Designing an Application for Glacier National Park's Backcountry Hiking Community

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Abstract

Planning a backcountry hiking trip in Glacier National Park requires extensive research and information from numerous sources, which can be challenging for many visitors. Our team worked with members of the Glacier National Park staff to develop a web application to assist hikers with the backpacking planning process. We analyzed interviews, online surveys, and existing hiking apps to determine design and features. The resulting web application contains a step-by-step planning guide with permitting and safety information, as well as an interactive map with trail specifics including trail elevation profiles and important campground information. We recommend that the Glacier staff continue the development of this application into a mobile platform and improves the current trail reporting system on their website.

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Executive Summary

Introduction

Glacier National Park attracts thousands of backpackers every year seeking to explore over 700 miles of remote backcountry trails across towering mountains, past glacial lakes, and through alpine meadows (National Park Service [NPS], 2020a). Backcountry hiking is the use of remote trails beyond the reach of typical day hikes, carrying your supplies in a specialized backpack while camping for consecutive days. Backpacking in Glacier requires planning that encompasses both general and park-specific trip preparation. General planning includes tasks such as choosing routes, packing appropriate gear, and obtaining a backcountry permit. The NPS backcountry camping website is the starting point for backpackers to familiarize themselves with backpacking in Glacier. While the park's website offers essential information for planning successful trips, navigating the website can be challenging. Information such as campsite rules, elevation change, and average trip duration is difficult to find. Trail conditions are reported on the trail status page, but this provides limited information that is often outdated.

Goals and Objectives

The primary goal of this project was to help Glacier visitors successfully plan backcountry hiking trips by developing an all-encompassing web application. Additionally, a secondary goal of this project was to support park rangers by providing them with relevant user experience data from post-hike surveys. To create a successful web application, our research methodology was divided into three objectives:

1. Identify hiking resources and park-specific information necessary to effectively plan a backcountry trip in Glacier.
2. Establish a feedback collection strategy by identifying how backcountry hikers exchange their trip experiences.
3. Identify design criteria and features necessary for a backcountry hiking app in Glacier.

To accomplish our goals and objectives we conducted a literature review, a survey of backpackers, and interviewed Glacier park staff. Additionally, we used multiple methods of analysis to identify what content and features to prioritize when developing our web application. More specifically we conducted an analysis of the current Glacier backcountry hiking planning process, a SWOT analysis of the existing planning process, and an application analysis of popular backcountry hiking apps to determine which features were missing as well as which ones aligned best with the needs of Glacier backcountry hikers.

Results

Limitations of the Current Planning Process

   The process of planning a backcountry trip and acquiring a permit from Glacier's website is complicated and can confuse new hikers. To identify the source of these problems, we conducted a process analysis of the steps required to plan a trip and to acquire a permit. We found that multiple online resources simplify the research steps by compiling aspects of relevant information, but none of the online resources address all the tasks necessary for planning a trip. The plethora of available resources indicates that the research step is a challenge for many hikers. Furthermore, in an interview with park staff, it was confirmed that one of the common permit application problems was applying for a trip that failed to follow all the rules and regulations. Application errors result in automatic rejections and show existing resources are providing sufficient material to help hikers plan trips and fill out permit applications (personal interview, September 14, 2020).

Trail reporting status page

   After reviewing the [NPS trail status page](#) during our preliminary research, it was confirmed during our interviews with Richard Menicke, Brian McKeon, and Sarah Moody that this is the only NPS source with recent trail information. This trail status page contains very limited information, including only when the trail was initially cleared and if the trail is open or closed. If major trail work is conducted, such as replacing a bridge or clearing a fallen tree, that will be documented; but, important information such as trail surface (i.e. large loose rocks, slippery when wet) is not included.

   As well as being limited in information and possibly outdated, the trail status page format is difficult to navigate for backcountry trip planning because it contains all the trails for the park. The trails are not organized as backpacking trails or day hikes, so it can be tedious to sort through the trails to find the specific trail information. Although trails are sorted by region, there is no search bar or means of filtering/organizing the trails. Additionally, the trail status page contains only simple black text with no images, symbols, or colors aside from a red bullet point for each trail section. This makes it very difficult to scroll through and quickly assess the information.

Application Analysis

   As a component of our application analysis, we compared map features in existing applications. Our map comparison found that the most common features are elevation profiles,

waypoints, and interactive maps. Additionally, the most common data points were the beginning and end of routes, peaks, and campgrounds. Although one app provided a summary of backcountry campgrounds, it discusses the campgrounds in a region, and not the individual site details. None of the available applications provide details on each backcountry campsite. Furthermore, we found that all the analyzed apps contain at least a minimal number of trails and routes for hiking in Glacier. Many of the apps also include trail reports or feature descriptions where users can rate and describe their experience. Finally, we found that apps provide a description of Glacier, although most were only a brief overview.

Overall, our comparison demonstrated that interactive maps, waypoints, and elevation profiles are the most influential map features. Additionally, we discovered that campground details are a limited resource among existing applications. Finally, we discovered that each application has unique features, which support the goal of their resources and their design.

Strengths, Weaknesses, Opportunities, and Threats

Our SWOT findings were centered around the current processes/resources used for backcountry planning in Glacier. Four notable points from the sections are listed below:

- Strength: the park provides important planning details in the permitting map found on the NPS webpage.
- Weakness: the park's only interactive map has limited content and no permitting information.
- Opportunity: commercial applications do not provide details on backcountry campsites.
- Threat: commercial applications can maintain their content, and Glacier would need to maintain and update their application with minimal IT support.

Our web application was designed to limit the weaknesses and threats while maximizing the opportunities and strengths of the backcountry planning process in Glacier.

Survey Data

To determine how to collect information from backpackers we used Qualtrics to generate an online survey form and collect responses. The online survey was distributed to our target audience through backcountry hiking blogs and specific Facebook groups. Our survey resulted in a total of 53 responses, of which 55% of backpackers feel that applications are missing features for backcountry trip planning. This demonstrates that there are opportunities to improve upon current resources. Furthermore, 68% of all respondents are likely to install an application if it has the features they feel are important, verifying that hikers are willing to try new applications. To

determine the features important to users, we asked respondents to rank each features' importance to a backpacking planning application. We found that that Downloadable Maps, Route Planning/Saving, Interactive Mapping, and National Park Information are important to most users, so we prioritized these when developing our application.

Benefits of an Interactive map

In addition to being a highly desired feature in our survey, we received confirmation from multiple members of Glacier's staff regarding the importance of interactive maps. In our interview with Permitting Supervisors Brian McKeon and Sarah Moody, the supervisors noted that the park does not provide an interactive backcountry map for hikers. Furthermore, they agreed that an interactive map would be a useful resource. One of the benefits of an interactive map is the ability to select waypoints with embedded descriptions. Additionally, when we asked which feature would be the most useful to backcountry hikers planning their trip, McKeon and Moody agreed that an elevation profile would be the most useful component to give hikers a better sense of trail difficulty and improve their chances of submitting a feasible permit (personal interview, September 14, 2020).

Web Application Development

After developing the layout and organization for the new web pages, we added content to each page based on our research results. We included pages on the planning steps required before a backpacking trip, the permitting rules and regulations in Glacier National Park, and safety guidelines. We condensed content identified in our research on to the pages, and we implemented hyperlinks to hiking resources so hikers could continue their research. Furthermore, we include a checklist on our landing page to allow hikers to track their progress through these pages.

Our most complex page is the interactive map. We implemented a topographic base map on ArcGIS Online and added various data layers. Our boundary and trail ArcGIS layers were obtained from park geographer Richard Menicke. Additionally, Menicke provided data on campgrounds and points of interest. We created detailed popups and overlays that contain relevant trail and campsite information (**Figure A**), park regions (**Figure**), and elevation profiles (**Figure**). Additionally, the map also allows trails segments to be combined to create multi-day trips that can be saved and can generate elevation profile graphs.
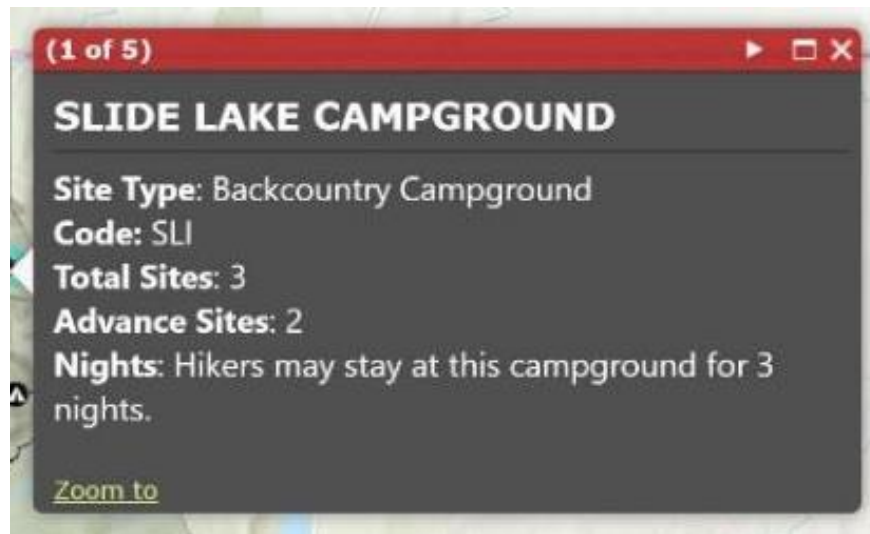
Figure A. Campsite description
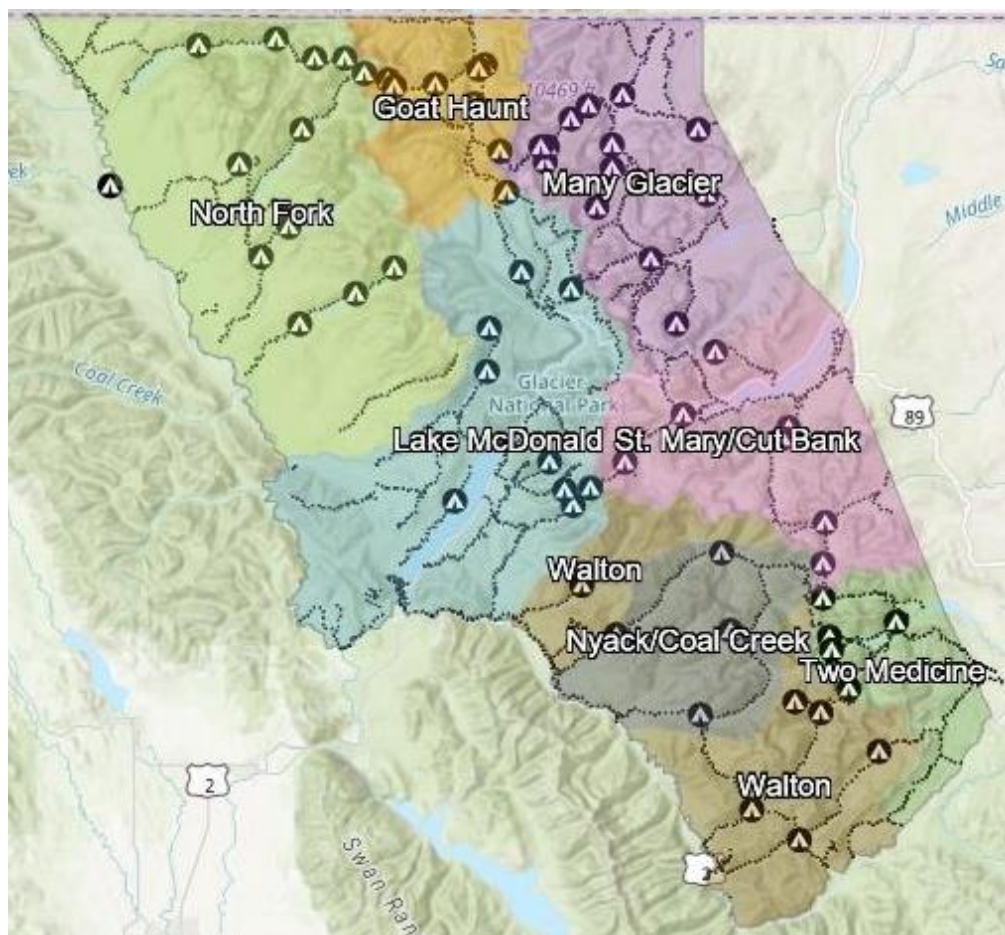
Figure B. Park Regions
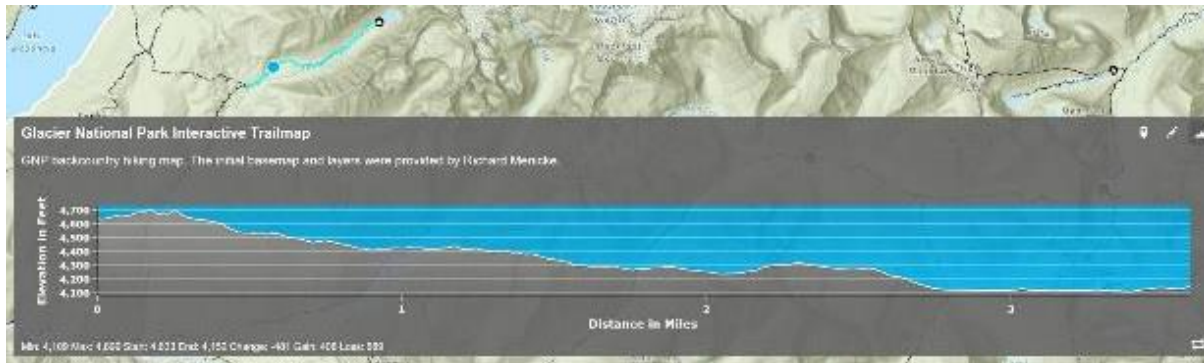
Figure C. Elevation profile of a trail

Recommendations

Going forward, we recommend that Glacier:

- Continues to develop the information and features contained in our web application as a fully-fledged mobile application.
- Authors a post-hike survey based on our model.
- Improves the design and layout of their current website's trail status page.

There are two possible avenues for continued development: by a future WPI project team, or through the involvement of a professional app development company. The professional development of a mobile app could be an investment, as it could function as a paid service like a virtual guidebook. Additionally, a mobile application would allow features such as downloadable interactive maps and real-time GPS tracking of hikers.

On our website, we created a survey for users to complete after their hike to collect trail information and trip feedback. We recommend that park staff author a similar post-hike survey. It is difficult for rangers to report on the extensive backcountry trails regularly, so the information provided by hikers could be used to produce recent trail reports and keep track of popular trails. The survey could easily be distributed by a QR code on visitor documents or a website link.

Small changes to the layout and format of Glacier's current trail status web page would make the trail reports much more useful to visitors. Using color-coded text and bullet points would allow visitors to easily see which trails are open or closed, and symbols to highlight common trail hazards such as wildlife, bridge construction, and downed trees would add more

clarity to trail warnings or closures. Adding a search bar or filters would improve the user's ability to find information on specific trails.

Conclusion

The main components of our project were data collection, data analysis, and web application development. In addition to our various process and research analyses, survey data aided our understanding of the problem and which features were important to our web application. Using this information, we created a functional model that consolidated important Glacier backcountry hiking information and incorporated many of the highlighted features. This web application included our interactive map with trail and campground details, trip saving capabilities, elevation profiles, and a post-hike survey. We recommend that Glacier develops a mobile application based on our functional model. In the meantime, the park can make tangible improvements by authoring and distributing a post-hike survey to collect recent trail information from visitors, as well as updating the design and layout of their trail status page

1.0 Introduction

Glacier National Park (GNP) attracts thousands of backpackers every year seeking to explore over 700 miles of remote backcountry trails across towering mountains, past glacial lakes, and through alpine meadows (National Park Service [NPS], 2020a). Divided into an east and west region by the Continental Divide, Glacier encompasses over one million acres and is the 8th oldest and 12th largest national park (Melroy, 2020; Poirot, 2019).

On the east side of the park, hiking trails start at around 5,000 ft and are suitable for hikers seeking alpine trekking with glacial and mountainous views. The more popular west side of the park is heavily forested and warmer, with a base elevation of about 3,200 ft. Regardless of which region, backcountry hiking in Glacier requires planning that encompasses both general and park-specific trip preparation. General planning includes tasks such as choosing routes, packing appropriate gear, and obtaining a backcountry permit. Special considerations unique to the landscape and wildlife of Glacier must be taken; these include preparing for potential grizzly bear encounters or planning to ford swift rivers, so hikers must follow specific guidelines to be safe. For instance, to address the bear concerns, the Glacier NPS website provides backpacking advice such as traveling in groups of four or more, carrying bear spray, and storing all food and odorous items properly (NPS, 2020a). In addition to the wildlife, special attention to the unique landscape of Glacier which is made up of steep, potentially dangerous terrain and obstacles such as glacial crevasses, rivers, and lakes must be considered.

The NPS backcountry camping website is the starting point for backpackers to familiarize themselves with backpacking in Glacier. This backcountry camping page provides information on permitting, trip planning, regulations, safety, trail status, and transportation services. In addition to the general web information, paper maps are available for purchase through organizations such as the Glacier Conservancy and are often used in conjunction with Glaciers' website.

While the park's website offers essential information for planning successful trips, navigating the website can be challenging. Information such as current trail conditions, elevation gain/loss, and average trip duration is difficult to find. The trail conditions are infrequently updated by staff, and there is no section for reports from recent backpacking visitors. The existing trail status page provides limited information that is often outdated. One reason is that the backcountry trails are too extensive for park rangers to hike and report on each trail regularly. Unfortunately, without accurate and timely reporting, backpackers may encounter unexpected trail hazards.

The ability to track and share current trail conditions with all visitors could be improved through the use of a user-generated trail reporting system. Another possible improvement identified by park staff would be updating the design of the park website and the addition of an interactive map. Furthermore, taking important information from a variety of sources and creating an all-inclusive Glacier backcountry hiking resource could improve the overall planning experience.

Our project goal was to produce a web application tailored to planning backpacking trips in Glacier National Park. To improve upon the available backcountry hiking resources, it first required extensive research and analysis of what is required to plan a trip in Glacier and how these existing resources are used by hikers. From this knowledge, we created an all-encompassing backcountry planning web application with a trip planning checklist, a permitting guide, an interactive map, and a post-hike trail report system.

2.0 Background

In developing a web application for backcountry hiking in Glacier National Park, it was essential to understand the context surrounding the goals of the project (Section 3). Therefore, in this section, we begin by discussing Glacier and its history. We then explain what backcountry hiking is and the special considerations related to backcountry hiking in Glacier. Finally, we describe existing resources for backcountry hiking, including web and mobile applications.

2.1 Glacier National Park

Glacier National Park (**Figure 1**) was first inhabited in the early 1700s by Native American tribes such as the Blackfeet and Salish Indians, who continue to live in this area today (Division of Indian Education, n.d.; NPS, 2016). Non-Native American settlers reached the area in the 1800s but did not arrive in significant numbers until the completion of the Great Northern Railway in 1891. To preserve the natural beauty of Glacier, influential leaders in the late 1800s began to push for the creation of a new National Park, the result of which was the establishment of Glacier in 1910 (NPS, 2016).

Climate change and other natural factors have resulted in changes to the landscape of Glacier. Between 1910 and 1980, the average summer temperature of the park increased by 1.66°C. Almost two-thirds of the park's glaciers disappeared between 1850 and 1980 (Hall, 2003). Due to forest fires, plants have migrated to new areas of the park, and avalanche paths have changed over time (Butler, 2001). To preserve Glacier, the park spent over 1.2 million dollars in 2015 and 2016 to mitigate the effects of forest fires and human activity and fulfill the goals of the National Park Service (Peterson, 2016).

Glacier National Park
Webcam Locations

1. Apgar Mountain - Northeast view
2. Apgar Mountain - Southeast view
3. Apgar Village
4. Apgar Visitor Center Plaza
5. Goat Haunt
6. Lake McDonald
7. Logan Pass - East view
8. Logan Pass - parking lot
9. Logan Pass - South view
10. Many Glacier
11. Middle Fork of the Flathead River
12. Park Headquarters
13. St. Mary Visitor Center
14. Two Medicine
15. West Entrance

Figure 1. A Map of Glacier National Park

(https://www.nps.gov/glac/learn/photosmultimedia/webcams.htm)

The goal of the National Park Service (NPS) is to preserve and connect people to the natural and cultural resources of the National Parks. This has become more challenging as the number of visitors to the park has increased over time (NPS, 2020c). In 2019, Glacier National Park saw over three million recreational visitors, including over thirty thousand backpackers, while 2009 had approximately two million visitors (NPS, 2019). To address the park's growing popularity, projects have been undertaken to fulfill the goals of the NPS by reducing the impact of visitors, educating people on sustainability, and enhancing Glacier's ability to operate (NPS, 2011). These projects have demonstrated early success in managing the impact of visitors on the park. For example, between 2004 and 2019, despite an increase in visitors, there has been no significant increase in the non-natural noise (Sevinsky, 2019). Glacier also has an ongoing project dedicated to reducing the risk of avalanches in the park, and Glacier's Bear Management Plan is open to review by the general public to ensure clarity and safety.

While many projects focus on the park itself, other projects go beyond the park's boundaries to connect people to the culture and the importance of nature. Glacier is working to aid local communities in preserving their culture or creating sustainability and seek to reinforce its role as an educational force in the areas of science and history.

2.2 Glacier Park Backcountry

Backpacking

For this project, backcountry hiking is defined as the use of remote trails beyond the reach of a typical day hike. Backcountry hiking generally includes carrying your supplies in a specialized backpack while camping for consecutive days. In Glacier, backpackers have access to 65 backcountry campgrounds with 208 total sites (NPS, 2020a). Furthermore, the NPS provides GPS coordinates for all GNP campsites through their website.

Route Planning

The sparse terrain and open vistas of the park's East side attract more crowds than the west side, causing those seeking solitude to generally elect to hike on the west side of the park. Trails on the East side start at 5,000 ft and include alpine trekking with glaciers and summit views (**Figure 2**). Especially notable is the Nyack/Coal Creek camping zone which offers backpackers isolation and higher levels of challenge and risk, as well as the 52-mile North Circle Loop.

Figure 2. Sparse Vistas of Spot Mountain

The west side of the park is heavily forested and warmer, with a starting elevation of 3,200 ft, and includes one of the most remote sections of the park, the North Fork (**Figure 3**). Furthermore, running through the park are segments of both the Continental Divide Trail (110 miles) and the Pacific Northwest Trail (50 miles).

Figure 3. Quartz Lake in North Fork, West Side

(https://www.flickr.com/photos/glaciernps/27375003203/in/album-72157648859607029/)

For transportation, visitors can use the free unlimited park shuttle that runs along the entire Going-to-the-Sun road every 15 minutes (**Figure 4**). To ride the entire road, visitors must switch shuttles at the Logan Pass which divides the east and west sides of the park. The NPS website details the location and connecting trails of each stop. Backcountry hikers benefit from using the shuttle as transportation to and from trails.
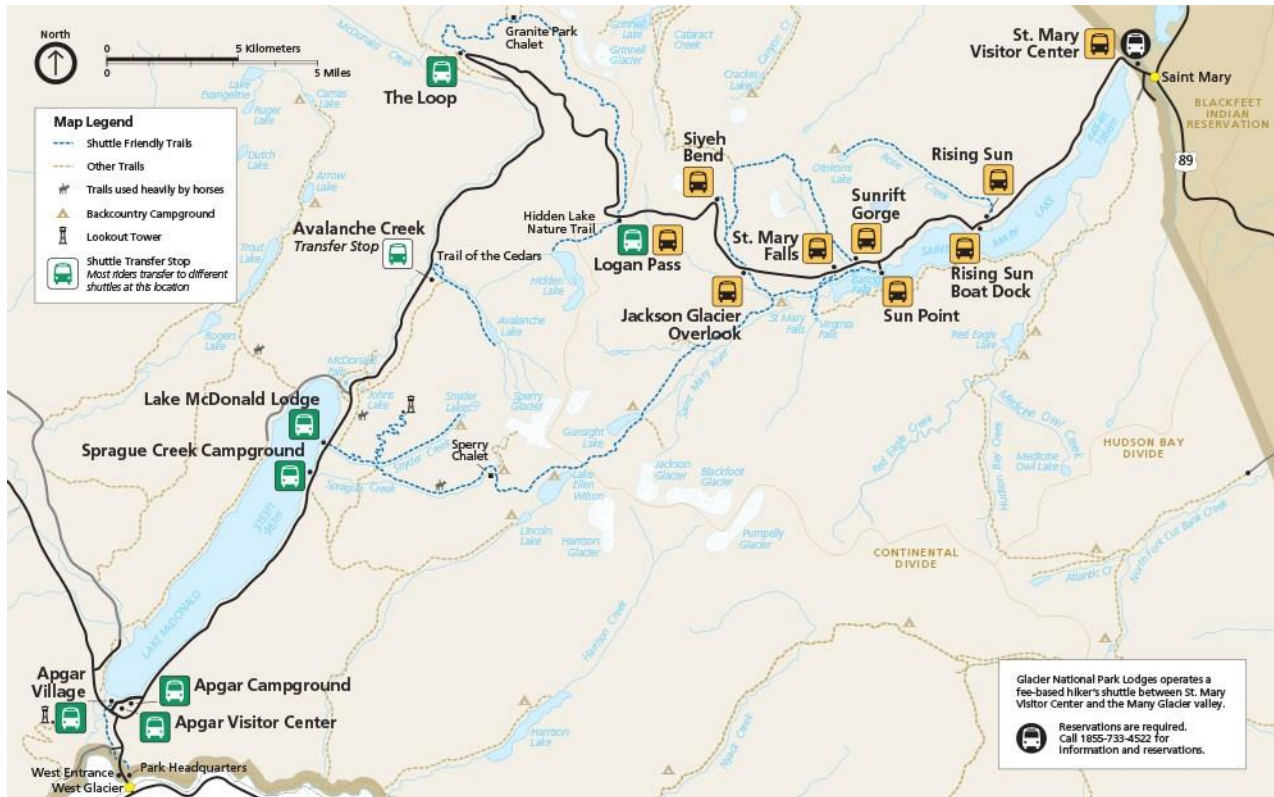
Figure 4. Going-to-the-Sun Road Shuttle stops

(https://www.nps.gov/glac/planyourvisit/shuttlestops.htm)

Permitting

Permits are required for any overnight camping in Glacier's backcountry to protect the fragile environment and prevent campgrounds from being overused and overcrowded. Permits can be obtained in advance or the day before, at $7 per person, per night. Approximately half of the total sites at each campground become available for visitors through advance online

reservations starting in March (

Glacier National Park

Backcountry Permit Advance Reservation Application

Group Size 1-8 Campers

Agency Use Only:

Permit Number	Last Name	First Name	Date Processed	Initials	Date Emailed

* Indicates required information

The following application is for one advance reservation only for groups of 1-8 campers. There is a $40.00 application fee ($10.00 initial processing fee + $30.00 fulfilled trip request fee). If backcountry personnel are unable to award an advance reservation itinerary based upon the parameters you indicate, the $30.00 fulfilled trip request fee will be refunded. Advance reservations cannot be made within 7 days of your intended trip start date. Applicants should expect a one month period of time between application submittal and notification of permit status. There is a separate camping fee of $7.00/person/night, payable upon picking up your permit at the park.

Trip Leader Name: * First: * Last:

* Mailing Address:

* City: * State: * Zip Code:

* Country: United States

* Telephone (Primary):   * Email Address:

* Number of Campers (1-8):   Number of Stock:

Is this application an amendment to an already existing advance reservation?   ◯ Yes   ◯ No

If 'Yes', what is the existing reservation number?

☐ I understand I will be charged a non-refundable $40.00 application fee ($10.00 initial processing fee + $30.00 fulfilled trip request fee). If backcountry personnel are unable to award me an advance reservation itinerary based upon the parameters I indicate, I will be refunded $30.00. The $10.00 processing fee is non-refundable. Amendments to existing advance reservations are subject to all fees. ($10.00 initial processing fee + $30.00 fulfilled trip request fee).

☐ I understand that Glacier National Park is a dynamic, natural environment where events and conditions are unpredictable. There is a possibility that trail and campground closures, campground environmental conditions, natural events (such as fires, aggressive animals, etc.), or other NPS management actions may render my itinerary infeasible. In the event that this occurs, every effort will be made to provide me with an alternate itinerary when I pick up my permit. THERE IS NO GUARANTEE THAT MY ROUTE WILL BE PASSABLE OR ITINERARY VIABLE WHEN I ARRIVE.

Please click on the links below for complete advance reservation application procedures, including backcountry campground regulations and restrictions, as well as other information to assist in your planning.

Backcountry Camping Home Page

Figure 5). For advance registrations, there is also a $10 application fee, and then a $30 fulfilled trip request fee due online for each permit application. If backpackers do not get an advance reservation, they can go to one of the Glacier permitting centers the day before or the day of their trip for a walk-in permit. For both types of permits the $7 per person, per night fee is due at the permit center once the visitor arrives in the park.

Permits are highly competitive, so by the time the permitting centers open for those seeking walk-in backpacking permits, there are often long lines, even though you cannot start lining up until 4:00 am. To improve the chances of getting a permit it is important to have

flexibility with planned trip date, range, and locations. Additionally, reserving a permit in advance can be competitive as applications open on March 15 and are chosen from a lottery.

Glacier National Park

Backcountry Permit Advance Reservation Application

Group Size 1-8 Campers

Agency Use Only:

Permit Number	Last Name	First Name	Date Processed	Initials	Date Emailed

* Indicates required information

The following application is for one advance reservation only for groups of 1-8 campers. There is a $40.00 application fee ($10.00 initial processing fee + $30.00 fulfilled trip request fee). If backcountry personnel are unable to award an advance reservation itinerary based upon the parameters you indicate, the $30.00 fulfilled trip request fee will be refunded. Advance reservations cannot be made within 7 days of your intended trip start date. Applicants should expect a one month period of time between application submittal and notification of permit status. There is a separate camping fee of $7.00/person/night, payable upon picking up your permit at the park.

Trip Leader Name: * First: [_____]   * Last: [_____]

* Mailing Address: [_____]

* City: [_____]   * State: [_____]   * Zip Code: [_____]

* Country: [United States]

* Telephone (Primary): [_____]   * Email Address: [_____]

* Number of Campers (1-8): [____]   Number of Stock: [____]

Is this application an amendment to an already existing advance reservation?   ○ Yes   ○ No

If 'Yes', what is the existing reservation number? [_____]

☐ I understand I will be charged a non-refundable $40.00 application fee ($10.00 initial processing fee + $30.00 fulfilled trip request fee). If backcountry personnel are unable to award me an advance reservation itinerary based upon the parameters I indicate, I will be refunded $30.00. The $10.00 processing fee is non-refundable. Amendments to existing advance reservations are subject to all fees. ($10.00 initial processing fee + $30.00 fulfilled trip request fee).

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Please click on the links below for complete advance reservation application procedures, including backcountry campground regulations and restrictions, as well as other information to assist in your planning.

Backcountry Camping Home Page

Figure 5. First Page of Backcountry Permit Advance Application

*(*B. McKeon, personal communication, September 17, 2020*)*

Trip Execution

Backpacking in Glacier requires considerations concerning common hiking etiquette, unique regulations, and location-dependent safety concerns. These considerations include yielding to uphill hikers, as well as practicing Leave No Trace principles. Additionally, park

regulations dictate that backcountry campers need to carry their paper permits on them at all times, as rangers will request verification. Furthermore, hikers should carry their passport if they want to pass through the Goat Haunt Ranger Station into Canada. Finally, safety concerns include the unpredictable nature of GNP's weather, increasing the risk of hypothermia. Additionally, visitors should use extreme caution near water and snow to avoid the dangers of drowning and falling into ice crevasses. Concerning wildlife safety, the park advises staying 100 yards away from bears and wolves, and 50 yards away from other wildlife (NPS, 2020a).

Glacier National Park Backcountry COVID Response

During 2020, GNP set restrictions to combat the COVID-19 pandemic and protect the health of visitors and staff members. All permitting centers, except the Apgar Center, were closed, the park limited staff, advance reservations were canceled, and backcountry camping permits were only available in person 24 hours before a trip (NPS, 2020a). Other facilities, such as the Many Glacier Hotel and Rising Sun Motor Inn, were shut down (NPS, 2020b). Furthermore, the limited park staff had to cancel and refund all the reserved backcountry permits for the 2020 summer.

2.3 Backcountry Hiking Planning Challenges

To enjoy the pristine wilderness of Glacier's backcountry, hikers face the challenge of planning a multi-day trip. These challenges include:

- Abiding by permitting rules
- Obtaining navigation information from maps
- Reviewing current trail conditions

Permitting Challenges

One challenge of backpacking in Glacier is obtaining the necessary permits to hike in the backcountry. As the permitting process can be cumbersome and involve an extensive review of information, planning a backcountry trip in GNP can present challenges to visitors (NPS, 2020a). Although the concept of the permitting process is very simple, some technicalities make the process difficult and can result in permit application denial. For example, advance reservations have a hiking limit of 16 miles per day. If you plan to hike further than that you can only obtain a walk-in permit. Trip itineraries must also be contiguous, so even if you consider it one trip, any transportation along roads via car, shuttle, etc. require multiple individual trip permits and may cause an application to be denied. Another challenge is that an advance reservation permit will not be mailed to you, it must be picked up in person at one of the permit centers the day before

your trip. The NPS website does not depict all the permit regulation details in an organized fashion, which can lead to many visitors struggling through the application process and often getting permit applications denied unless they do extensive research through various other sources and tutorials to aid in the permitting process.

Maps and Information

Glacier has over 700 miles of backcountry trails dispersed across the park, which can confuse even the most experienced hikers when trying to plan a trip (NPS, 2020a). Backpackers must plan ahead by determining where they intend to go, and what to expect in their chosen route. Additionally, they must learn what supplies they need, where they will be camping, how long they can camp there, and what elevation changes and terrain to expect. A simple trail map (**Figure 6**) or brochure does not show all of this trail information, and there are currently no interactive maps provided by the NPS for Glacier's backcountry. Navigation and trail information is not located in one resource for the visitor to easily find, which forces them to sort through numerous sources before finding the necessary information. Thus, a more efficient way of obtaining this information would be beneficial to help visitors plan a backcountry hiking trip at GNP.
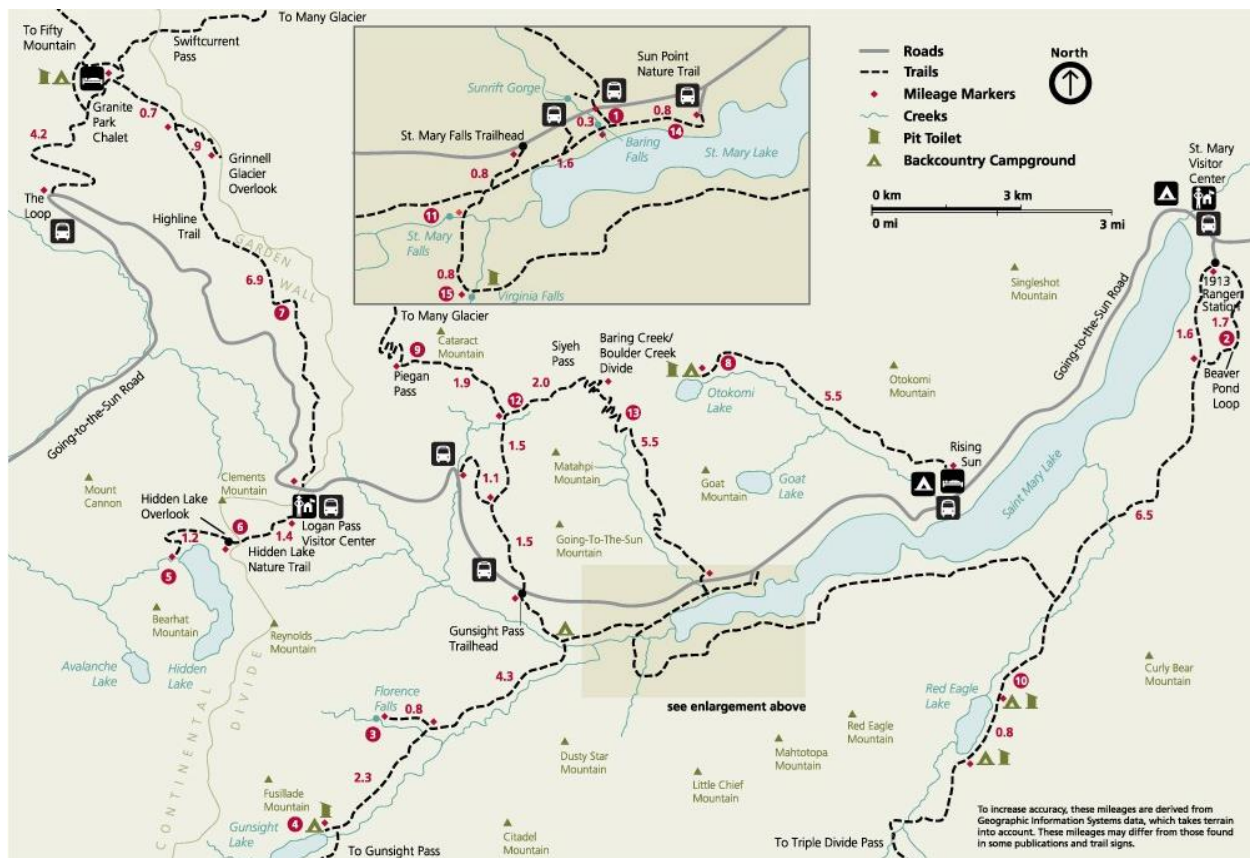
Figure 6. Trail Map of Saint Mary and Logan Pass trails

(https://www.nps.gov/glac/planyourvisit/hikingstmary.htm)

Exchange of Trail Reports

Reports on trail conditions, hazards, campsite issues, and animal sightings are critical to both visitors and park management. Backpackers use trail reports to plan hikes and prepare for current trail conditions, and park management uses them to oversee trail and site maintenance. For example, if there are frequent bear sightings in an area documented in trail reports, a backpacker planning a hike can avoid that area. Additionally, with recent trail reports by park visitors, park management would be able to close a hazardous trail until it could be patrolled and evaluated by a park ranger.

Currently, official GNP trail reports are done only by park rangers and posted on the NPS Trail Status page (**Figure 7**). These reports are infrequent and generally brief since park rangers cannot conduct trail reports daily (NPS, 2020a). While this information is helpful to determine the open/closed status of a trail, it does not give the recent trail report information valuable for planning. Trail reports from visitors following their hike provide a source of up-to-date information as compared to that of the ranger reports. An example of this visitor trip reporting

system is the popularly used website and mobile application AllTrails, however, they have limited coverage of Glacier's backcountry trails. Unfortunately, in order to find these backcountry trail reports visitors must search through various other sources such as posts on forums and Facebook Groups, creating a frequent disconnect in the exchange of backcountry trail reports between hikers and rangers in GNP.

Mokowanis Lake Trail
■ Stoney Indian Pass Trail to Mokowanis Lake / 1.0 mi.
Clear. 6/10/2019 per B12

Ptarmigan Tunnel Trail
■ Elizabeth Lake to the Ptarmigan Tunnel/ 4.8 mi.
Ptarmigan Tunnel: OPEN 7/11/2019 per 650

CLOSED 10/7/2019 PER 650 Elizabeth Lake Suspension Bridge: REMOVED 9/25/2019 Trail clear. per 224 Neese 8/17/2019

Figure 7. Example of park ranger trail reports for the Belly River area, GNP

(https://www.nps.gov/applications/glac/trail/trailstatus.cfm?t=BR)

2.4 Backcountry Hiking Resources

The tools for planning a backpacking trip have continued to evolve with technology, yet many aspects of backpacking still lend themselves to the need for physical maps. Trail guides were once limited to books but have become increasingly available on websites and mobile applications. Digital resources, such as websites and mobile apps with digital maps, are becoming an increasingly common tool to plan and execute backpacking trips.

Traditional Resources

Physical maps and trail guides are the primary means of planning and executing backpacking trips. A paper map is the most durable and simple way to navigate while in the backcountry. Therefore, paper maps such as the ones sold by the Glacier Conservancy should always be carried and safeguarded. Additionally, the size of paper maps makes it easier to read and compare with other resources such as digital maps (Berendsohn, 2018). In the case where safety is paramount, the reliability and detail of physical maps are unmatched. Paper maps and permits are excellent resources for executing backcountry trips due to their simplicity and reliability.

Digital Resources: Websites and Mobile Applications

Digital resources provide a way to plan trips and search for information such as hiking trails. Websites can receive and display trail status as well as past user experiences. With up to date trail reports and easy to browse resources, platforms such as AllTrails (**Figure 8**) provide a

simple way for hikers and backpackers to choose a predefined hiking route. Furthermore, users can leave trail or trip reviews to help future hikers with their planning. These trail databases help backpackers find and plan their trips. Additionally, websites are used to facilitate the permitting process. For example, GNP provides a link to pay.gov, the backcountry permit application through the NPS website (NPS, 2020a).

Existing hiking apps do not incorporate permitting details or applications, but they do contain trip reviews and digital maps similar to websites. Moreover, these apps have unique features such as GPS tracking and provide a different user interface. Although the majority of material needed to plan a trip is available through apps or websites, resources are spread across multiple platforms which force hikers to collect and process the information. Overall, the planning and permitting process requires a combination of digital and physical resources.
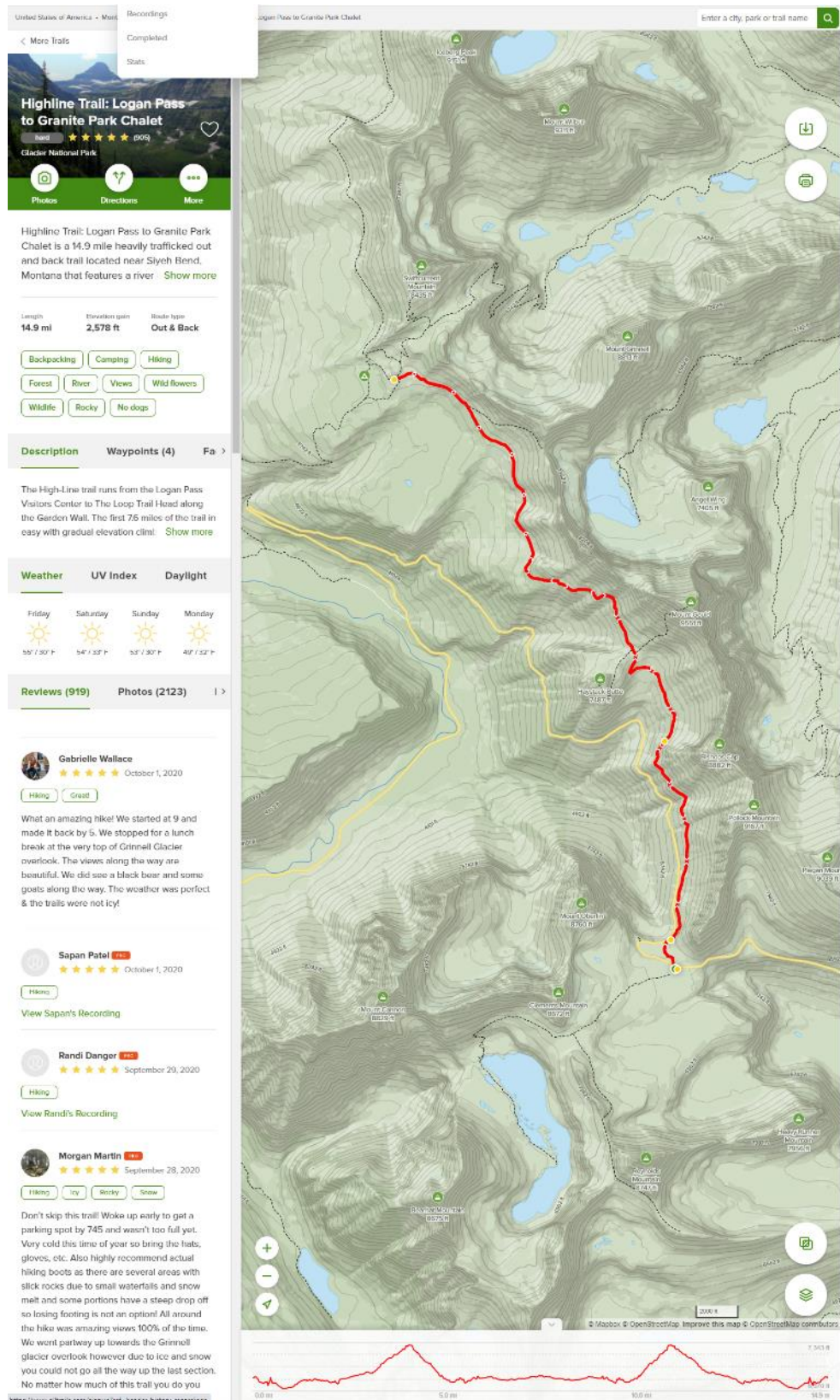
Figure 8. AllTrails Trail Overview

(https://www.alltrails.com/explore/trail/us/montana/highline-trail)

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Map Development

A trail map is one of the key features of any hiking websites and applications. These maps contain data such as trails, elevation, and distance. The National Park Service uses a program called ArcGIS, by ESRI, to create and distribute their digital maps (R. Menicke, personal communication, September 2, 2020). ESRI is a software development company that creates mapping and data investigation tools (What we do | about ESRI, n.d.). The ArcGIS software allows users to develop maps by starting with a basemap and adding data layers to create one inclusive map with a multitude of visual information. The software is also capable of providing symbols, legends, and running analysis techniques on the data in the map (ArcGIS Online, n.d.). Additionally, ESRI offers an Advanced Programming Interface (API) and a Software Development Kit (SDK), which allows software developers to directly integrate an ArcGIS map into their website or mobile application. The API, in particular, can be used to integrate a web map that is fully developed through the ArcGIS Online (AGOL) into a website (ArcGIS for Developers, n.d.). The ArcGIS suite of products provides software for mapping development from a basemap to a complete map inside a website or an app. Moreover, ArcGIS provides the ability to focus on specific regions and their unique geographic identities.

2.5 Mobile Applications for Hiking

Hiking, especially in the case of long backcountry trips, can be both dangerous and difficult. However, advancements in mobile applications have produced effective trip management platforms. There is currently an array of hiking apps, such as Chimani, with features that provide trip data, downloadable maps, GPS tracking, and general information about hikes (Glacier National Park Guide by Chimani, n.d.). These apps have common features that mostly target day hiking, but differences in features cause hikers to use multiple apps to satisfy their planning needs.

[Chimani](), [AllTrails](), [Gaia GPS](), and [Guthook Guides]() are among the applications available to hikers. Chimani provides an overview of GNP with information ranging from biking and picnicking to hiking (Glacier National Park Guide by Chimani, n.d.). Gaia GPS allows hikers to look at maps, create waypoints, record hikes, print maps, and share data (Gaia GPS membership, n.d.). AllTrails includes a map with basic layers such as trails and points of interest, an elevation profile, hiker reviews, and weather (Explore Nyack-Coal Creek Loop, n.d.). Guthook Guides is centered around an interactive map that displays the selected trail with waypoints such as campsites, peaks, roads, and trail junctions (Guthook guides app features, n.d.). A detailed analysis of existing hiking applications and their features is discussed in Section 4.

Smartphone and Mobile Application Capabilities

Hiking applications are an important resource; however, phones have limitations such as battery life and mobile connection. Although GPS features in apps can provide a resource for park navigation, they can also be unreliable. The GPS units in mobile phones require a receiver which is composed of the interaction between a microprocessor and an antenna. The receiver components work together to establish a connection between the phone and satellites. The system will run when it is searching for a signal which drains the phone's battery (Pramanik et al., 2019). When hikers embark on multi-day hiking expeditions, limited battery life could create safety risks. Additionally, Glacier is a remote area with limited service, which reduces access to information such as park regulations while hikers are executing their trip. To address these issues, an app would need to incorporate an offline mode to avoid connection issues during a hike. A phone is a potential resource while hiking, but the GPS and signal restraints render mobile devices unreliable as a tool to execute extended backcountry trips. Instead, a mobile application could be relied on for planning where the information and resources for execution are identified and developed before the hike. During trip planning, an application would allow early preparation to limit the risks associated with trip execution and reliance on cell phones.

2.6 Software Development

Software development for mobile and web platforms require design strategies and team practices to create a resource that is functional and practical. Organization and navigation are inherently built into the structure of applications, and the style can impact how well the user is able to interact with the program. Similarly, Agile is a practice used to streamline the development process, optimize features, and incorporate user experience (Matharu et al., 2015). Together these strategies maximize the functionality of a website or application.

Organization and Navigation

In mobile and web applications, the organization and navigation can be developed to direct users, convey information, and simplify a process. Figueroa and Juárez-Ramírez (2017) found a significant correlation between application navigation design and executive function (the amount of mental strain required by a task such as planning). Furthermore, they examined the ability to exert control over executive function through design. The study found that different navigation styles changed the amount of executive function required to traverse the app. Additionally, an intuitive design reduces the barriers of entry for first-time users. **Figure 9** depicts a few navigation design options such as carousel and grid. Navigation and organization are fundamental for planning backcountry hikes because of the quantity of information required.

As a result, the transition between ideas such as the backcountry permit process and park regulations need to be comprehensive and produce a logical flow of information.
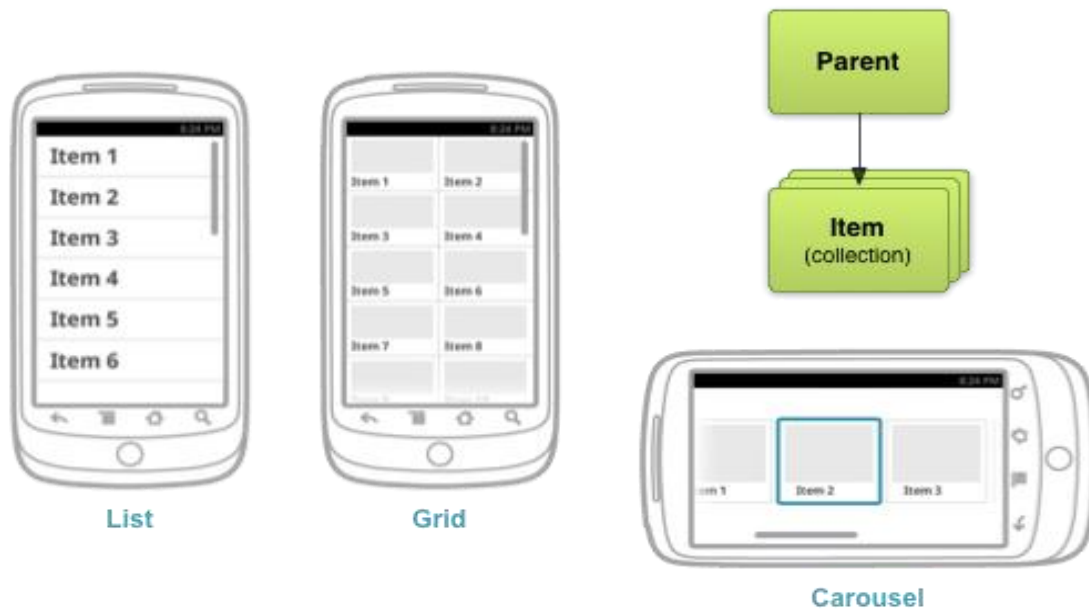

Figure 9. Example of Navigation Styles

User Experience and Efficient Design

Application and website development are complex interactions between humans and computers. Therefore, it is important for the designer to specifically target their user's needs. Practices such as agile, user experience, and lean are often implemented to increase the effectiveness of software design. Lean concepts originate in manufacturing and focus on adding value, reducing waste, and striving for efficiency. Agile is a methodology similar to lean that involves incorporating customers in the design process, modifying designs regularly based on user needs, emphasizing team dynamics/management, and establishing development strategies (Matharu et al., 2015). Throughout software development, confirming the value of each feature relative to the user's needs is vital to the success of the product. In the present project, the content is primarily a resource for the hiker, and incorporating user experience provides a stronger planning platform. Beverly May, a startup CEO and app developer wrote about the importance of user experience and avoiding assumptions about the users' needs because it can cost wasted development and repeated program alterations (May, 2012). The development of a quality mobile application revolves around communication between designers and stakeholders.

As a result, a hiking application, through the development process, would naturally incorporate the feedback and ideas of the hiking community. The direct interaction between the hikers and the developer allows the application to inherently implement the features that hold the most value to the user, which in turn will provide the hiker with the most useful, efficient resource for planning a backcountry trip.

3.0 Methodology

The primary goal of this project was to help Glacier visitors successfully plan backcountry hiking trips by developing an all-inclusive web application. Additionally, a secondary goal of this project was to support GNP rangers by providing them with relevant user experience data such as post-hike surveys. To create a successful web app, our research methodology was divided into three objectives with corresponding research questions.

3.1 <u>Objective 1</u>: Identify hiking resources and park-specific information necessary to effectively plan a backcountry trip in GNP.

Before designing the app, we determined the resources and information needed to plan a backcountry trip in GNP. To provide us with this information, our team created the following list of research questions:

    1.1. What is different about backcountry hiking in GNP?
    1.2. What information is essential for backpackers to plan trips in the GNP backcountry?
    1.3. What permits do hikers need, and how do they obtain them?

To answer research questions 1.1 and 1.2, we prioritized determining what is unique about Glacier and consequently what information backcountry hikers need to know to plan a hike. This information was obtained through a literature review that familiarized us with backcountry hiking in the park and how it is managed. Data was gathered from government websites and hiking blogs and analyzed using content analysis to identify information relevant to backcountry hiking in Glacier. To understand maps used for planning a backcountry trip, we organized a semi-structured interview of the GNP Geographer, Richard Menicke (see **Appendix C**: Interview of GNP Geographer for examples of interview questions). Richard provided us with ArcGIS data layers of backcountry trails and campsites, as well as explained the geographical regions used to organize park ranger management.

To address research question 1.3 of understanding the complex permitting process at Glacier, we conducted a semi-structured interview with the Supervisor of Backcountry Permits Program, Brian McKeon (see **Appendix D**: Interview of Supervisor of the Backcountry Permits Program for examples of interview questions). Brian answered questions regarding the specifics of the permitting process to help us identify difficulties and incorporate a solution into our app. Data was recorded by taking notes during our interview over a phone call. We used thematic analysis of the information gathered during this interview to prioritize the feasibility of our app content.

3.2 <u>Objective 2</u>: Establish a feedback collection strategy by identifying how backcountry hikers exchange their trip experiences.

We created the following questions to help guide our methodology for this objective:

2.1. How do backcountry hikers currently share their trip experiences?
2.2. What type of information do backpackers share about their trips?
2.3. What are practical ways to allow for sharing post-trip experiences?

To address research question 2.1, we used Qualtrics to generate an online survey form and collect response data. The online survey was distributed to our target audience through backcountry hiking blogs and specific Facebook groups. Our multiple-choice and short-response questions provided insight into the resources and information hikers use to communicate within the community (**Appendix A**: Online Survey of Backcountry Hikers: Q8-10). We applied statistical and thematic analysis to the data to identify the best methods for sharing trip experiences. To answer question 2.2, we used data from the survey and observation of backcountry hiker forums to determine which information backpackers would want to see or share. To answer research question 2.3, we examined popular platforms for sharing hike experiences.

3.3 <u>Objective 3</u>: Identify design criteria and features necessary for a backcountry hiking app in Glacier National Park.

Before developing our web application, we analyzed the data from our survey, compared available hiking applications, and reviewed the permitting process to determine the design criteria and features for the web application. The third section of our survey addressed which features were necessary for the hiking community. Additionally, we used Strength, Weakness, Opportunity, and Threat (SWOT) analysis on existing hiking apps to determine which features were missing as well as which ones aligned with the needs of backcountry hikers in Glacier National Park. Similarly, we used process analysis, a technique to break down a procedure into discrete steps and stages, to provide insight on how the organization/navigation of our web application could improve the permitting and planning processes (Aaron, Jane E., 1999). Finally, we used our process analysis and research results to determine which data layers to include in our interactive map. **Figure 10** depicts our process from data to feature selection and organization. We created these research questions to guide our design criteria:

3.1. What are the features of currently available applications?
3.2. What planning features are missing from currently available applications?
3.3. What features do hikers find the most important in a planning application?

3.4.How will the app information and structure be organized to aid planning?

Feature Analysis

The third aspect of our survey was designed to answer research questions 3.1-3.3. We used Excel to perform computations on the survey data for our statistical analysis, which allowed us to understand the significance of our survey responses. More specifically, we used the results to help us understand what features should be implemented to satisfy the needs of the GNP backcountry hiking community.

Additionally, we used SWOT and application analysis to compare currently available hiking applications and their features. Our analysis primarily answered research question 3.2 and focused the design of our app from all the possible features to the few that would make our design unique. For the app comparison, we acquired the data on each app from a collection of sources such as app stores, app reviews, web sources, and personal testing. We also compared and contrasted the data layers used in currently available hiking applications to determine the most popular waypoints. After we analyzed the data, we represented the results graphically. For our SWOT analysis, we compared the strengths, weaknesses, opportunities, and threats of Glacier's backcountry planning process and available resources. The content for each category was based on our background research, application analysis, and our survey and displayed in four color-coded boxes. We used the comparison technique to maximize the opportunities and strengths for the backcountry planning process and minimize the weaknesses and threats.

Furthermore, to answer research question 3.4, we used process analysis to decompose the planning and permitting process. Our process analysis would provide insight into how the organization and flow of our app could increase planning efficiency. We acquired the permitting process data in parallel with Objective 1 from interviews with the sponsor and the NPS website. We used process analysis as a tool to break down the specific steps, stages, and information used in the planning process. This provided us with the criteria for how to design a web application to maximize the flow of content and reduce the burden of trip planning and permitting for hikers. Furthermore, breaking down the process illustrated which waypoints or details such as campground locations could fill holes in existing resources. We collected the data through online research and represented our results graphically. Overall, we used our analysis techniques to select the most valuable features and flow that would simplify the backcountry trip planning
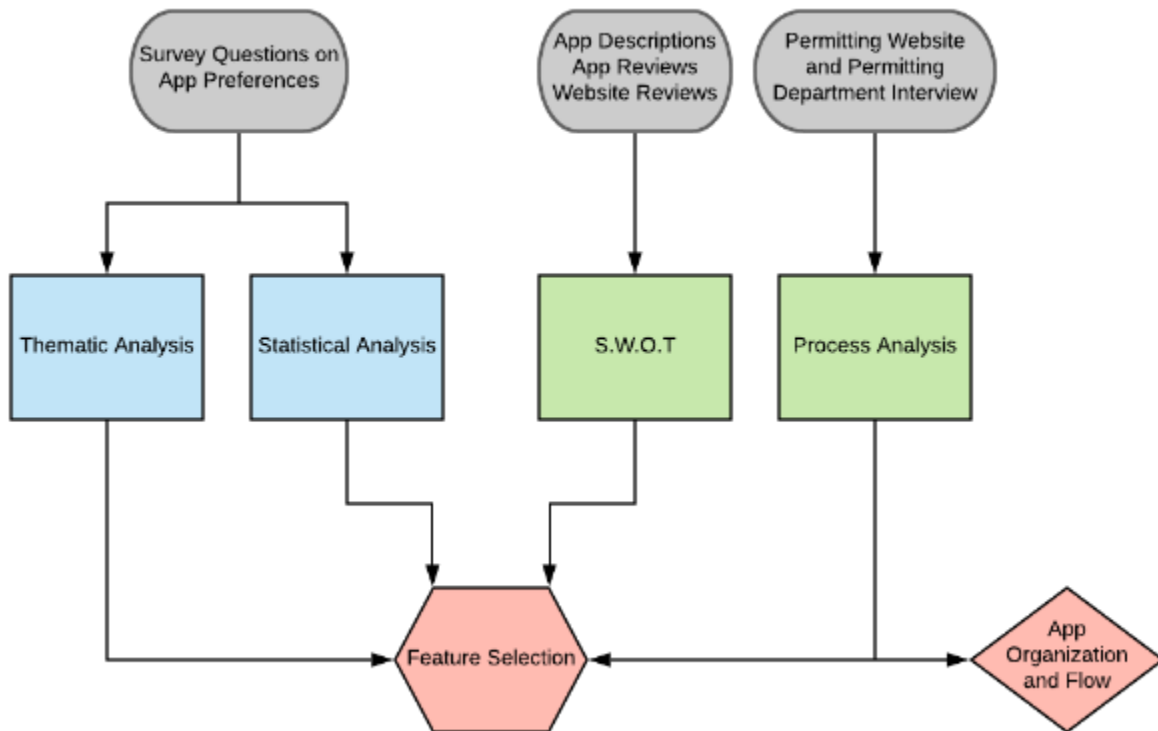
process.

Figure 10. Feature Selection Methodology

Software Development

We used Agile Scrum to develop software as a team. This project methodology focuses on incremental development that allowed our project to pivot. Scrum is a series of meetings designed to engage in rapid planning and implementation cycles. As seen in **Figure 11**, Scrum includes creating a task backlog and conducting frequent reviews of the deliverable as well as conducting weekly planning meetings, daily progress meetings, and weekly review meetings. Agile is a series of principles dependent on a small team that embraces change; it focuses on the individual skills of the team. We used a web application to easily deliver the content to our sponsors, advisors, and users. We used HTML, CSS, and JavaScript as they are the basic building blocks of an interactive website. We used VSCode for code editing due to its excellent support and variety of features, as well as GitHub for version control. These code development tools allowed us to create a web application on a WPI server.

Figure 11. Agile Scrum

(https://neonrain.com/agile-scrum-web-development/)

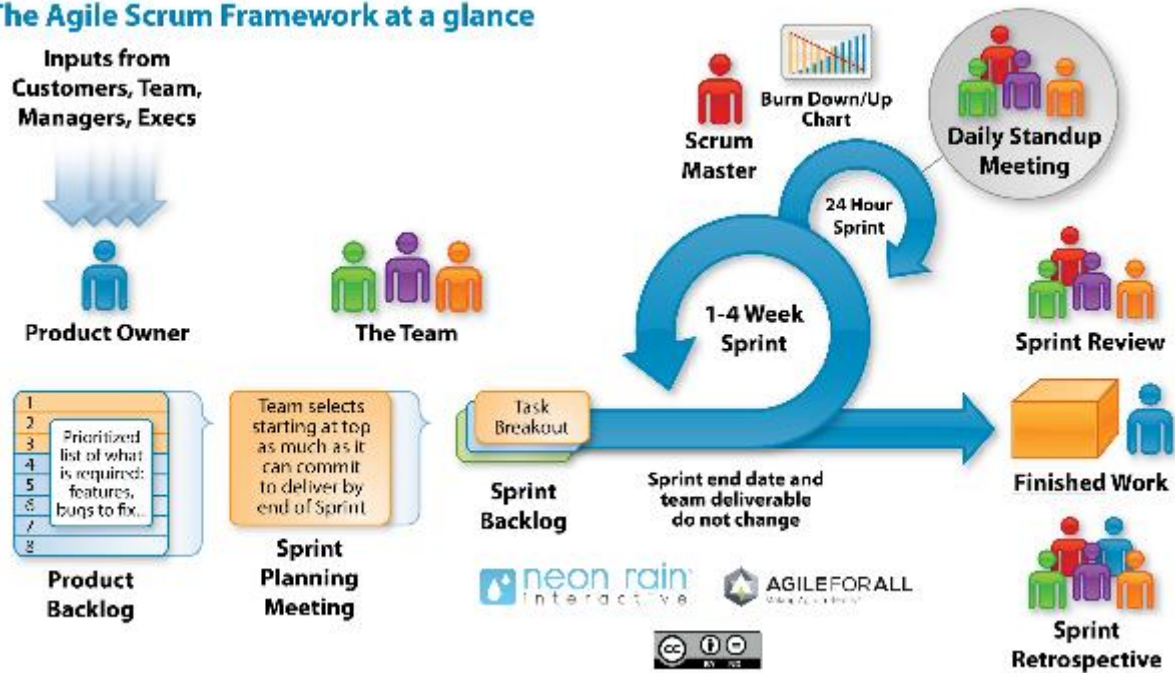## 4.0 Results

By addressing the answers to our research questions for each objective in Section 3, we determined that the current system used to plan a backcountry hiking trip in Glacier has various limitations. For example, the planning and permitting process is expansive, yet the park website is difficult to navigate and existing mobile applications such as Chimani only partially cover the information needed to plan a backcountry trip in Glacier. Below we detail our results from addressing our research questions.

4.1 Existing Resources and the Backcountry Planning Process

The resources and information needed to plan a backcountry hiking trip in Glacier were identified in order to determine the areas of improvement in the current system. As discussed in Objective 1, content analysis was performed on the most popular search results for 'backcountry camping in Glacier National Park'.

The NPS webpage on Backcountry Camping contains the most information on the specifics of permitting, regulations, and safety; however, to learn more about backpacking, other sources such as REI must be consulted. Also, blogs such as Clever Hiker are popular for attempting to combine the specific considerations of Glacier to the overall challenge of backcountry camping.

In an interview with the park's Geographer Richard Menicke, we learned that visitors generally use park provided maps, from either the NPS website or ranger stations (personal interview, September 2, 2020). Furthermore, we learned additional information about the permitting process from Supervisor of Backcountry Permits Brian McKeon; namely, we learned of the difficulty visitors face in completing the permitting process due to common mistakes such as not understanding how far a hiker should expect to go in one day or by not providing alternative routes on the permit application (personal interview, September 14, 2020). Overall, by identifying the resources used in planning a Glacier backcountry trip, the limitations as presented below become apparent.

Limitations of Current Planning and Permitting Processes

The process of planning a backcountry trip and acquiring a permit from Glacier's website is complicated and can confuse new hikers. To identify the source of these problems, we conducted a process analysis of the steps required to plan a trip and to acquire a permit. As seen in **Figure 12**, prospective visitors must first research, choose their trails, and choose a flexible date range. Then they may either seek an advance or in-person reservation and determine

transportation to the trail-head. Once on-site, visitors must pick up their advance permit or apply for the walk-in permit before beginning their trip. We found that multiple online resources simplify the research steps by compiling aspects of relevant information, but none of the online resources address all the tasks necessary for planning a trip.

The plethora of available resources indicates that the research step is a challenge for many hikers. Furthermore, in an interview with park staff, it was confirmed that one of the common permit application problems was applying for a trip that failed to follow all the rules and regulations. Application errors result in automatic rejections and show existing resources are not providing sufficient material to help hikers plan trips and fill out permit applications (B. McKeon, personal interview, September 14, 2020).

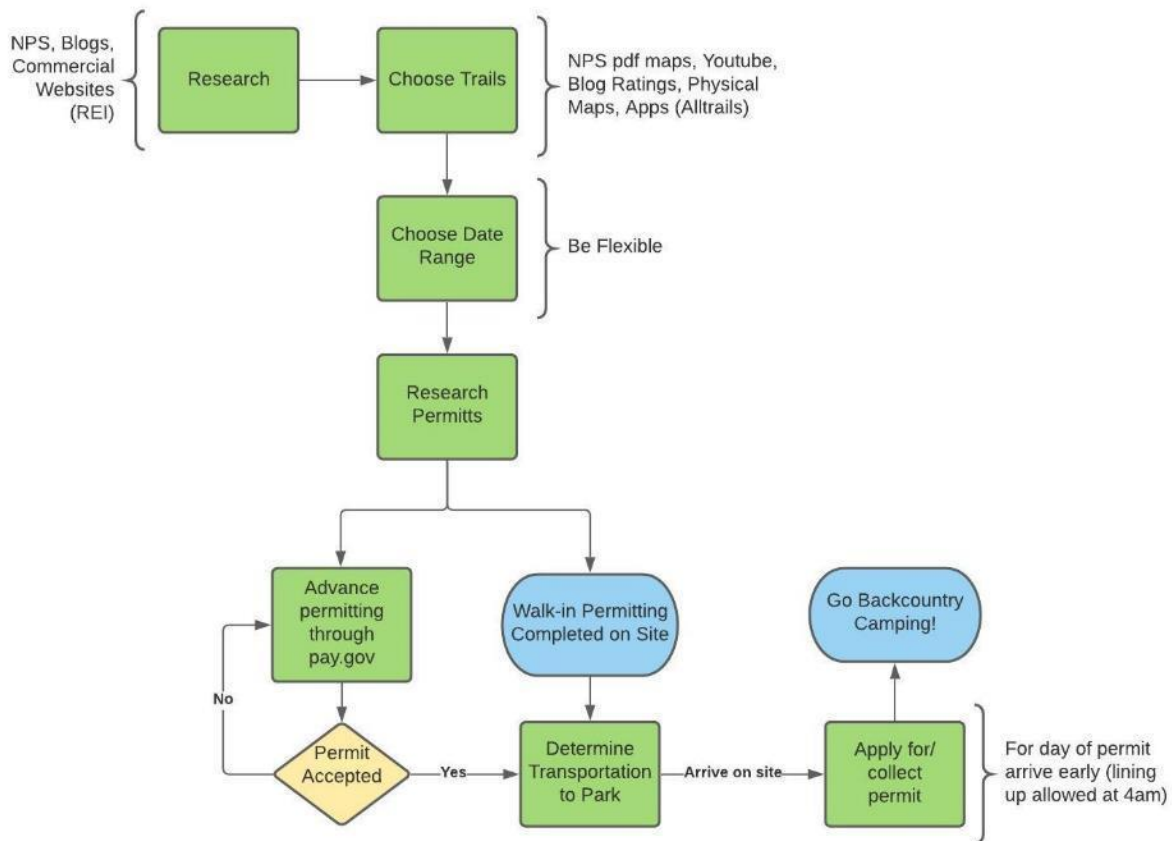

Figure 12. Process Analysis of planning a backcountry camping trip in Glacier

Glacier NPS Website Navigation

One of the first places a prospective Glacier backcountry hiker will go while researching to create a trip is the Glacier National Park website. Our process analysis of collecting the necessary information from the website, shown in **Figure 13**, found that many pages on the

website were missing information we expected. For example, the "Permits and Reservations" page directs hikers to a separate page for more information, but this link does not currently work, leaving backpackers wondering if they are missing information. Our process analysis additionally found that the interactive map on the website was missing information such as park regions and elevation profiles, which helps determine the status and difficulty of the trail. The web pages that do list the park regions are also inconsistent in regard to how many regions there are and their names. These issues remain unresolved because the Glacier IT department has limited staffing and is primarily concerned with keeping the NPS website running rather than improving user experience (Richard Menicke, personal interview, September 2, 2020).
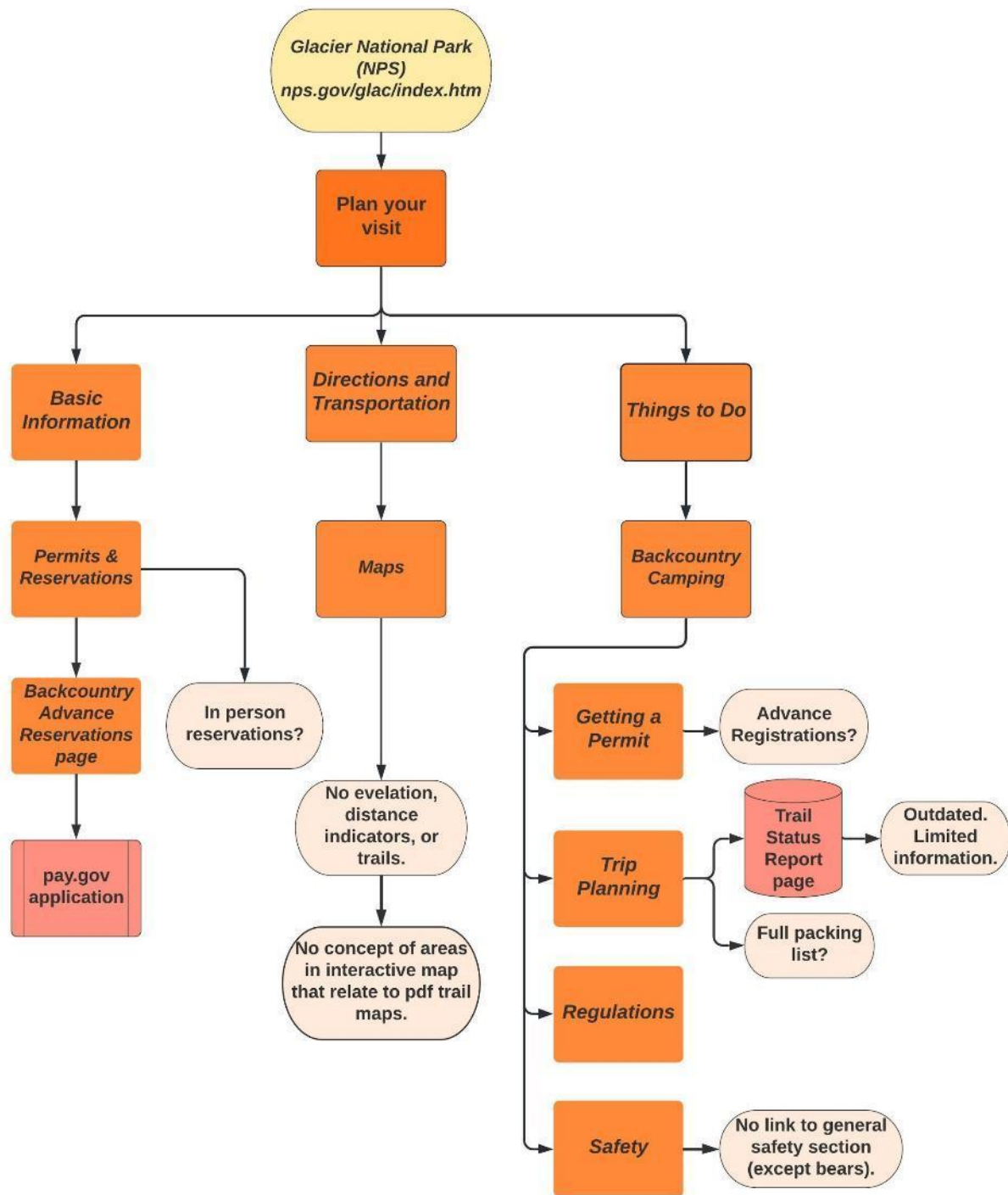
Figure 13. Process Analysis of the Glacier National Park Service website concerning backcountry camping information

Trail Status Reporting System

 After reviewing the [NPS trail status page](#) during our preliminary research, it was confirmed during our interviews with Richard Menicke, Brian McKeon, and Sarah Moody that this is the only NPS source with recent trail information. This trail status page contains very limited information, such as when the trail was initially cleared, and if the trail is open or closed. If major trail work is conducted such as replacing a bridge or clearing a fallen tree, that will also be documented. However, the NPS states this information "may be outdated and inaccurate regarding downed trees, brush, or other dynamic natural conditions or events." Important information such as trail surface (i.e. large loose rocks, slippery when wet) is not included. (**Figure 19**) (NPS 2020d).

 As well as being limited in information and possibly outdated, the trail status page format is difficult to navigate for backcountry trip planning because it contains all the trails for the park. The trails are not organized as backpacking trails or day hikes, so it can be tedious to sort through the trails to find the specific trail information. Although trails are sorted by region, there is no search bar or means of filtering/organizing the trails. Additionally, as shown in **Figure 14** the page contains only simple black text with no images, symbols, or colors aside from a red bullet point for each trail section. This makes it very difficult to scroll through and quickly assess the information without mixing up different trails, trail sections, and what is open or closed.

Figure 14. Trail Status Report page of some St. Mary Lake Region trails

(https://www.nps.gov/applications/glac/trail/trailstatus.cfm?t=SM)

Application Analysis

The goal of our project was to develop an application to help backcountry hikers plan their trips and to help staff with trail reports and permit processing. To avoid redundancy and ensure product value, we compared existing hiking applications. Our goal was to determine which features were available and what components were collectively missing from applications. We compared the maps and general features for the following applications: AllTrails, Gaia GPS, Guthook Guides, Hiking Project, National Park Guides, Chimani, ViewRanger, Topo Maps+, Avenza, and Maplets.

Our map comparison found that the most common features are elevation profiles, waypoints, and interactive maps. 8 of the 10 applications utilize an interactive map, and 6 out of

the 8 maps include an elevation over distance profile (see **Appendix E**: Application Comparison - Map Features for the comparison chart). Additionally, all 10 apps include waypoints or layers, but the most common data points were routes, peaks, and campgrounds. 7 of the 10 apps included campground layers or waypoints, but only Avenza provided backcountry campground details. Although the National Geographic maps in Avenza provides a summary of backcountry campgrounds, it discusses the campgrounds in a region, and not the individual site details. None of the available applications provide details on each backcountry campsite.

Our feature comparison found that although each app has unique features, there are similarities between content. For example, all the apps contain at least a minimal number of trails and routes for hiking in Glacier. Hiking Project, National Park Guides, and ViewRanger only display routes created by users, whereas the remaining applications have predefined routes or trails. Additionally, 6 of the 10 apps include trail reports or feature descriptions where users can rate and describe their experience (see **Appendix F**: Application Comparison – Features). Alternatively, our comparison found that 8 out of 10 apps provide a description of Glacier, although most were only a brief overview.

Overall, our comparison demonstrated that interactive maps, waypoints, and elevation profiles are the most influential map features. Additionally, we discovered that campground details are a limited resource among existing applications. Finally, we discovered that each application has unique features, which support the goal of their resources and their design.

Strengths Weaknesses, Opportunities, and Threats

Our team conducted a SWOT analysis to compare the strengths, weaknesses, opportunities, and threats of Glacier's backcountry planning process and available resources. The SWOT table in **Figure 15** was built from application comparison findings, process analysis findings, online research, and personal interviews. Our web application was designed to limit the weaknesses and threats while maximizing the opportunities and strengths for the backcountry planning process in Glacier.

Our SWOT findings were centered around the current processes and resources used for backcountry planning in Glacier. As shown in the SWOT table (**Figure 15**), a notable strength was the parks permitting website map, which included imperative permitting information such as campsite codes, site details, regions, and trails. However, the park does not have an interactive map where users can select trails or campsites to see the specific information they want or need. Furthermore, we found that the park discusses important safety concerns on their web page, but the organization and design make it difficult to navigate and reduces comprehension.

Additionally, the park puts significant effort into updating the trail status reports, but the format of the web page makes it difficult to locate specific information.

Our team also identified opportunities and threats to improving the process of planning a backcountry trip in Glacier. For example, based on our application analysis, we determined that an opportunity for improvement could be to include campground details on an interactive map. Additionally, Glacier has the opportunity to develop a free resource for backcountry hikers that does not require subscriptions, unlike some of the existing applications. Finally, one of the largest opportunities is the ability to create a resource that is specifically targeted toward backcountry hiking in Glacier. Existing apps have a diverse scope of audiences which limits their ability to provide detailed information specific to Glacier National park. However, the current apps have an established following and user base that have generated detailed trail reports, trip comments, and descriptions. This is a threat to Glacier because they will need to establish trail/trip reports and descriptions with a limited initial following.

Strengths	Weaknesses
- Permitting website map details - Online application for reservations - Website presents important safety concerns - Staff is responsive and helps with planning - The park maintains trails and updates the known trail status	- No interactive map for permitting - Park interactive map has limited content - Organization of web pages makes it difficult to navigate - Graphic design of web pages reduces readability and comprehension - Status page relies on staff reporting - Resources are designed for all audiences, but more challenging for beginners - Cellular reception in the park is limited
Opportunities	Threats
- Glacier can provide in depth details of backcountry trails and campgrounds - Commercial apps have limited details on Glacier's backcountry trails - The apps don't provide campground details - Glacier can provide full app functionality without subscriptions - Glacier has project development support through the conservancy - Increase IT support and hire summer programming interns	- Glacier would need to keep resources up to date. - Existing apps are established within the hiking community - Database of comments and descriptions - Government regulations and oversight of development - Other apps can include tracking features and data collection - Commercial apps provide offline features in apps and downloadable maps.

Figure 15. SWOT Analysis Table

Survey Data

Of our 53 survey respondents, 83% of them have experience with backcountry hiking, verifying that we reached our target audience of backpackers. We found that 55% of respondents felt that existing applications are missing features for backcountry trip planning, so there are opportunities to improve upon the current resources. Furthermore, **Figure 16** shows that 68% of all respondents would likely install a backcountry planning application if it has the features they felt were important, verifying that hikers are willing to try new applications.
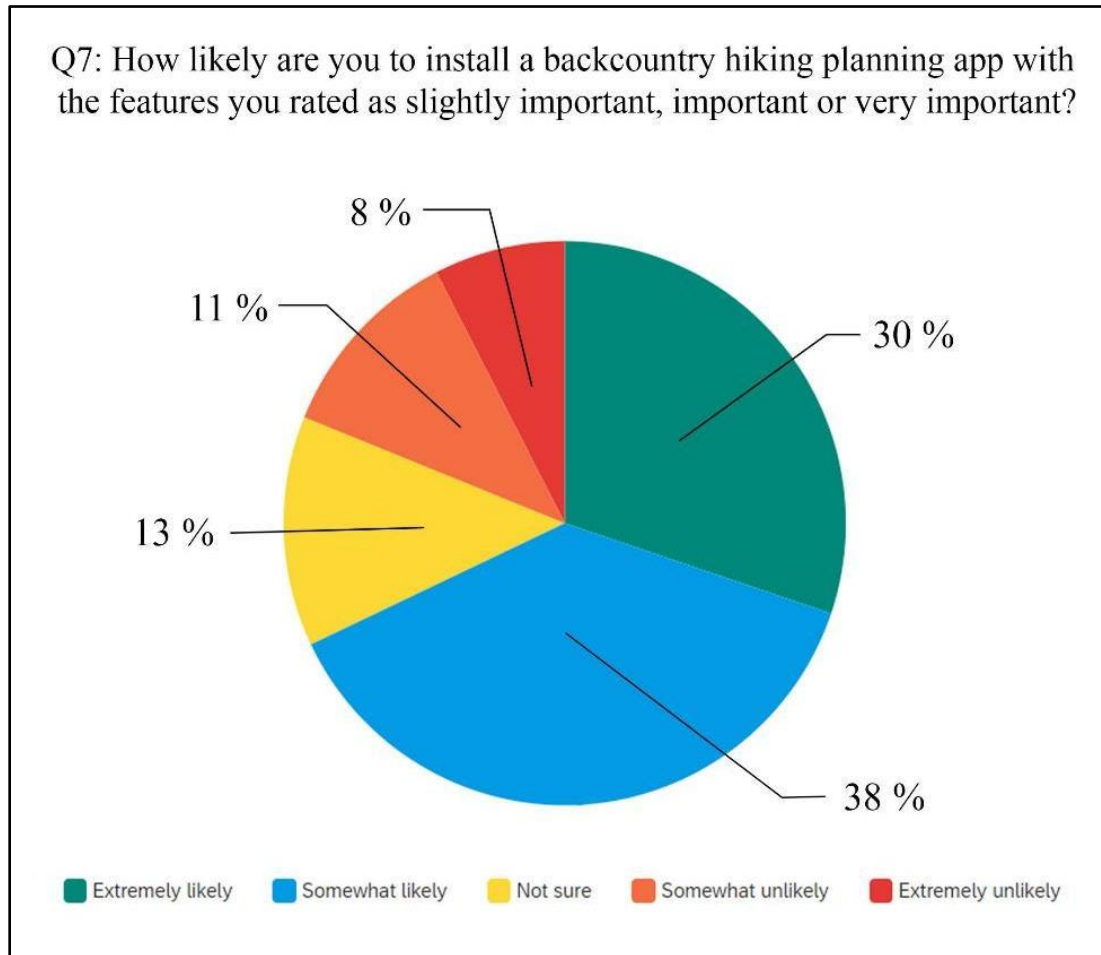
Figure 16. Likelihood to download an app with features users felt were important

To determine which features are important to users, **Figure 17** shows how respondents ranked the importance level of the given features for a backpacking planning application. There was great variation in responses, so no specific features were distinguished as being the "most" important, rather all being important aside from Social Platform/Media Sharing.
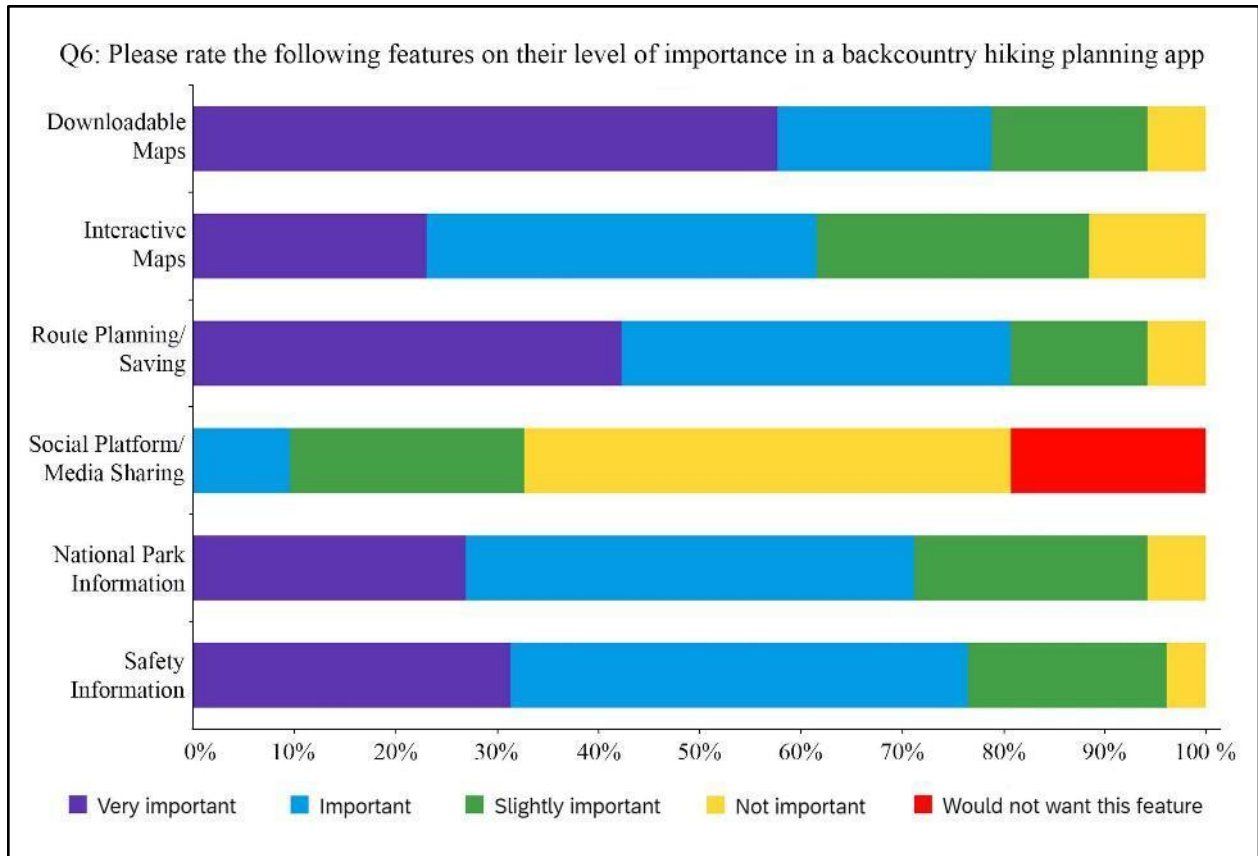
Figure 17. Stacked bar chart of the level of importance of the listed features

Question 4 proved to be more valuable in determining the most important features for our application. **Figure 18** shows that Downloadable Maps, Route Planning/Saving, Interactive Mapping, and National Park Information are most important to users, so we prioritized these when developing our application. Question 5 also provided an open response for what features were missing, and the responses repeatedly showed that an interactive mapping feature should include elevation gain, as well as the ability to save generated routes. Additionally, the user interface must be easy to navigate and could have the potential to export routes as GPX and KML files to GPS devices such as Garmin inReach.
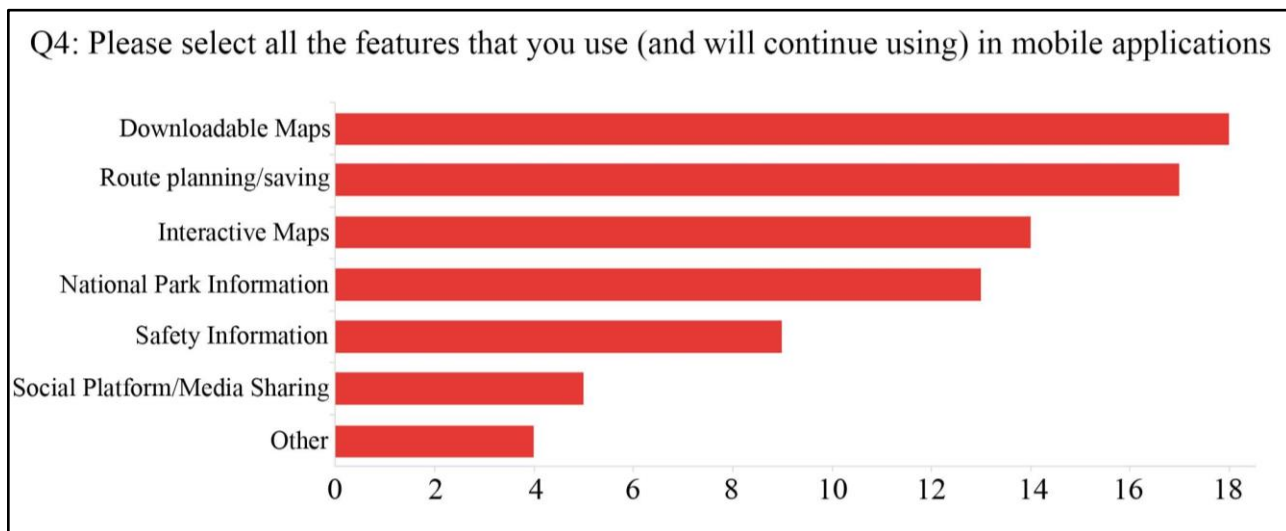
Figure 18. Feature Ranking for use in planning backcountry trips

Benefits of an Interactive Map

In addition to being ranked as the third most desired mobile application feature in our survey, we received confirmation from multiple members of Glacier park staff regarding the importance of interactive maps. In our interview with Permitting Supervisors Brian McKeon and Sarah Moody, the supervisors noted that the park does not provide an interactive backcountry map for hikers. Furthermore, they agreed that an interactive map would be a useful resource. One of the benefits of an interactive map is the ability to select waypoints, embed descriptions, and analyze data. Additionally, when we asked which feature would be the most useful to backcountry hikers planning their trip, McKeon and Moody agreed that an elevation profile would be the most useful component to give hikers a better sense of trail difficulty and improve their chances of submitting a feasible permit application (personal interview, September 14, 2020).

4.2 Web Application Design and Development

We created a web application to solve the aforementioned problems with the current backcountry hiking planning resources. After thorough research into the areas of improvement, our web application contains updated content, design, and features such as a post-hike trail reporting system and an interactive map for trip planning.

A Simple and Concise Design

   To create a simpler and more concise website, we condensed the important information into a few web pages accessed from the home page. Every page can be accessed from the website's header, shown in **Figure 19**. The "Plan Your Trip" page covers essential information for planning a backpacking trip, while the "Permitting Prep" page walks users through the permitting process. Our "Safety Tips" page connects information from multiple NPS websites and highlights a variety of hazards. Condensing the content into fewer pages than Glacier's website significantly reduced the navigation required to find any given type of information.
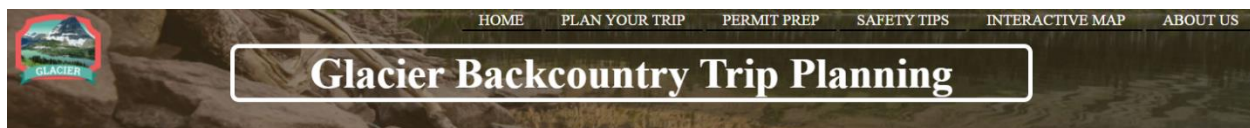

Figure 19. Website Header

   New features were also added to aid the planning process. For example, a checklist was added to the home page which summarizes the necessary steps for backpackers to plan a trip, receive a permit, and stay safe. It automatically tracks which of our web pages have already been visited. Additionally, Glacier's website lacked an interactive map for trip planning, which was developed and added as a feature on the "Interactive Map" page. Furthermore, hikers can use our embedded links to conduct further research if desired.

Web Application Content

   After developing the layout and organization for the new web pages, we added content to each page based on our research results. For example, our planning page incorporates a packing list and a detailed step by step instruction for how to plan a backcountry trip in Glacier National Park. This content was determined through our process analysis and researched best practices. We also include links to the park's backcountry camping site, physical maps, and weather reports.

   The planning list naturally transitions to the permitting page, which is centered around a discussion of the permitting process including the two types of permits (walk-in and advanced). Additionally, the page provides tips for obtaining a permit that are easily overlooked and are not described on the NPS website. For example, our page recommends that hikers plan four possible routes to increase their chances of receiving a permit. We collected the tips from forums such as WikiHow and Hike734, as well as from our interview with the Park Permitting Supervisors.

   Our safety page was developed by summarizing key points from NPS web pages including bear safety, backcountry safety, the 10 essentials, and hike smart. Our safety page lists

considerations for backpacking in general as well as ones unique to Glacier. Most importantly, our map was designed to be the backbone of our content with an elevation profile, trail geographic data, campground geographic data, and points of interest. Our map is meant to be the primary planning resource included in our website for backpackers in Glacier National Park.

Interactive Map Development

Based on our application analysis finding that interactive maps, elevation profiles, and waypoints are the most common app features, our team prioritized creating an interactive map. Additionally, our survey data showed that interactive maps are a highly important feature. Based on our interview with Glacier permitting supervisors McKeon and Moody, we developed our map to include campground details, trails, and an elevation over mileage profile.

To create the interactive map (**Figure 20**), we implemented a topographic base map on ArcGIS Online and added various data layers. Our boundary and trails layers were obtained from park geographer Richard Menicke. Additionally, Menicke provided data on campgrounds and points of interest, which were modified to display the desired content. We designed the layers so that when clicked, the trails and campgrounds provide details such as mileage for trials (**Figure 21**) or descriptions for campgrounds. The campground details fill a gap in the current application resources, and also include information such as how many nights one can stay at a site, the number of livestock allowed, the permitting code, and when the site opens (**Figure 22**). Additionally, we designed the map to provide an elevation over distance profile for selected trails (**Figure 23**). Finally, users can save multiple trail segments together as a trip to be viewed later.
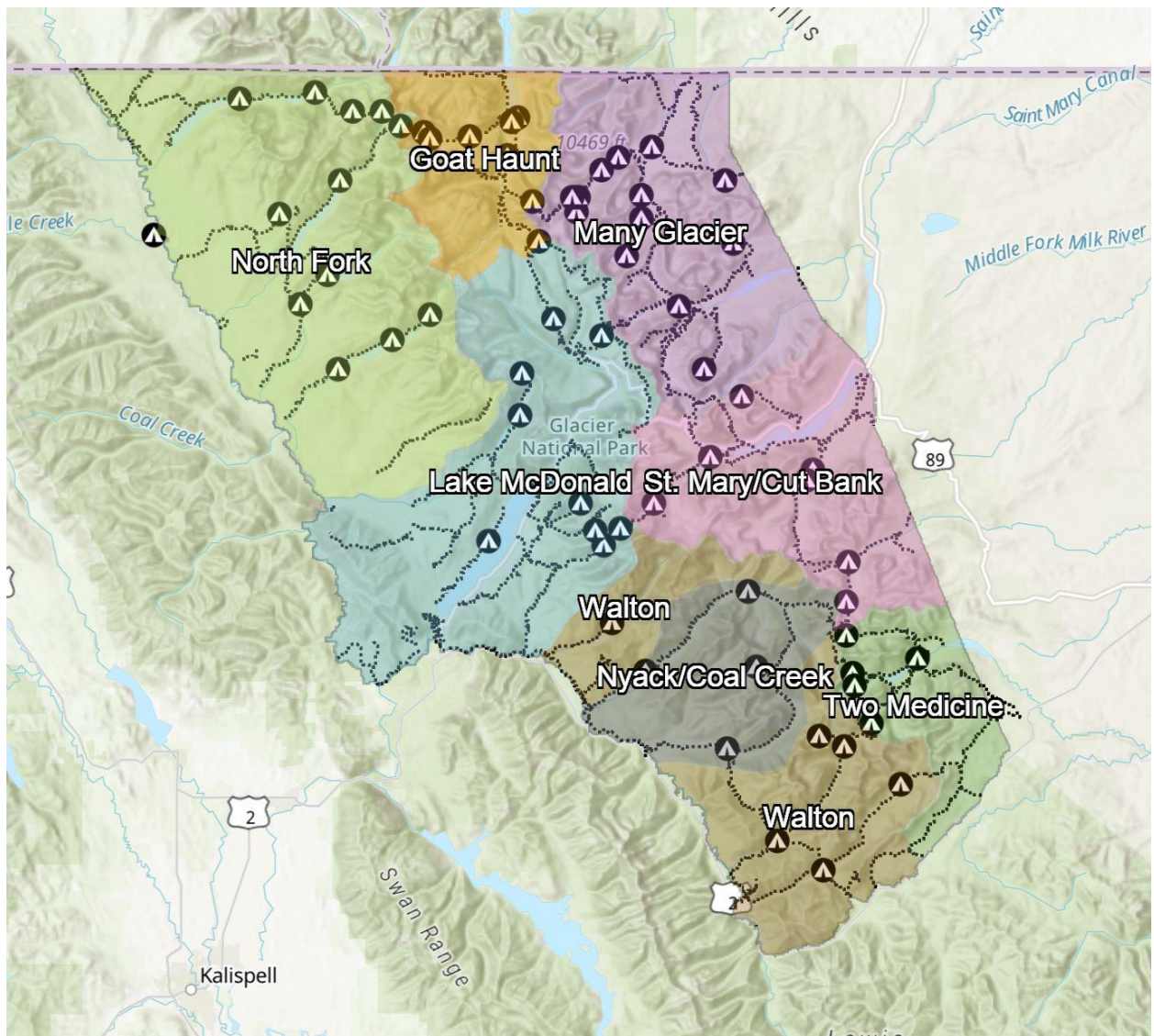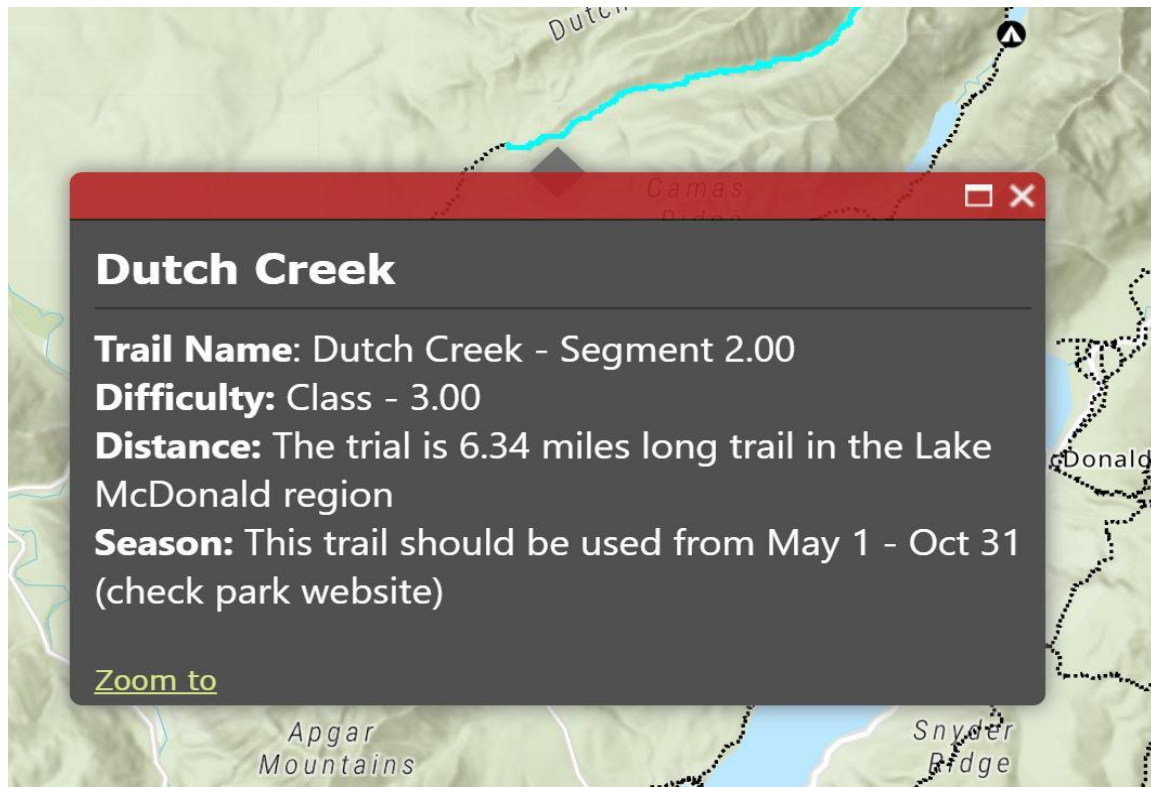
Figure 20. Interactive Map

Figure 21. Trail layer and description
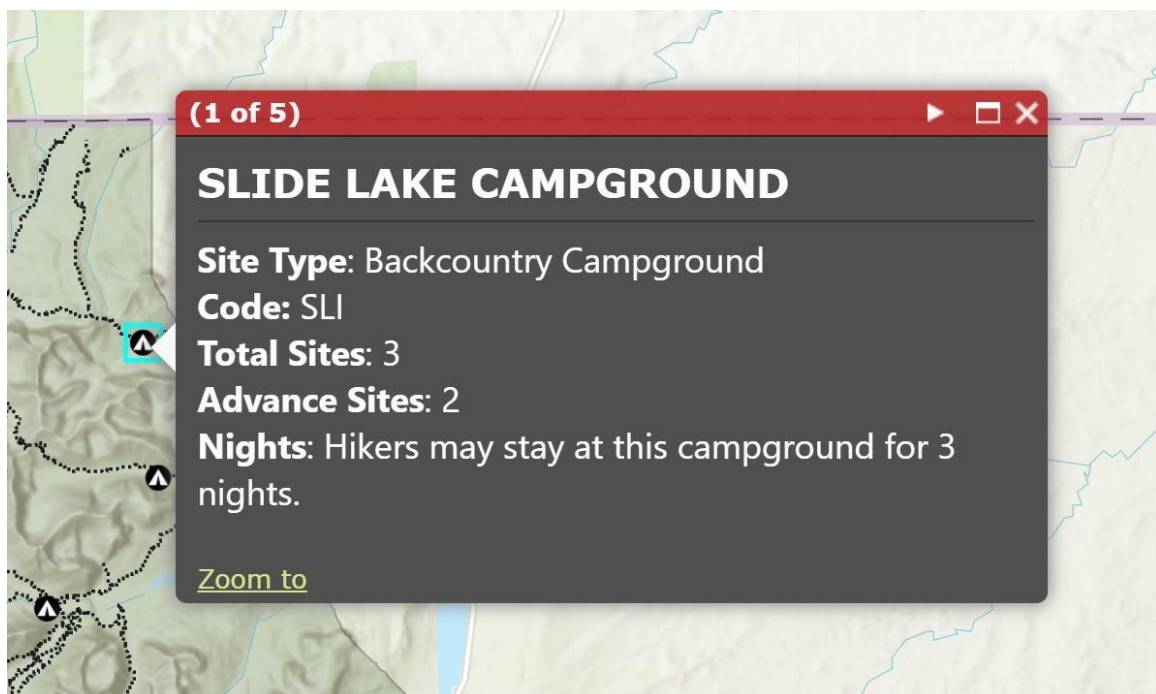
Figure 22. Campground layer and site details
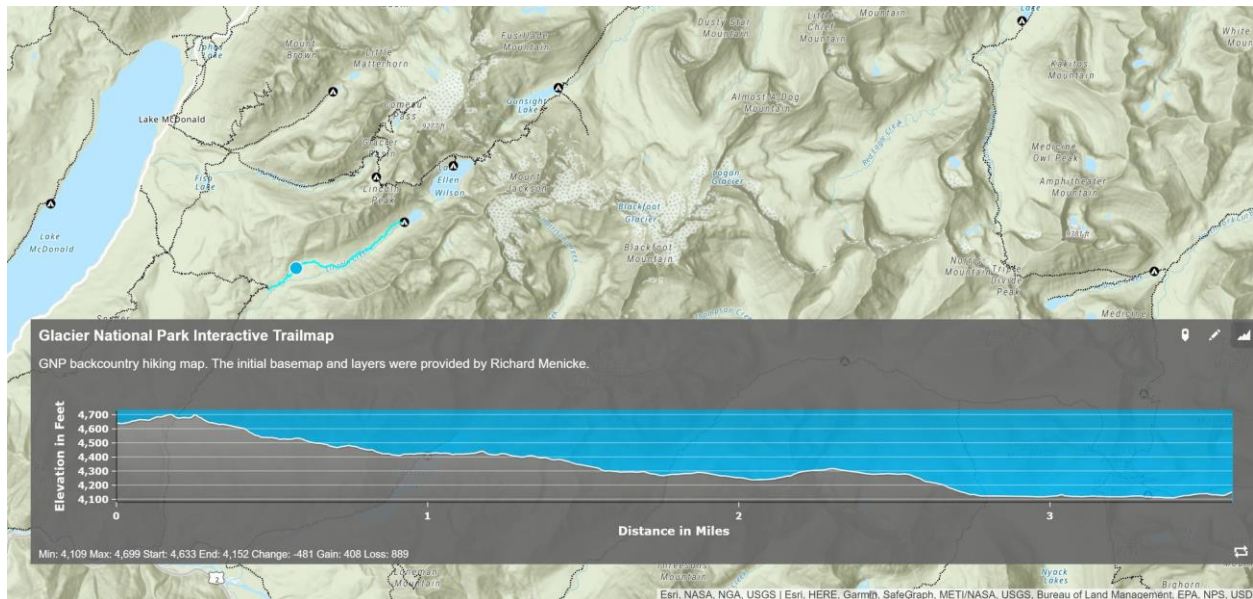
Figure 23. Elevation over distance profile graph

Post-Hike Trail Reporting System

As the park geographer for 28 years, Menicke has worked on numerous projects and therefore gained extensive knowledge concerning park management and function. During our interview, he noted the value in our hiker generated trail reporting system because it will be able to provide more recent information than is possible with the current system which relies solely on park rangers (R. Menicke, personal communication, September 2, 2020).

To provide an accurate and up to date trail reporting system without increasing the workload on rangers, we created a post-hike survey (**Appendix G**: Post Hike Survey Model) that utilizes backpackers to collect a continuous stream of the most recent trail information. After finishing a backpacking trip and returning to an area with an internet connection, the hiker can fill out a brief post-hike survey that collects key information from their hike. The survey incorporates identifying issues/hazards by region so the rangers responsible will be automatically notified of the issue and can address it if needed.

A draft of the post-hike survey was created using Qualtrics (**Figure 24**), and includes brief multiple choice or fill in the blank questions regarding the hiker's trip experience, the weather, the trail conditions, and any obstacles they encountered. Each hike is rated from 0 to 5 stars, and there is an option to attach a picture and any additional trip information that would be helpful to others planning a hike.

Figure 24. Example of the questions in the post-hike survey

5.0 Recommendations and Conclusion

The goal of our project was to develop an application to assist in planning backcountry hiking trips in Glacier National Park. Glacier would benefit from continuing to develop this project into a mobile application for visitors to use. Additionally, improving upon the park's digital trail reporting system and digital maps will help hikers execute successful backcountry trips.

5.1 Recommendations

Recommendation 1: **Glacier should continue to develop the information and features contained in our web application as a fully-fledged mobile application.**

There are two possible avenues by which this recommendation can be accomplished: by a future WPI project team, or through the involvement of an app development company. If a WPI team continues this project we recommend using ArcGIS AppStudio because the app can be distributed across all relevant platforms. The ArcGIS development tools provide a wide range of features to implement, most notably the use of their interactive maps. Additionally, a guide to a future team with links to our work and the resources we used is provided in **Appendix H: Developers' Guide**.

If a future WPI team does not continue the project, Glacier should turn the project over to a professional application development service. This could be done by creating a Glacier specific guide in a larger app such as Guthook Guides. If developed from scratch, this mobile app could be an investment, as it could function as a paid service like a virtual guidebook. Additionally, having our web application translated to a mobile application would allow features exclusive to mobile platforms to be implemented. For example, GPS tracking can be included so that visitor's hikes are digitally recorded and can be accessed by the post-trip survey report, and by rangers for data collection and analysis. Additionally, downloadable maps could be added to a mobile app, which is the highest-ranked feature in our survey (**Figure 17**). Accessible without internet connection and coupled with GPS tracking, visitors could use downloadable maps to track in real-time where they are in Glacier. Our documentation and website code is provided on GitHub and is linked in our "About Us" page.

Recommendation 2: **Glacier should author a post-hike survey based on our model.**

On our website, we created a survey for users to fill out after the completion of their hike to collect feedback on the trip and information on the trails. We recommend that park staff author a similar post-hike survey. As previously discussed, it is difficult for rangers to report on the extensive backcountry trails regularly. There is a wealth of knowledge and information to be gathered from hikers' experiences. Although park staff would have to take the responses to their survey tentatively concerning hikers' experience levels, these post-hike responses could provide direction to possible problems on trails and which trips in Glacier are the most popular.

An online survey is easily distributable through a QR code on visitor documents or a website link, which can be completed shortly after a backpacking trip once the visitor returns to an area with an internet connection. In addition to a general trip report, this survey should include a selection for any on-trail issues they encountered (downed trees, washed-out bridge, etc.) and the location of the issue (trail and region). This information could be routed to the ranger for the corresponding region, where they can address it if needed. Park management can also use this data to establish recurring issues to attend to or to analyze backcountry visitors' trip experiences. The data collected should also be presented online, after moderation or filtering, so that park visitors planning their trip can view up to date trail reports.

Recommendation 3: **Glacier should improve the design and layout of their current website's trail status page.**

Within Glacier's current website trail status page, some small changes to the layout and page format would make trail reports much more useful to visitors. When looking over each report quickly, it would be helpful to have the red bullet points only for closed trail sections, as well as the word "CLOSED" changed to bold red text. Similarly, for open trails, this square bullet point would be made green for each corresponding trail segment. In addition to text, symbols for common issues (such as bears, downed trees, or bridge construction) would help quickly highlight safety issues for viewers. An example that incorporates these recommendations to the current trail status reports is shown in **Figure 25**. While these will help convey the information more effectively, our group also recommends adding a filter and search bar feature to allow visitors to quickly identify the status of a particular trail.

Gunsight Pass Trail

■ **Gunsight Lake to Gunsight Pass/ 3.0 mi.**

🐻 Trail POSTED for bear frequenting 8/5/2020 per 623

Projected initial clearing date: 7/24/2020 per 650 ✔

Gunsight Lake Suspension Bridge: INSTALLED 6/29/2020 per 650 ⚠

Removed 9/28/2020 per 650 High angle and dangerous snowfields present between Gunsight Lake and Gunsight Pass.

❄ ⚠ The pass has one remaining high angle snowfield with a dangerous run out. Highly recommend proper equipment/training/experience if you intend to cross this snowfield. 7/19/2020 per 623

Beaver Pond Trail (behind 1913 Ranger Station)

■ **1913 Ranger Station to Red Eagle Trail / 1.2 mi.**

CLOSED as part of general east side closure due to pandemic. See park web site for map with latest area closure.

Projected clearing date: CLEARED 5/27/2020 per 650

Figure 25. Example of a modified trail report

5.2 Conclusion

The main components of our project were data collection, data analysis, and web application development. We collected data through an online survey and research on other digital resources including mobile hiking apps and hiking forums. Our analysis of the data highlighted problems with Glacier's website that complicates the process of planning a backcountry trip and applying for a permit. The online trail reporting system was also found to be difficult to use and lacks recent, detailed information. While Glacier's website has an interactive map, a feature desired by most backpackers in our survey, the map lacks any information besides permit center locations.

Our web application was designed to address these issues by guiding hikers through all the tasks for planning a trip and acquiring a permit. Information pertinent to backcountry hiking was consolidated into concise web pages, which contain all the necessary information as well as hyperlinks to additional resources. We implemented a checklist to help users track their progress through our site and through the planning and permitting processes. Our interactive map was created on top of ArcGIS software and includes detailed park regions, trails, campgrounds, points of interest, elevation profiles, and the ability to combine trails into a larger trip. Additionally, we included a model post-hike survey to gain insight into the state of the trails and visitor experiences.

For our web application to be useful in the long-term it would require extended maintenance. Instead, we recommend that Glacier develops a mobile application based on our

functional model with the inclusion of important mobile-specific features such as downloadable interactive maps. In the meantime, the park can make tangible improvements by authoring and distributing a post-hike survey to collect recent trail information from visitors, as well as updating the design and layout of their trail status page.

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Appendices

Appendix A: Online Survey of Backcountry Hikers

Note: Some questions will only be displayed to respondents according to their answers on previous questions, such as the length of their backpacking trip in Glacier only if they have been backpacking there.

Our team is designing a mobile application to aid with planning a backcountry hiking trip, and want to determine what features and content is important to potential users.

In this survey backcountry hiking is defined as the use of remote trails beyond the popular day hikes in a park. Backcountry hiking includes carrying your supplies in a backpack and camping in isolated and undeveloped areas for consecutive days.

How much experience do you have with backcountry hiking?

○ None
○ A little
○ A moderate amount
○ A lot
○ Very experienced
○ Not sure/Prefer not to answer

Select all the platforms/methods you use to plan a backcountry hiking trip

☐ Mobile Applications
☐ Websites
☐ Books
☐ Physical Maps
☐ Other [_____]

What top 3 features in mobile applications do you use most to plan a backcountry hiking trip?

[_____]

Please select all the features that you already use (and would continue using) in mobile applications.

- ☐ Downloadable Maps
- ☐ Interactive Maps
- ☐ Route planning/saving
- ☐ Social Platform/Media Sharing
- ☐ National Park information
- ☐ Safety Information
- ☐ Other [_____]

Is there something you feel mobile applications are missing for backcountry trip planning?

- ○ Yes [_____]
- ○ No

Please rate the following features on their level of importance in a backcountry hiking planning app.

	Very important	Important	Slightly important	Not important	Would not want this feature
Downloadable Maps	○	○	○	○	○
Interactive Maps	○	○	○	○	○
Route planning/saving	○	○	○	○	○
Social Platform/Media Sharing	○	○	○	○	○
National Park Information	○	○	○	○	○
Safety Information	○	○	○	○	○
Other [_____]	○	○	○	○	○
Other [_____]	○	○	○	○	○

How likely are you to install a backcountry hiking planning app with the features you rated as slightly important, important, or very important?

- ○ Extremely likely
- ○ Somewhat likely
- ○ Not sure
- ○ Somewhat unlikely
- ○ Extremely unlikely

How do you learn about trails before hiking them?

- ☐ Published Trail Guides
- ☐ Online Articles
- ☐ Mobile Apps
- ☐ Word of Mouth
- ☐ Other [   ]

How much do you value reviews from:

	Highly Valued	Valued	Somewhat Valued	Slightly Valued	Unimportant
Official Guides (eg. National Geographic)	○	○	○	○	○
Prominent Backpackers (eg. Andrew Skurka)	○	○	○	○	○
Individual Reviews (eg. User Reviews on AllTrails)	○	○	○	○	○

How do you share your trail experiences and reviews? (Please select all that apply)

- ☐ Mobile Apps
- ☐ Social Media
- ☐ Online Articles
- ☐ Word of Mouth
- ☐ Other [   ]

Have you ever gone backcountry hiking in Glacier National Park?

○ Yes

○ No

○ Not sure/Prefer not to answer

How many days was your trip?

How old are you?

○ 18-24

○ 25 - 34

○ 35 - 44

○ 45 - 54

○ 55 - 64

○ 65+

○ Prefer not to say

Appendix B: Survey and Research Questions

Survey Questions	Research Questions
Question 3	Objective 3 - What features do hikers find the most important in a planning application?
Question 4	Objective 3 - What are the features in currently available applications?
Question 5	Objective 3 - What planning features are missing from currently available applications?
Question 6	Objective 3 - What features do hikers find the most important in a planning application?
Question 7	Objective 3 - What features do hikers find the most important in a planning application?
Question 8	Objective 2 - How do hikers currently research trail guides and trip reviews?
Question 9	Objective 2 - How do hikers currently research trail guides and trip reviews?
Question 10	Objective 2 - How do hikers currently share their trip experiences?

Appendix C: Interview of GNP Geographer

- What is your role in the park?
- What projects are you involved in currently?
- What is it like to work in a National Park (and specifically in Glacier)?
- What is your experience with ArcGIS?
- We have access to all public files, are there any maps that could be useful that are not available publicly?
    a. Is it possible for us to access internal references?
- Are there maps containing backcountry campsites?
    a. How do you recommend we interface with these maps or datasets to apply it to our app?
- What data layers are most commonly used at Glacier?
- What applications and for what purpose does Glacier National Park currently apply GIS data layers?
- How is ArcGIS data updated/collected by GNP, and can we assist through our app?

Appendix D: Interview of Supervisor of the Backcountry Permits Program

- What is your main purpose as Supervisor of the Backcountry Permits Program?
- What are some of your job responsibilities?
- What is the purpose of only allowing about 50% of each site available in advance?
- Do you recommend visitors get an advance permit or a walk-in permit?
- Are there any interactive maps for planning a backcountry trip, or is the campground map What do visitors struggle with in the permitting process?
- What are some frequent questions from visitors trying to get a permit?
- What are the most common visitor mistakes you encounter in permit applications?
- Are there any flaws in the current permitting process or application system?
- to you, how could the permit process be improved from the administration side?

Appendix E: Application Comparison - Map Features

Map Feature Comparison					
Application	**Maps**	**Downloadable Maps**	**Waypoints/Layers**	**Elevation Profile**	**Notes**
AllTrails	Mapbox interactive map	Download GPX	Start, stop, custom, trails, campgrounds, and peaks	Elevation over mileage with grade	None
Gaia GPS	ESRI interactive map	Download GPX/KML and download National Geographic maps with premium	Trails, campgrounds, and peaks	Elevation over mileage with grade	Download offline maps with membership
Guthook Guides	Interactive map	Offline Maps with guide purchase	Start, stop, trails, trail crossings, campgrounds water, and roads	Total Acent, total decent, and elevation over mileage profile with waypoints	Layers are treated as waypoints and contain detailed discriptions/Reviews
Chimani	Mapbox interactive map	None	Trail head/start	None	Access to Glacier on Chimani Website - not available on android.
Hiking Project	Mapbox interactive map	Download GPX	Start, stop, directional arrows, trails, campgrounds, and peaks	Elevation over mileage with grade	None
National Park Trail Guide	Google interactive map	None	Start, stop, directional arrows, trails, and peaks	None- total ascent and decent given	None
ViewRanger	Google interactive map	None	Trails, start, stop, images, trail report/instructions, points of interest, and	Mobile application has elevation over distance profile	Create custom routes from GPX or from scratch
Topo Maps+	Interactive map	Downloadable GPX file or map within app- includes National Geographic maps	Trails, campgrounds, and custom	Elevation over mileage profile	App not available for androids
Avenza Maps	Geospacial PDF maps	National Geographic maps, National Parks Service maps, etc. Must purchase select guides	Trails and campgrounds	None	
Maplets	JPEG or PGN maps	Download maps directly to phone for local storage	Trails, campgrounds, pit toilets, peaks, and mile markers	None	

Appendix F: Application Comparison – Features

Feature and Content Comparison									
Application	Weather	Park Details	Glacier Hiking Trails	User Generated Routes	Trail Reviews	Record Hike	Offline	Subscription Cost	Notes
AllTrails	Four daily low-high, UV index, and sunrise/sunset	Brief overview of park/trails and individual trail descriptions	178 total routes	Users can create their own routes, but they are for personal use	Trail reviews and ratings written by hikers and display next to trail map	Pro Feature	Pro feature	$29.99 per year	
Gaia GPS	None	Brief overview of regions with links to NPS websites	191 total routes	Users can create their own routes by drawing along predefined trails. More options unlocked with premium	Trail reviews and ratings written by hikers and displayed below the trail map	Record elevation and speed	Membership feature	Membership: $17 per year Premium: $36 per year	
Guthook Guides	None	None	None	None	Social feed to follow other hikers. Comments left on waypoints	None	Included with guide	Varies by guide from $5 - $60	Purchase guides individually
Chimani	Sunset and sunrise included in perks program	Overview of Glacier, hiking, biking picnics, etc	67 total hiking trails	None	None	None	Included in chimani perks program	$29.99 per year or $99.99 lifetime purchase	Photo gallery
Hiking Project	Average monthly weather including precipitation and temp	Brief overview of Glacier, camping, tours, shuttles, etc	185 total routes	Routes added by hikers some tails are not listed ex: Gunsight Pass	Trail description shared by hikers, and can be edited by other users.	Record route with speed, elevation, and distance	View map and info	Free	Filter by trail type
NPS Trail Guide	Average monthly weather including precipitation and temp	Brief overview of Glacier, camping, tours, shuttles, etc	147 total routes	Routes added by hikers some tails are not listed	Trail description shared by hikers, and can be edited by other users.	None	View map and info	Free	Made by REI and hiking project - features are very similar to hiking project
ViewRanger	None	Minimal - only if specified in trail description	36 total routes	Users or organizations create all routes	Trail description shared by hikers, and reviews can be left by other hikers	Record tracks with speed, elevation, and distance	Select maps free offline others unlocked as premium feature	$19.99 per year	Track friends on hikes, autoplot routes, and AutoPlot
Topo Maps+	None	Included in select maps such as National Geographic Maps	Trails included in maps	Users can trace their own routes. Snap to trail and custom routes - pro feature	None	Record hikes with elevation, distance, and speed	Offline maps and GPS. Download by region	$47.99 per year	Does not support android devices
Avenza Maps	None	Select maps: Overview of region with short history, brief hiking description, backcountry safety overview, and summary of backcountry campground details	Trail in individual map downlaods and map bundles	None: professionally developed maps	None	Uses GPS to record route with elevation, speed, and distance	Offline services are included and use the device GPS to get current location	$29.99 per year plus cost of select maps	
Maplets	None	Brief overview of Glacier	Trails in individual map download	Users can upload maps they have made	None	None	GPS used to locate your position on certain maps - not all maps included	None	

Appendix G: Post Hike Survey Model

What route did you hike? (Briefly list major trail sections)

How would you rank your overall enjoyment of this hike?

Highlight from 0 stars (did
not enjoy) to 5 stars
(enjoyed greatly)   ☆ ☆ ☆ ☆ ☆

Did you encounter any hazards or obstacles?

○ Yes
○ No

What kind of hazards/obstacles were they? (briefly state what and where)

☐ Animal (aggressive bear @junction of St Mary Lake and Red Eagle Trail

☐ Trail (fallen tree @ about 1 mile into Loneman Lookout Trail)

Briefly describe general trail conditions

What was the weather like?

How would you rank the trails difficulty?

○ Extremely easy
○ Somewhat easy
○ Neither easy nor difficult
○ Somewhat difficult
○ Extremely difficult

How long did your trip take? (days/hours)

Do you have any pictures or brief videos that would help hikers prepare?

Drop files or click here to upload

Any other information that would be useful for others planning this hike?

Appendix H: Developers' Guide

Our developers' guide is a resource for future developers and discusses our code, server, and ArcGIS maps. Our website code can be found on our GitHub repository. It is open source under the Apache 2.0 license, so our work can be used freely by any project using that Apache 2.0 license. A future developer could clone or fork the repository to continue working with our resources. Our project can be run by creating a web server with our "www/" folder as the file directory. The project uses a Node JS server which can be run in the terminal from the "server/" folder using the command "node server/server.js". To use the server, the database must be initialized. This can be done by using the source file "init.sql". For our project, we were provisioned a WPI server and subdomain which has allowed us to run our web application on backcountry2020.wpi.edu. We were able to access this server via SSH and pull our updates from GitHub into the live server. We developed our project using VSCode, including its Live Server plugin to run a demo server. Furthermore, we used Git and ran the Node server through the Ubuntu terminal.

Our development process relied upon weekly planning meetings under the Scrum methodology. We would create a backlog of tasks to accomplish such as creating content, updating the interactive map, changing the layout and formatting, etc. We updated our progress in our daily meetings throughout the week. At the end of the week, we would demonstrate the progress to our team and often to our advisors to receive feedback. Another key piece of development was receiving feedback from friends external to the project who could review content, formatting, and ease of use. We used the Model View Controller design pattern to best separate the logic of the page. In our case: the model was the MySQL database and ArcGIS layers, the view was the HTML/CSS, and the controller was the JavaScript on both the client and server.

Our code could be grouped into three major sections: the basic web page content, the interactive map, and the database server. Aside from the interactive map, the web pages were created using HTML and CSS. There was a minimal amount of JavaScript used to store and update the landing page checklist. The ArcGIS interactive map was built using the template provided by Esri. There is HTML/CSS to provide formatting, but the main functionality was made using JavaScript code loaded through the Dojo loader. Lastly, the RESTful database server was made using Node JS and Express JS. The functionality was created in JavaScript which queried the MySQL database. Our data was stored as a User, based on an incrementing user ID number, and a Trip, based on the embedded ArcGIS Polyline geometry.

Finally, the interactive map was created using ArcGIS Online (AGOL). After receiving a license from WPI, we started with the basic topographic basemap provided by AGOL. Glacier National Park Geographer Richard Menicke provided trail and boundary layers, as well as data on campgrounds and points of interest. Our team added data from the Glacier National Park permitting map to the given campground information to create our final campground layer. Additionally, we removed points of interest data that were irrelevant to backcountry hiking. The campground and points of interest were uploaded to ArcGIS through the add layer by file option in the map viewer. After completing the campground and points of interest layers, we created a new polygon layer and added regions based on the Glacier National Park permitting map. Once all our layers were finalized, we created a new web map and added the layers. We adjusted visibility ranges, colors, symbols, and transparency to improve the map's appearance. The trail and boundary layers are available through Richard Menicke's profile. Finally, the hiking map, campground layer, points of interest layer, and region layer are available through Devon Poisson's profile.

For further information, contact us at gr-Backcountry2020@wpi.edu