with gravity, causes blocks of rock to tumble from the canyon walls. Figures 10-13 are pictures of rockfalls in the park.

Figure 10: Rockfall at the end of St. Louis Canyon.

Figure 11: A massive boulder that fell from Tonty Canyon wall.

Figure 12: A recent rockfall in Kaskaskia Canyon that disintegrated into sand.

Figure 13: An example of sheeting in LaSalle Canyon.

Methods

From Raw Data to a Feature Class

Data for this research project was gathered from multiple sources: the Illinois Department of Natural Resources (2013), field observations, the Illinois Geospatial Data Clearinghouse (2014), and *Time Talks* by the ISGS (2005). Once all of the data was gathered, feature classes for the injuries, hazards, and trails were created in ArcGIS.

Before hiking the trails or creating feature classes, it was necessary to gather data on previous injuries at Starved Rock State Park. The Illinois Department of Natural Resources provided data on a total of 40 injuries and deaths related to the natural hazards at Starved Rock State Park encompassing a five and one-half year span from January 2008 to August 2013. This is the five and one-half year study period used for this research. This data came in the form of Case Incident Reports filed by park rangers and police. The data do not include accidents caused by pre-existing conditions such as asthma or human activities like suicide, drug busts, or lost persons. Locations of injuries were used in the calculation the hazard rating for each trail.

Figure 3 from *Time Talks* by the ISGS (2005) was the background image for my data. The image was scanned into, and georeferenced in, ArcGIS. Feature classes of major stairway locations, floodplains, park boundaries, and hiking trails were created from this image.

The park has sectioned off the hiking trails into four types: bluff trails, river trails, interior canyon trails, or connecting trails. This research called for a more descriptive approach for the trails. For this study, the trails were sectioned off and named based on the canyon or physical feature to which they were closest. For example, the newly-named Illinois Canyon trail was the section of trail going into Illinois Canyon; the newly-named East bluff connecting trail

was a bluff trail along the eastern side of the park with no canyons along it (see Figure 15). Figure 14 shows a map of the park. Its trail labels can be used to compare with those created in in this investigation shown in Figure 15.

Field work involved walking all of the trails and recording observable natural hazards and their locations on a park map. Field work was conducted on Nov. 16, 2013, March 29, 2014, and Sept. 20, 2014.There were six different hazards observed, as recorded in the hazards section above: rockfalls, flooding/erosion locations, steep slopes/major staircases, canyons, falling trees and tree branches, and high elevation vantage points of the Illinois River. Of these six, only locations of rockfalls were explicitly recorded. Four hazards (excluding falling trees and tree branches) were already recorded on either the park map or the scanned topographic image (Figure 3). The falling trees and tree branches feature class was created from a reclassified land use raster courtesy of the Illinois Geospatial Data Clearinghouse (2014). All of these hazards were made into feature classes (shown in Figures 16-19). Rockfalls, major staircases, and canyons were point feature classes. Flooding locations, falling trees and tree branches, and high elevation vantage points were polygon feature classes. The hiking trails were a line feature class.

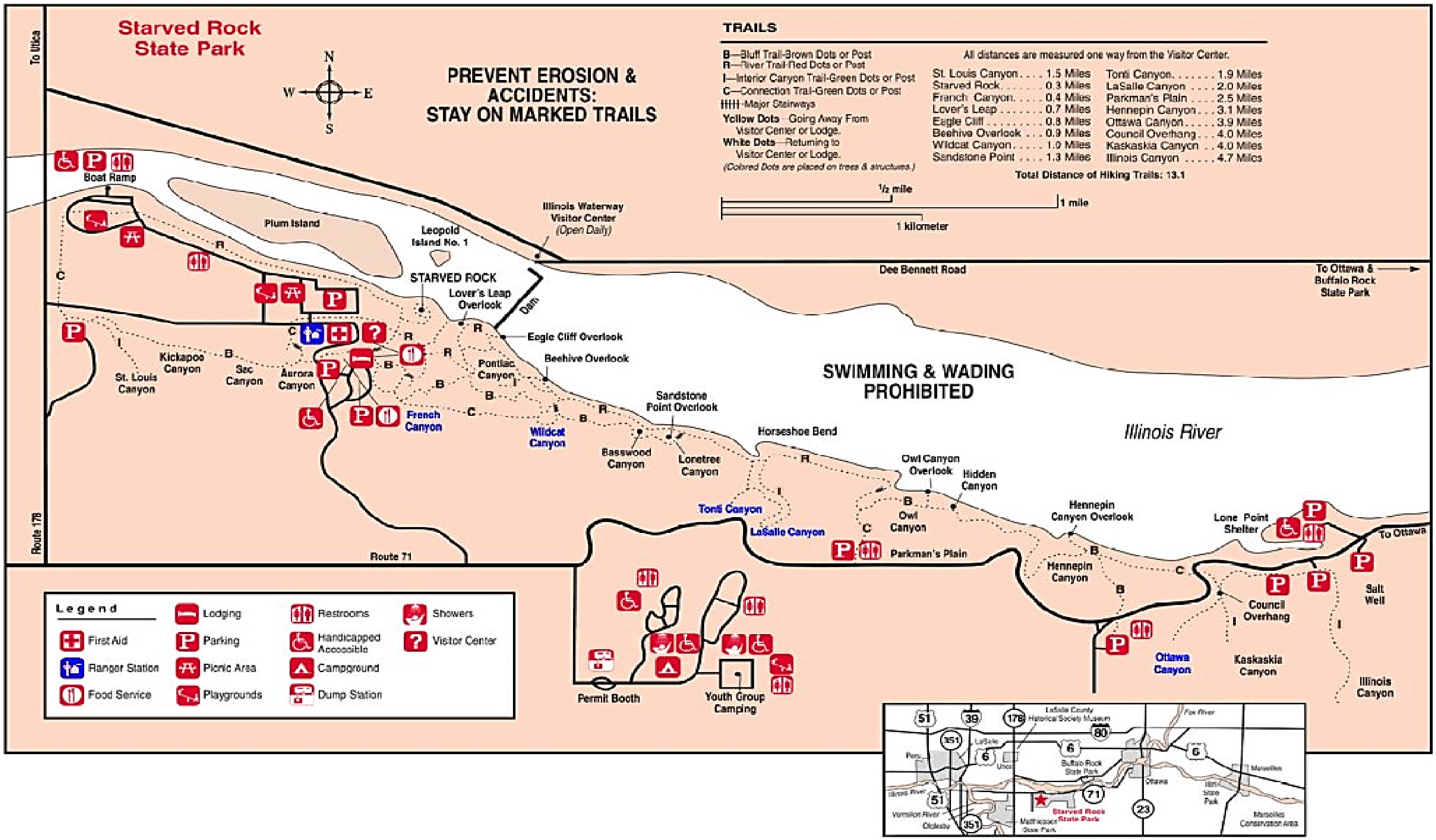

Figure 14: Map of Starved Rock State Park that is given to visitors. The different canyons are labeled, but the trails are labeled bluff (B), river (R), interior canyon (I), or connecting (C) trails. Image courtesy of http://images.summitpost.org/original/391306.jpg.

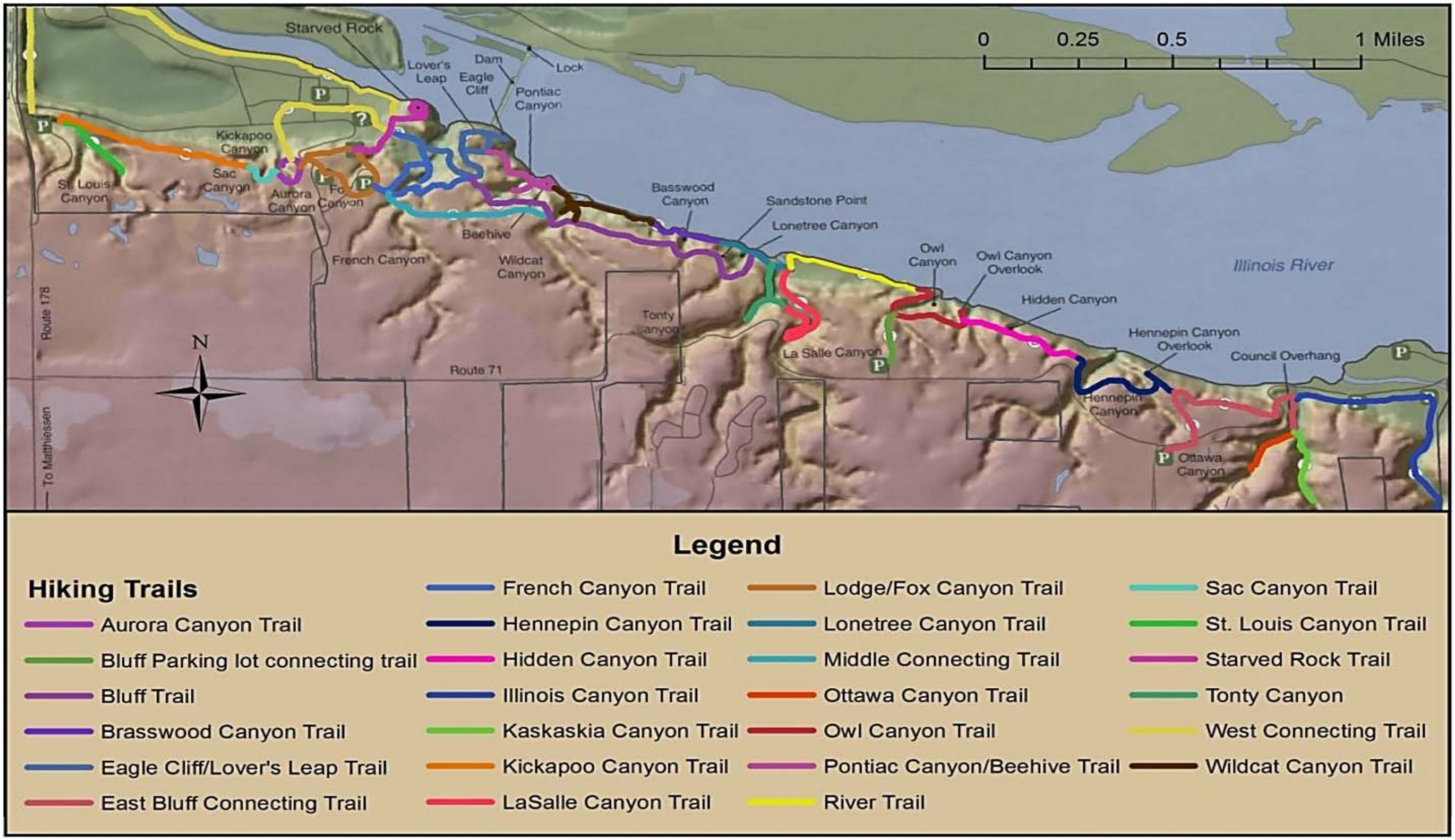

Figure 15: Map of Starved Rock State Park created during this investigation. The trails were sectioned off and named based on the canyon or physical feature to which they were closest.

The following feature sets show where the hazards occur in the park (Figures 16-19). Because the entire park is forested, according to the land use raster from the Illinois Geospatial Data Clearinghouse (2014), that feature set is not included. Locations of injuries are included in Figure 19. The injury locations were determined from details in the case incident reports (IDNR 2013).

Flooding/Erosion Locations and High Elevation Vantage Points of the Illinois River

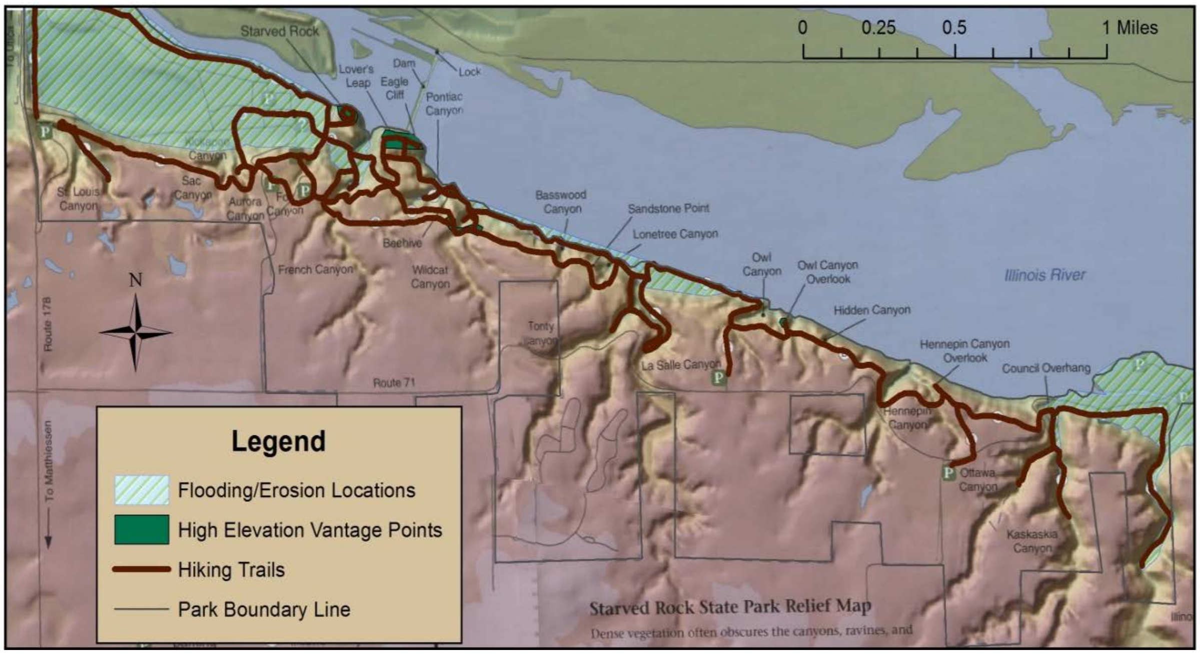

Figure 16: The feature classes for flooding/erosion locations and high elevation vantage points of the Illinois River.

Canyons and Major Staircases

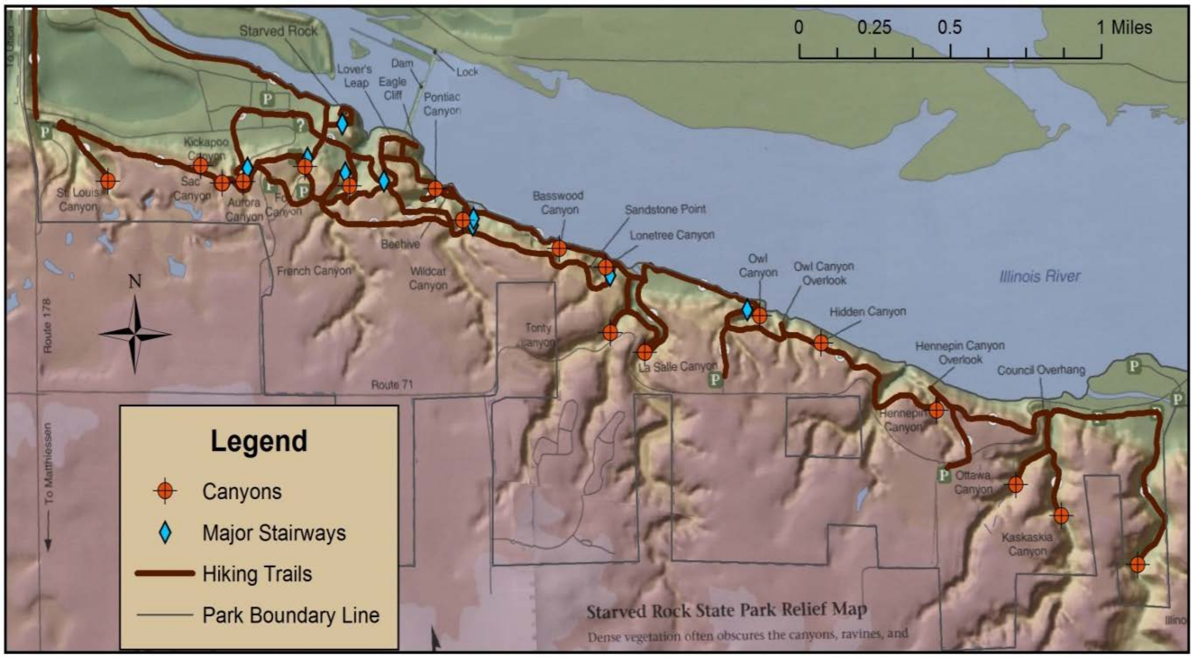

Figure 17: Feature classes for canyon locations and major stairways.

Rockfall Locations

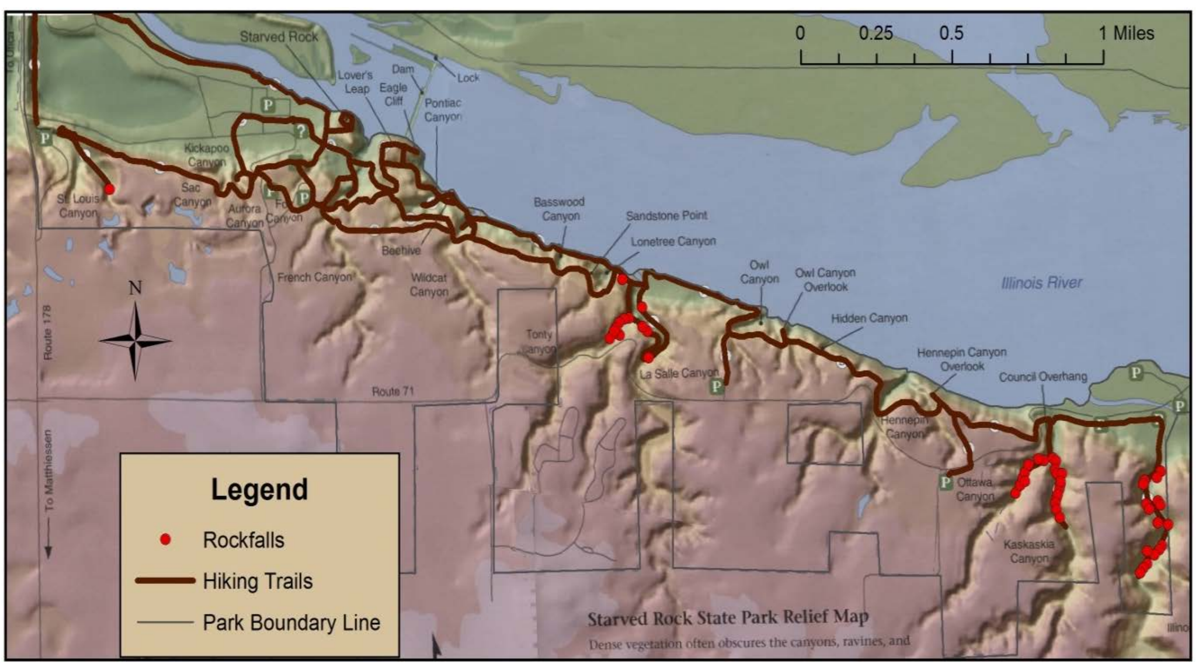

Figure 18: Feature class for rockfall locations.

Locations of Injuries

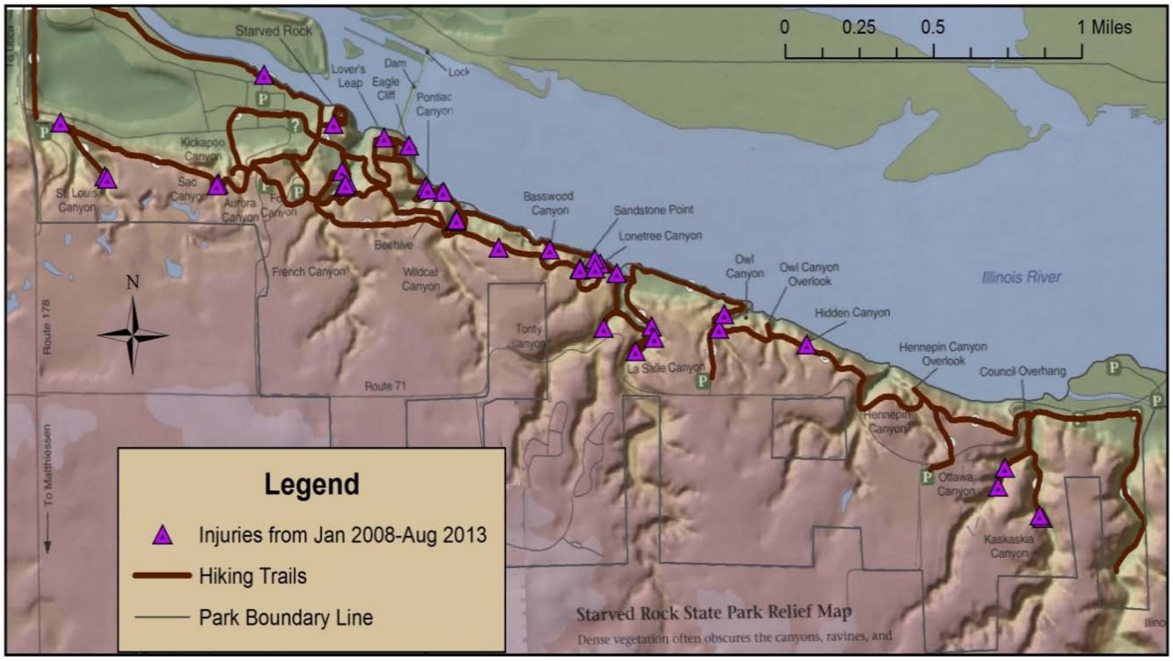

Figure 19: Feature class for Injury locations determined from case incident reports.

The Process

All of the feature classes were converted to the coordinate system NAD1983 StatePlane Illinois East FIPS 1201 (US Feet). Feet were used because it is the most useful unit for the general public in the United States; the Eastern State plane system was used because LaSalle County is within the eastern region of Illinois. The geographic coordinate system/datum used was the GCS North American 1983 (with the North American 1983 Datum).

The next step was to spatially join the hazard feature classes to the hiking trails feature class. Manual spatial joins were carried out in ArcGIS. The resulting table contained every hazard occurrence for each trail. Table 1 shows that table.

To create a hazard rating for each trail, the hazards needed to be related mathematically to each other. Initially, all of the hazards were simply added together for the hazard rating, but not all hazards are created equal. Some are more dangerous than others—

their timing is uncertain and they have the potential to cause more bodily harm. To allow for this, a weighted sum equation was created.

Table 1: The Joined table of hiking trails and hazards

Trail Name	Trail Length (miles)	Rockfalls observed	Canyons	Past Injuries/ deaths from 2008-2013	Major Stairways	Forested? [1=yes]	Flooding Risk	High Vantage Points
Illinois Canyon Trail	0.92	17	1	0	0	1	1	0
Kaskaskia Canyon Trail	0.24	13	1	2	0	1	1	0
Tonty Canyon	0.34	7	1	1	0	1	0	0
Ottawa Canyon Trail	0.18	8	1	2	0	1	0	0
LaSalle Canyon Trail	0.49	4	1	3	0	1	2	0
Wildcat Canyon Trail	0.50	0	1	2	2	1	1	1
St. Louis Canyon Trail	0.24	1	1	2	0	1	1	0
Lonetree Canyon Trail	0.21	1	1	4	0	1	1	0
Owl Canyon Trail	0.41	0	1	2	1	1	1	1
French Canyon Trail	0.80	0	1	6	1	1	2	0
Starved Rock Trail	0.38	0	0	1	2	1	1	1
Aurora Canyon Trail	0.17	0	1	0	1	1	0	0
Pontiac Canyon/ Beehive Trail	0.43	0	1	3	0	1	2	1
Bluff Trail	0.97	0	0	3	1	1	1	1
Eagle Cliff/Lover's Leap Trail	0.66	0	0	2	1	1	1	1
Basswood Canyon Trail	0.22	0	1	2	0	1	1	0
Kickapoo Canyon Trail	0.55	0	1	1	0	1	0	0
Sac Canyon Trail	0.13	0	1	2	0	1	0	0
Lodge/Fox Canyon Trail	0.56	0	1	0	0	1	0	0
Hidden Canyon Trail	0.34	0	1	1	0	1	0	0
Hennepin Canyon Trail	0.49	0	1	0	0	1	0	0
Middle Connecting Trail	0.47	0	0	0	0	1	0	1
West Connecting Trail	2.02	0	0	1	0	1	1	0
East Bluff Connecting Trail	0.75	0	0	0	0	1	1	0
River Trail	0.41	0	0	0	0	1	1	0
Bluff Parking lot connecting trail	0.16	0	0	0	0	1	0	0

Table 1: This table shows the type and number of hazards along every trail.

Each hazard was judged using six categories based mostly on yes/no statements. If yes, the category was given a score of 1. If no, a score of zero was given. The only category not scored this way was the “How Dangerous are they?” category; it was scored on a scale from 0-4, with zero being not dangerous/ potentially life threatening to four being very dangerous/ potentially life threatening. The other five categories are as follows: Past injuries caused by the hazard, future injuries likely to be caused by the hazard, past deaths caused by the hazard, future deaths likely to be caused by the hazard, and frequent occurrences of the hazard. The “frequent occurrences” category was judged based on how frequently these hazards might occur or how often injuries occurred due to these hazards; if the hazards caused injury or occurred at least once each year, they were given a score of 1. If not, zero was again assigned to the category. The score for each category was added together to get the final weight that would be assigned to each hazard in the hazard equation. The final weights were as follows: Flooding/ Erosion=1, High Vantage Points=3, Major Staircases=5, Falling tree branches=7, Canyons=8, and Rockfalls=8. See Table 2 for the computation of the hazard weights.

Table 2: How the hazards were assigned a weight:							
Hazard:	Past Injury	Future injury likely?	Past Death	Future Death likely?	Frequent occurrences? (At least once per year?)	Dangerous?	Total:
	Yes. 1 point/ No. 0 points	Yes. 1 point/ No. 0 points	Yes. 1 point/ No. 0 points	Yes. 1 point/ No. 0 points	Yes. 1 point/ No. 0 points	Very. 4 points/ Fairly. 3 points./ Somewhat. 2 points/ Slightly. 1 point./ No. 0 points	
Flooding/Erosion	0	0	0	0	1	0	**1**
High Vantage Points	0	1	1	0	0	1	**3**
Major Staircases	1	1	0	0	1	2	**5**
Falling tree branches	1	1	0	1	1	3	**7**
Canyons	1	1	1	1	1	3	**8**
Rockfalls	1	1	0	1	1	4	**8**

Table 2: Objectives used to assign a weight for the weighted sum hazard equation.

The final step to create the hazard equation was to consider the length of each trail. Hiking a longer trail carries a higher risk of tree branches falling on a park visitor than a shorter trail does. Instead of adding 7 to each trail just for being forested, a score of 7 was given to every 1.0 mile of trail. This led to the equation below:

Total Hazard Rating = 1F + 3H + 5S + [(7/1.0miles)*(x miles)]+ 8C + 8R

F= number of flooding/erosion instances along the trail

H= number of High Vantage points along the trail

S= number of major staircases along the trail

X= number of miles of the trail

C = number of canyons along the trail

R = number of rockfalls along the trail

To calculate the hazard rating, I took the values in Table 1 and multiplied them by the values in Table 2 using the hazard equation. This result was then rounded to the nearest whole number and the hazard rating was thus computed.

For example, if a trail has 1 flooding/erosion risk, 2 major staircases, 5 rockfalls, and is 1.2 miles long, the hazard rating for that trail would be (1*1) + (3*0) + (5*2) + [(7/0.1miles)*(1.2 miles)]+ (8*0) + (8*5) = 51.84. When rounded, the hazard rating would be 52.

The hazard ratings were arranged from highest to lowest. The trails were split manually into three categories: least, somewhat, and most hazardous. The split between least and somewhat hazardous was determined subjectively by experience and by difficulty. If the trails at or above a certain rating were deemed moderately difficult by hiking experience or by the park, that was where the split was placed. The split between somewhat and most hazardous was easy to determine. A large gap existed between the bulk of the ratings and the highest four; that as well as hiking experience placed the split below the 4th highest rating. Trails with a rating from 1 to 15 were given a “least hazardous” rating and were colored green on the Hazard Map. Trails with ratings between 16 and 50 had a “somewhat hazardous” rating and were colored yellow. Trails that scored greater than 50 were given a “most hazardous” rating and colored red.

Results

The hazard ratings for the trails ranged from 0 to 151. Table 3 below shows the ratings for each trail.

The top four trails in the table—Tonty canyon, Ottawa Canyon, Kaskaskia Canyon, and Illinois Canyon trails—scored far and above the others. These trails' ratings were so high because all had a large number of rockfalls along their paths.

The lowest rated trail, the Bluff Parking lot connecting trail, had only a tree fall risk. When that weight of 7 was multiplied by the trail's length of 0.16 miles and rounded to the nearest whole number, a rating of 1 was calculated.

Table 3: Hazard Rating for each trail	
Trail Name	Hazard Rating
Illinois Canyon Trail	151
Kaskaskia Canyon Trail	115
Tonty Canyon	74
Ottawa Canyon Trail	73
LaSalle Canyon Trail	45
Wildcat Canyon Trail	25
French Canyon Trail	21
Owl Canyon Trail	20
St. Louis Canyon Trail	19
Lonetree Canyon Trail	18
Starved Rock Trail	17
Pontiac Canyon/Beehive Trail	16
Bluff Trail	16
West Connecting Trail	15
Aurora Canyon Trail	14
Eagle Cliff/Lover's Leap Trail	14
Lodge/Fox Canyon Trail	12
Kickapoo Canyon Trail	12
Hennepin Canyon Trail	11
Basswood Canyon Trail	11
Hidden Canyon Trail	10
Sac Canyon Trail	9
Middle Connecting Trail	6
East Bluff Connecting Trail	6
River Trail	4
Bluff Parking lot connecting trail	1

Table 3: The hazard ratings computed using the hazard equation on page 27.

Figure 20 below is the Hazard Map depicting which trails are least, somewhat, and most hazardous. It is based on the numbers from Table 2. This is the map that might be given to park visitors to make them more informed about how hazardous the trails are.

Discussion

These results are significant because rating trails by how hazarous they are is something that has never been done before. This is a new way to look at trails, not by difficulty, but by how hazardous they are. This method can be used state-wide to evaluate the hazards of any park. It can be easily modified to incorporate other hazards. This information is valuable to both the park and the public. Starved Rock State Park might publish the Hazard Map (Figure 20) to help better inform visitors about the hazards along the trails. Hikers can experience less danger by being aware that there are specific hazards along the trails. Some families come to parks assuming that they are completely safe, like a playground, but this is rarely the case (Brotman 2011). In 2013 at Starved Rock State Park, a child was walking off-trail with his siblings when he fell into a canyon and was injured. The parents stated that they would have never let their children explore the area had they known the hazards that were there; they thought it was safe (IDNR 2013). While there may be a parental responsibility to watch where they are going and obey the trail signs, the park could help by distributing the Hazard Map (Figure 20) and describing the hazards one can encounter in the park.

Starved Rock State Park already does a great job at preventing accidents. They try to keep the public away from dangerous areas using signs, barricades, and caution tape. There are signs everywhere informing visitors that it is illegal to climb the canyons and go off-trail (see Figure 21). Barriers are in place to keep the public away from dangerous places and situations. But, in the end, the responsibility lies with the individual.

Figure 20: The Hazard Map of Starved Rock State Park. Background image from *Time Talks* (ISGS 2005).

Figure 21: One of the many signs to encourage hikers to stay away from hazardous off-trail areas.

It was noted in the geologic history section that the canyons are thought to be carved out by streams tributary to the Illinois River. We made an interesting discovery in the course of this research. Pictures were found from the 1970s of Tonty Canyon (Figure 22). When compared to pictures taken 40 years later of the same canyon, they show very little erosion by the stream has taken place, but sheeting was a dominant feature in the sandstone (Figure 23). There is definitely more than stream erosion at work in these canyons.

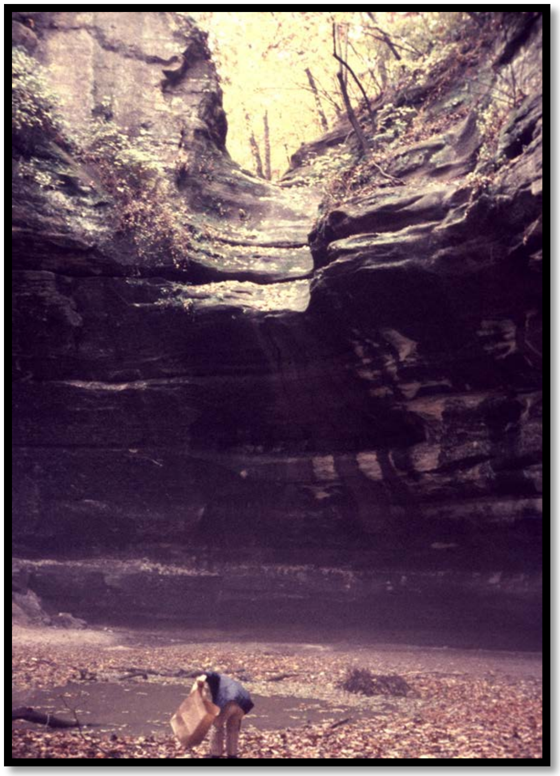

Figure 22: Tonty Canyon, October 1974. Photo courtesy of Max Reams.

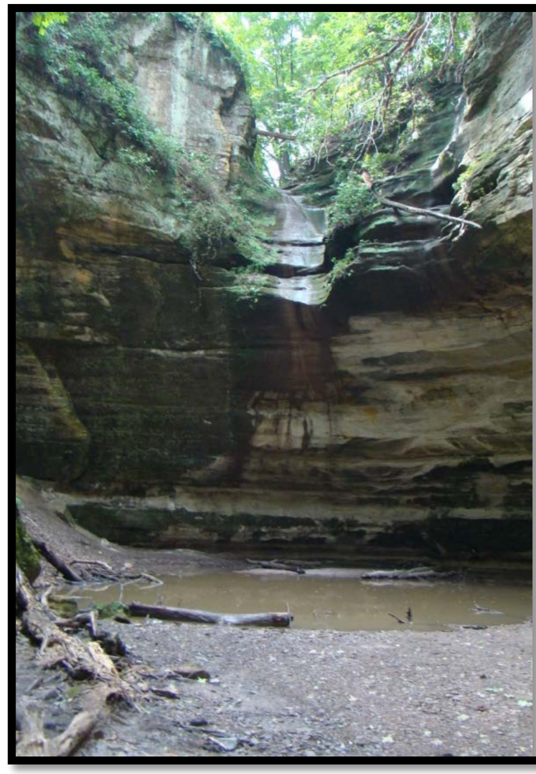

Figure 23: Tonty Canyon, September 2014. Photo courtesy of Max Reams.

There are two rock arches found along the trails as well; one along Ottawa Canyon trail and one called Council Overhang along the Kaskaskia Canyon Trail. These are stabilization phenomena. The sandstone is eroding and changing shape in order to come into a more stable equilibrium. This causes rockfalls along the trails, which were included in the rockfalls feature class. The rock arch along Ottawa Canyon trail has been untouched, so the rockfalls are still present (Figures 24-25). The rock arch that is called Council Overhang has been cleared away by park workers, but contains boulders just off the path that confirm the occurrence of past rockfalls (Figure 26).

Figure 24: Ottawa Canyon Arch. October 1974.

Photos courtesy of Max Reams.

Figure 25: Ottawa Canyon Arch.

September 2014. Photos courtesy of Max Reams.

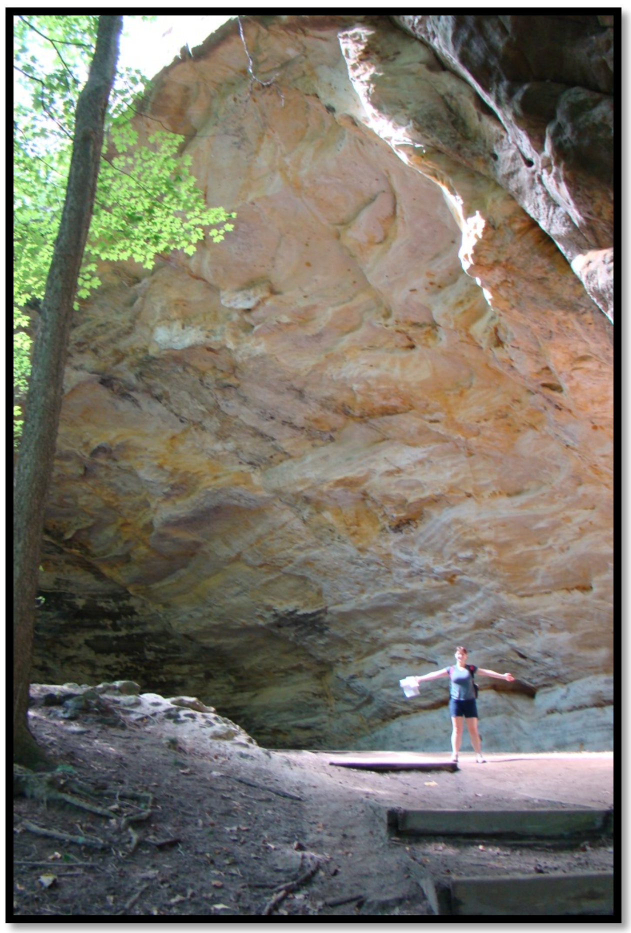

Figure 26: Council Overhang. Past rockfalls can be seen at the bottom left of the picture.

There are more rockfalls present than recorded in this research. The numbers represent the minimum amount of rockfalls in each canyon/trail; it is difficult to count the number of rockfalls because multiple rockfalls occur in the same area, often on top of each other. If there did seem to be one rockfall on top of another, the entire accumulation was counted as one rockfall; we could not be certain if there were two or more separate events as we had no method for dating the rockfalls to see if they had occurred at different times.

Future Research

The age of the rockfalls is a question raised during this research. Some rockfalls had clearly occurred much earlier in time. Evidence for this was tree growth around or on top of them and sand accumulation underneath due to weathering. Many recent sites had not been severely weathered; some had fresh surfaces exposed. All rockfalls, old and recent, were given an equal weight of 8 in the hazard equation. If a method could be determined or utilized for dating the rockfalls, Optically Stimulated Luminescence for example, the more recent ones could be separated from the older ones. Each could have different weights in the hazard equation because old rockfalls are not as hazardous as new ones. New rockfalls show where the rock is currently trying to establish an equilibrium; there are forces and stresses at work that could produce more rockfalls around the new sites, thus making them more dangerous.

Additionally, this work could be expanded to include many more years of Case Incident Reports. The five and one-half year period chosen for this study was a managable amount for an undergraduate to complete. A Masters' or PhD student's research might encompass 50 or more years of reports.

This method for rating trails by their hazards could be used in other parks state-wide or nation-wide. Hazards can easily be added or subtracted from the hazard equation and case incident reports can be aquired for each park. The true test of a new research method comes when others try it out.

Conclusion

Scenic Starved Rock State Park in LaSalle County, IL was the site of a hazard-assessment case study. A method for rating hiking trails by their natural hazards instead of difficulty was successfully implemented in this case study. The hazards found were the following: flooding/erosion, major (steep) staircases, high elevation vantage points of the Illinois River, canyons, falling trees/tree branches, and rockfalls. Using ArcGIS, feature classes were made out of each hazard and spatially joined to one another. A weighted sum hazard equation was created in order to find the hazard rating for each trail. Tonty canyon, Ottawa Canyon, Kaskaskia Canyon, and Illinois Canyon trails were the most hazardous trails in the park due to their many rockfalls.

This new method does not replace the old one for difficulty, but could complement it. This method could be used state-wide or nation-wide on hiking trails with or without a difficulty class rating. If the Hazard Map (Figure 20) is deemed helpful by the park, it could be printed and distributed to visitors; it might be one more way to help keep visitors safe and coming back again and again to enjoy the unique beauty of Starved Rock State Park.

References

Brotman, B. (2011, July 25). How do you explain park deaths? You can't. *Chicago Tribune*.

etrieved from http://articles.chicagotribune.com/2011-07-25/features/ct-talk-brotman -yosemite-0725-20110725_1_park-deaths-grand-canyon-poor-judgment

Buckman, J. (2014, April). Stories from Starved Rock [Personal interview].

Collins, T. (2014, August 6). Storm damage can't keep Starved Rock from setting record. *NewsTribune*. Retrieved February 21, 2015, from newstrib.com/main.asp?SectionID=2&subsectionID=28&articleID=38251.

Dankert, J. (2014, July 10). Outdoors - LaSalle News Tribune - LaSalle, IL. Retrieved February 28, 2015, from http://newstrib.com/main.asp?SectionID=54&subsectionID=172&articleID =37739

Difficulty Rating Systems. (2014). Retrieved February 16, 2015, from http://www.14ers.com/classes.html

Dziedzina, D. (2011, May 27). Flooding on Illinois River closes some riverfront facilities at Starved Rock State Park. Retrieved February 28, 2015, from http://www.chicagonow.com/illinois-outdoors/2011/05/flooding-on-illinois-river-closes-some-riverfront-facilities-at-starved-rock-state-park/

GoWaterfalling.com. (2011, November 26). Starved Rock State Park. Retrieved March 1, 2015, from http://gowaterfalling.com/waterfalls/starvedrock.shtml

Grimm, A. & Bowean, L. (2011, September 6). Starved Rock officials stress caution after second fall in a week. *Chicago Tribune*. Retrieved from http://articles.chicagotribune.com/2011-09-06/news/chi-starved-rock-officials-stress-caution-after-second-fall-in-a-week-20110906_1_trail-head-officials-stress-caution-yosemite-national-park.

Illinois Department of Natural Resources. (2014). *Starved Rock State Park.* Retrieved from http://dnr.state.il.us/lands/landmgt/parks/i&m/east/starve/park.htm.

Illinois Department of Natural Resources. (2013). *Case Incident Reports.* Retrieved on 18 September, 2013.

Illinois Geospatial Data Clearinghouse. (2014). *Land use Raster.* Retrieved on 21 March, 2014.

Illinois State Geological Survey. (2005). Time Talks: The Geology of Starved Rock and Matthiessen State Parks. U.S.A.

Islam, M. M., & Sado, K. (2000). Flood hazard assessment in Bangladesh using NOAA AVHRR data with geographical information system. *Hydrological Processes*, (14), 605-620.

Kolata, D.R. & Nimz, C.K. (Eds.). (2010). Geology of Illinois. Urbana-Champaign, IL: Illinois State Geological Survey and the University of Illinois.

Liu, J. G., Mason, P. J., Clerici, N., Chen, S., Davis, A., Miao, F., ... & Liang, L. (2004). Landslide hazard assessment in the Three Gorges area of the Yangtze river using ASTER imagery: Zigui – Badong. *Geomorphology*, *61*(1), 171-187.

McConnaughhay, M. (2014, September 20). Interview with Mark McConnaughhay, Site Superintendent of Starved Rock State Park [Personal interview].

Meyers, E. (2011, December 5). Indiana Man drowns at Starved Rock. Chicago Tribune. Retrieved from http://www.chicagotribune.com/news/local/breaking/chi-indiana-man-drowns-at-starved-rock-20111204-story.html.

Nott, J. (2004). Palaeotempestology: the study of prehistoric tropical cyclones—a review and implications for hazard assessment. *Environment International*,*30*(3), 433-447.

Reams, M.W. (2013). *Geology of Illinois State Parks: A guide to the physical side of 28 must-see wonders of Illinois.* Charleston, SC.

Sterrett, C. (2013, May 5). Starved Rock staff still battling damage from flood. *News Tribune.* Retrieved from http://newstrib.com/main.asp?SectionID=2&SubSectionID=27&ArticleID=28711.

Walder, J.S. & Driedger, C.L. (1994). Rapid Geomorphic Change Caused by Glacial Outburst Floods and Debris Flows along Tahoma Creek, Mount Rainier Washington, U.S.A. *Arctic and Alpine Research, 26(4),* 319-327.

Wiggers, R. (1997). *Geology Underfoot in Illinois.* Missoula, Montana: Mountain Press Publishing Company.

Appendices

Appendix A—Generalized Metadata for the new feature classes

Table 4—Generalized Metadata for the new feature classes			
Feature Class	Source	Projected Coordinate System	Data Format
Rockfalls1	Hand made from field data collected at Starved Rock State Park.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Point
Rockfalls2	Hand made from field data collected at Starved Rock State Park.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Point
Canyons	Hand made from field data collected at Starved Rock State Park.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Point
Injuries	Hand made from Case Incident reports provided by the Illinois Department of Natural Resources.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Point
Major Stairways	Hand made using the major stairway locations on the relief map raster from Time Talks by the ISGS.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Point
Forested Areas	Hand made using the land use raster from the Illinois Geospatial Data Clearinghouse	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Polygon
Flooding Locations	Hand made using both the relief map raster from Time Talks by the ISGS and the field data.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Polygon
High Vantage Points	Hand made using both the relief map raster from Time Talks by the ISGS and the field data.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Polygon
Hiking Trails	Hand made using the trails on the relief map raster from Time Talks by the ISGS.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Line
Park Boundary Line	Hand made using the printed boundary of the relief map raster from Time Talks by the ISGS.	NAD1983 StatePlane Illinois East FIPS 1201 (US Feet)	Line

Appendix B—List of Tables

Appendix C—List of Figures