Development of GPS-based Datasets for Navigation on the Sun Corridor Trail between Sedona and Williams, AZ

By Ross Bolesta

A Practicum Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geography

Northern Arizona University

Department of Geography, Planning and Recreation

March 2023

Committee Members:

Dr. Amanda Stan - *Associate Teaching Professor*, Northern Arizona University

Dr. Frank Vernon – *Assistant Professor of Practice,* Northern Arizona University

Cynthia Nemeth - *Parks & Recreation Director*, Coconino County

Table of Contents

Figures

Tables

1. Abstract

The Sun Corridor Trail (SCT) is a project led by several local, state, and federal agencies to connect existing roads and trails between Las Vegas, NV and Douglas, AZ for a cohesive multi-use experience, showcasing the beauty of the American Southwest. The Sun Corridor Trail Association (SCTA) aims to connect over 40 towns and cities along the trail, resulting in a boost in local economies through increased bike tourism. The SCTA hopes to diversify the biking community by having the SCT maintain a high degree of user comfort, stopping through a city, town, or community with access to food, water, and shelter every 30 to 40 miles. To support the goals of the SCTA, I compiled spatial data from existing sources and used GIS to develop a series of GPX files for northbound navigation on the SCT from Sedona, AZ to Williams, AZ. The GPX files contain important waypoint information such as route junctions, local attractions, convenience stores, local restaurant and food options, and lodging. Trail users can download and import the files onto a smartphone or GPS device to navigate the trail, allowing travelers and backcountry navigators of all experience levels to explore the SCT with confidence. My work sets the foundation for developing similar waypoint data for future route segments of the SCT.

2. Introduction

In the 1970's, a schoolteacher living in Flagstaff, AZ named Dale Shewalter had a vision to create a cross-state trail that would connect several climate zones and biomes in Arizona (Arizona Trail Association, n.d.). Dale walked from Nogales, AZ (on the southern border of Arizona) to the Utah state line to determine the possibility of developing a trail that ran from the northern to southern border of the state. Dale's passion led him to be hired by the Kaibab National Forest to lead the effort to develop and advocate for what is now the Arizona National Scenic Trail (AZT). Today, this trail attracts visitors from all over the world due to its diverse range of scenery and terrain. However, to hike the entirety of the AZT, termed 'thru-hiking', one must be comfortable with the task of isolated backcountry travel. The AZT contains many sections that require trail users to possess primitive backcountry navigation skills, move through unforgiving terrain, endure long distances without the guarantee of readily available freshwater and carry all basic human necessities. As public interest has grown in diversifying the outdoor recreation community in recent years, the need for a long-distance trail that is suitable for both novice and experienced backcountry travelers is higher than ever (Gress & Hall, 2017). The Sun Corridor Trail (SCT) is a proposed trail that has the potential to meet these needs as well as providing a plethora of benefits to both small communities and large urban centers.

The initial stages of developing the SCT began in the early 2010s by several individuals working for Maricopa County Parks and Recreation during brainstorming sessions (Czinar, 2021). It began as a vision to connect the Maricopa Trail with the Tribute Trail, two well-established urban loop trails in Phoenix and Tucson, respectively. As discussions continued, the idea was developed further with interest in the trail starting in Douglas, AZ and ending in Las Vegas, NV, connecting existing primitive roads, trails, and paths rather than primarily building

new trails (Anderson et al., 2021). Due to the length and diverse ownerships in land between trail segments, the development of the SCT is a collaboration between several city, county, state and federal land management agencies between Nevada, California, and Arizona. The nature of connecting these existing routes makes the development of the SCT more economically viable due to having most of the trail infrastructure already in place. In addition, the creation of the SCT would have minimal environmental impact by primarily containing human traffic in areas that are already designed for travel and recreation.

The Sun Corridor Trail Alliance (SCTA) has a vision to "connect communities, further economic development, and nature-based tourism opportunities, while enhancing quality of life on a regional scale" through the creation of the trail (Anderson et al., 2021). They hope to accomplish this by meeting the following basic criteria for all route segments:

- Prioritize the use of pre-existing roads, trails, and paths
- Run through a city, town, or community with access to food, water and shelter every 30 to 40 miles
- Maintain consistent surface terrain suitable for a gravel bike, which is a no-suspension hybrid between a road bike and a mountain bike
- Maintain a consistent and relatively low level of difficulty in both trail difficulty and logistical planning
- Highlight aesthetics in both city and rural settings
- Prioritize trail segments on public lands
- Fulfill the desires of both novice and experienced trail users

This trail plans on connecting both small towns and large urban centers by utilizing the established urban trail systems in Las Vegas, Flagstaff, Sedona, Prescott, Phoenix, and Tucson as a framework for the trail. As route segments are pieced together between these larger urban hubs, the SCTA plans on having the SCT run through lower-income communities that do not have a strong tourism infrastructure (Anderson et al., 2021). This allows trail users to recognize and celebrate the differences in cultures between each community that the trail passes through. Additionally, these smaller communities could benefit from an economic boost that would come from increased bike tourism (Bowker et al., 2017).

3. Background

3.1 COVID-19 and Biking

At the start of the coronavirus pandemic, many individuals were required to social distance by staying at home and not visiting public spaces. In large cities, many rely on public transportation such as trains, subways, and buses to commute to work. However, it became unsafe to use mass public transportation due to overcrowding and the inability to socially distance (Lindsey, 2021). Many people who didn't own cars were searching for ways to commute and turned to biking as the answer.

In April of 2020, shortly after the pandemic began, biking activity increased by over 150% in large urban hubs in the United States, United Kingdom, China, Ireland, and Germany (Schwedhelm et al., 2020). As vehicle traffic decreased, biking became more attractive to the average commuter (Lindsey, 2021). Due to this increased demand in cycling, many urban areas opened emergency bike lanes to meet the demand. The City Bike service, which is a pay-and-go bike-sharing service in New York city, saw a 67% increase in demand for their services starting in March 2020 (Schwedhelm et al., 2020). Philadelphia saw a 470% increase in bike traffic on some of their more popular urban trails (Schwedhelm et al., 2020). Additionally, people of all ages have become more interested in biking since the pandemic began. The United States experienced a 56% increase in children's bike sales and a 121% increase in adult leisure bikes (The NPD Group 2020).

In addition to the increase in bike sales and commuting traffic, biking also provided a lifeline to many during the pandemic as many individuals developed mental health issues during this time (Ufnalska, 2020). Physical activity became harder, especially for those who had an established workout routine indoors. Biking is an attractive alternative to many, as it ensures

COVID-safe precautions by nature. If someone is biking in a social setting, they are likely to be at least six feet away from another biker, which meets the standard social distancing recommendations. In addition, physical activity outdoors presents a lower risk of contracting any illness compared to indoors (Ufnalska, 2020). The biking community grew stronger during the COVID-19 pandemic, which was shown through increased activity on fitness-tracking smartphone applications (Byers 2021; Curry 2021).

3.2 Fitness Tracking Applications and Bike Culture

The modern culture surrounding many outdoor exercise activities such as biking, running, and hiking revolve around fitness and route-tracking applications. One of the most popular applications is Strava, which is used for both navigation and fitness tracking. The popularity of Strava grew immensely since the COVID-19 pandemic began. Strava had around 55 million users at the end of 2020, and grew to 76 million in March 2021 and 95 million by December of that year (Byers 2021; Curry 2021). The increased activity in biking was also shown through activity on Strava. Users can record their runs, bike rides, hikes and more and publish their 'activities' to their Strava profiles for others to see. Strava recorded a total of over 1.8 billion activities as of December 2021, marking a 38% increase from 2020 (Byers 2021). Strava has a social component to the application, where users can follow each other, compete on certain routes, and give 'kudos' to others for their tracked activities. The social component of Strava has been shown to maintain user activity compared to other route-tracking applications (Straiger et al., 2016).

Route-tracking applications can also be used for research purposes. Korpilo et al. (2016) tracked the density of mountain bikers in a popular urban forest in Helsinki, Finland. All the data

used for the study was crowdsourced and free of charge since the data was readily available over the internet. The user agreements of many of these applications states that the data stored and recorded on the app can be accessed by others. This results in crowdsourced data that is relatively free of user-generated bias, as many of the users that generate this data are not aware that it is being used for research purposes. All the tracked routes from Strava users can be accessed and downloaded as GPX files.

3.2.1 GPX File Format

One of the most universal file types used for route-tracking and navigation purposes on both personal smartphones and GPS devices is the GPS Exchange Format (GPX) file format. This file type was created in 2002 with the goal of being a universal file format for recording, exchanging, and manipulating location-based data between several mediums (Foster, n.d.). GPX files are written in an extensible markup language (XML), which is a programming interface that allows users to define their own tags. The universal nature of the XML format allows GPX files to be transferable among all common operating systems, such as Windows, MacOS and Linux (Foster, n.d.). These files can also be transferred between personal computers, smartphone applications and personal GPS units without warping or losing any data. All GPX files are stored in a World Geodetic System 1984 (WGS 84) datum, which is a universal geographic coordinate system used in most global positioning systems (GPS, Hazzard, n.d.). GPX files are also supported by almost all mapping software packages such as ArcGIS Pro and QGIS as well as recreation and navigation-based applications such as BaseCamp from Garmin. The files generated from this project will be in GPX format due to its universal applicability.

3.3 Smartphone Guides for Long Distance Trails

Long-distance trail travel has skyrocketed in popularity in the last 20 years. The Appalachian Trail (AT) has reports of nearly 20,000 people finishing at least 2,000 miles of the trail as of 2019, but about 14,000 of those hikes have been reported since 2000 (Rogers & Leung, 2020). Similarly, the Pacific Crest Trail Association saw a spike in permit allocations from 1,879 in 2013 to 4,453 in 2015 (Dustin et al., 2019). Due to the biking surge from COVID-19, popularity in long-distance bike touring is also likely to increase along with the general boom in outdoor recreation (Nudelman, 2022). And, as technology has changed throughout the years, individuals traveling long-distance trails are starting to rely more on smartphones than paper maps (Rogers & Leung, 2020; Dustin et al., 2019; Gee, 2019). One smartphone application that is popular amongst thru-hikers is FarOut Guides (formally Guthook).

FarOut Guides started in 2010 when co-founders Paul Bodnar and Ryan Linn met while thru-hiking the Pacific Crest Trail (PCT). The idea of FarOut Guides is to combine maps, compasses, guides and water reports into an intuitive, multi-use smartphone application for long-distance trail travelers. This is done by combining a network of digital backcountry trail maps as well as a feature that allows trail users to input data on water availability, trail conditions, and amenities such as convenience stores and restaurants. The result is an up-to-date system of trails as well as information on the status of water sources and trail conditions, which can enhance the confidence of users. Since its first release of the PCT guide for iOS users in 2012, the app has grown in popularity in the thru-hiking community (Gee, 2019). From 2016 to 2019, the FarOut Guides smartphone application was downloaded over 300,000 times. (Gee, 2019). In 2021, a survey of 654 PCT thru-hikers found that 84.3% of them used the PCT FarOut Guide during their hike (Mac, 2022).

As the SCTA focuses on diversifying the outdoor recreation community and increasing access to the outdoors, the creation of GPX files for navigation on the SCT would be beneficial. Publishing a guide for sections of the SCT that are futher along in the planning process could increase public awareness and interest in the SCT at an early stage, which may expedite the process of formal completion of this trail and potentially increase funding.

3.4 Previous Work

The majority of this project serves as an expansion of work completed by Adam Smath, a Northern Arizona University (NAU) alumnus who developed their practicum project working with the SCT. Smath's project (Smath, 2021) focused on field testing a variety of roads to help recommend a route for two sections of the SCT: Sedona, AZ to Flagstaff, AZ and Flagstaff, AZ to Williams, AZ. Adam tested roads using a gravel bike, which is a no-suspension hybrid between a road bike and mountain bike. The SCTA proposes that the entirety of the SCT can be traveled via gravel bike, so Adam's goal was to fully complete the two sections utilizing roads suitable for this. The main framework surrounding Adam's testing is the USFS-designated Road Maintenance Level (Apodaca et al., 2012), a system which breaks road conditions into five categories:

- **Road Maintenance Level 5** - High degree of user comfort (typically paved, double-lane and mostly free of surface aggregate.

- **Road Maintenance Level 4** - Moderate degree of user comfort (typically paved or aggregate surfaced, double, or single lane with a consistent surface texture).

- **Road Maintenance Level 3** - Suitable for passenger cars (typically has potholes, wash boarding, low to moderate traffic and single lanes).

- **Road Maintenance Level 2** - Suitable for high-clearance vehicles (Fairly rocky with few warning signs of conditions and no consideration for surface smoothness).

- **Road Maintenance Level 1** - Closed/Unmapped roads (Motor vehicle traffic prohibited, barriers in place, used for emergencies).

Figure 1: Roads field tested by Adam Smath (Smath, 2021)

Smath (2021) biked several suitable roads and took detailed notes on terrain, difficulty, scenery and aesthetic value. His rides were recorded on a smartphone using the Strava application, which was then brought into ArcGIS Pro to match up with USFS road data. Based on his testing, Adam created a route recommendation from Sedona to Flagstaff and from Flagstaff to Williams. The recommendations involved a detailed description of the route, photos from field testing, and a final route recommendation map (see Figure 2).

Figure 2: Adam Smath's final route recommendation (Smath, 2021)

3.5 Project Overview

In this project, I developed series of GPX files for northbound navigation on the SCT from Sedona, AZ to Williams, AZ. To accomplish this, I completed three specific tasks:

1. I compiled spatial data from existing sources and used GIS to create a complete route line between Sedona, AZ and Williams, AZ, using the route recommended by Smath (2021).

2. I updated the route recommendation of Smath (2021) by creating a new route section through the City of Flagstaff, which had not been previously developed.

3. I developed a series of nine waypoint classes including, but not limited to route junctions, amenities, and attractions, with an emphasis on local businesses and applied a set of

inclusion/exclusion criteria to reduce redundancy and maintain consistency in waypoint inclusion.

The GPX files were broken down into what will be referred to as Section 1 (Sedona, AZ to Flagstaff, AZ) and Section 2 (Flagstaff, AZ to Williams, AZ). Since the majority of the SCT will utilize existing roads and trails, several geographic information systems (GIS) datasets needed to be sourced that contained the specific roads and trails used on the SCT. This data was stored and manipulated using Esri's ArcGIS Pro 3.0.1 software, that is the industry standard amongst GIS work. Since datasets of this type are often large and contain hundreds or thousands of entries, queries were used to select specific paths while the non-utilized paths were eliminated from the dataset. The roads then needed to be edited to match the specific portion utilized for the trail, further eliminating unused route sections.

To make the GPX files useful for trail users, especially those who plan to complete this SCT section in entirety, several types of waypoint information needed to be created to assist the trail user in navigating the road/trails as well as locating amenities and attractions. All waypoints were created from scratch, utilizing coordinate data from Google Maps. All spatial data created in ArcGIS Pro was exported as GPX files, that were then merged, edited and refined for on-trail use.

Although the GPX files contained all information necessary to navigate on the SCT between Sedona, AZ and Williams, AZ, files in this format do not always transfer to GPS applications in an optimal way. Because of this, I recreated both of the Section 1 and Section 2 files specifically for use in Ride With GPS, which is a popular web-based and smartphone application used for bike navigation.

4. Methods & Results

4.1 Route File Creation & Results

4.1.1 Data Acquisition and Framework

The SCT will consist mainly of preexisting roads and trails, so a variety of GIS data was collected to build a route map. The following table shows the three main datasets that were used to extract the actual route segment.

Table 1: Datasets sourced for route file creation

Dataset Name	Description	Source	Feature Type	Use Case
All Roads Network 2021	All roads contained in the state of Arizona from the City to National level (excluding many roads owned by the USFS)	AZGeo Data (Arizona Dept. of Transportation)	Line	Used to gather roads within the City of Flagstaff that the SCT proposes to travel on.
Road	Roads within the Southwestern Region USFS lands planned and managed for motor vehicle access including State roads, county roads, private roads, permitted roads, and Forest Service roads.	FSGeodata Clearinghouse (Forest Service)	Line	Used to gather all roads Forest Service and national roads that the SCT proposes to travel on.
FUTS Trails	A network of all trails that are part of the Flagstaff Urban Trail System (FUTS)	ArcGIS Online Portal (City of Flagstaff)	Line	Used to gather urban trails in Flagstaff that the SCT proposes to travel on.

When combined, these datasets Smath (2021) field tested for their practicum project as well as my route recomendation through the City of Flagstaff. 'All Roads Network 2021' and 'Road' were both downloaded from AZGeo Data ArcGIS Online Portal and FSGeoData, respectively. The 'FUTS Trails' feature layer was imported directly from the ArcGIS Online portal within ArcGIS Pro. All datasets are open-source and free to use and manipulate. The

process of creating the route line started with loading each of the datasets outlined in **Table 1**

and shown in **Figures 4-6** into ArcGIS Pro. Each dataset was reprojected using the Project

geoprocessing tool and was put into a WGS 1984

geographic coordinate system to match the accuracy of

GPX files. This tool produces a new dataset with the

desired projection. From here, each dataset was retitled to

a more intuitive name, then imported into a new file

geodatabase titled 'InitialDatasets' for further

manipulation.

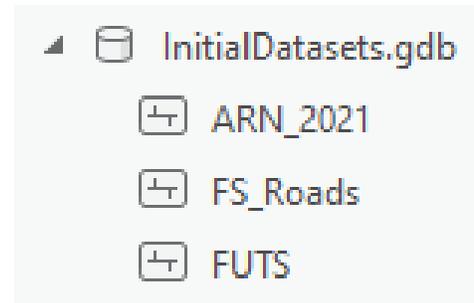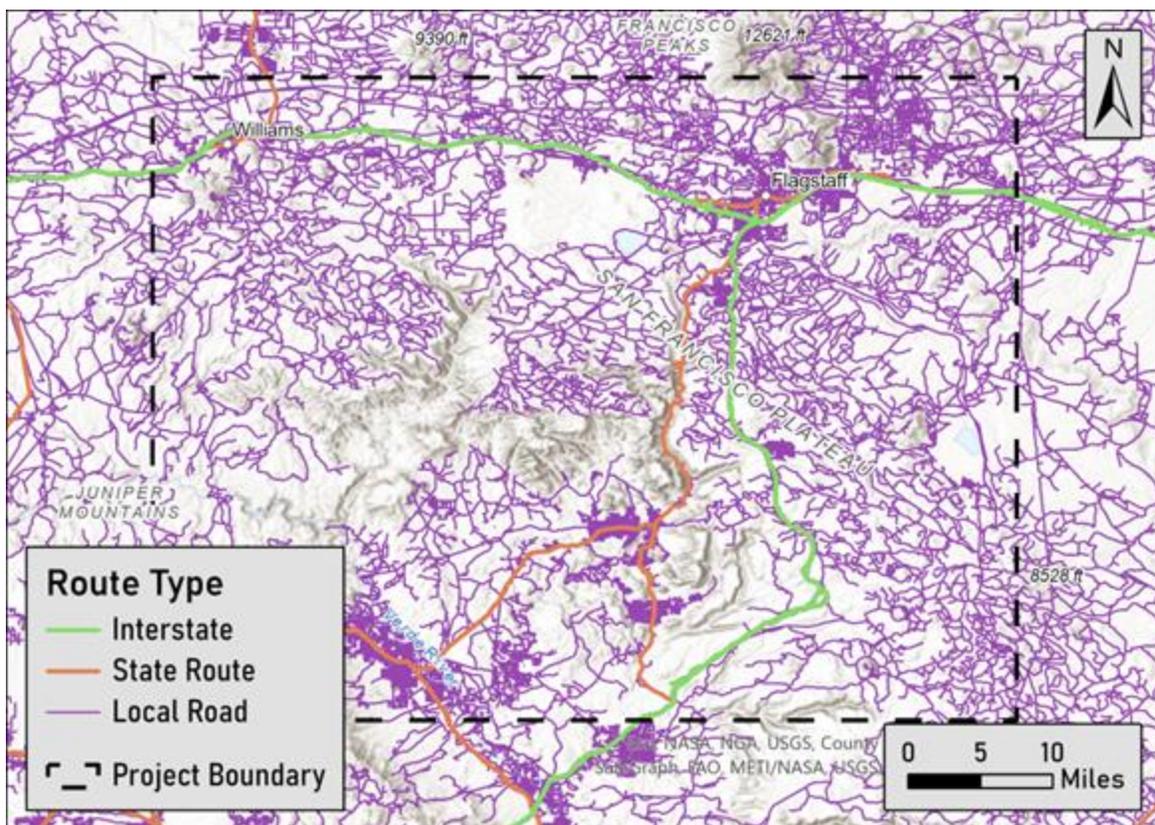*Figure 3: Renaming initial datasets.*

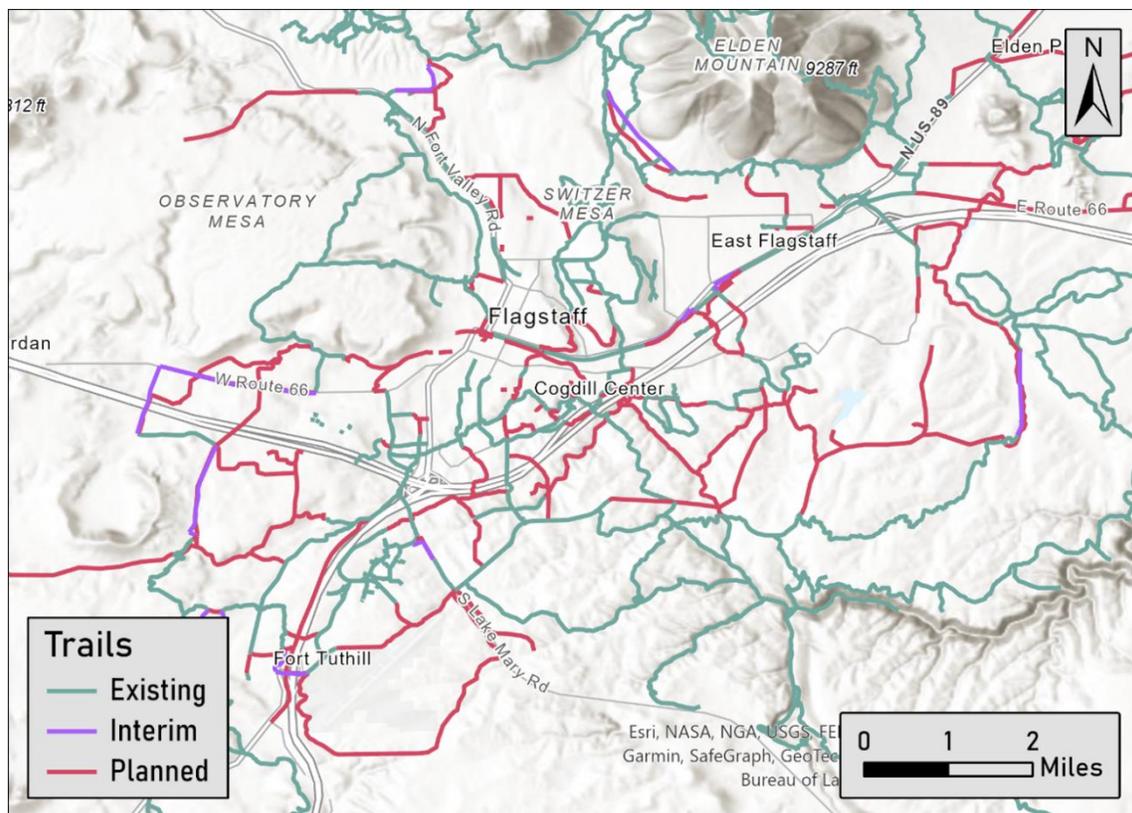*Figure 4: All Roads Network 2021 dataset symbolized by route type.*

Figure 5: *Flagstaff Urban Trail System symbolized by status.*
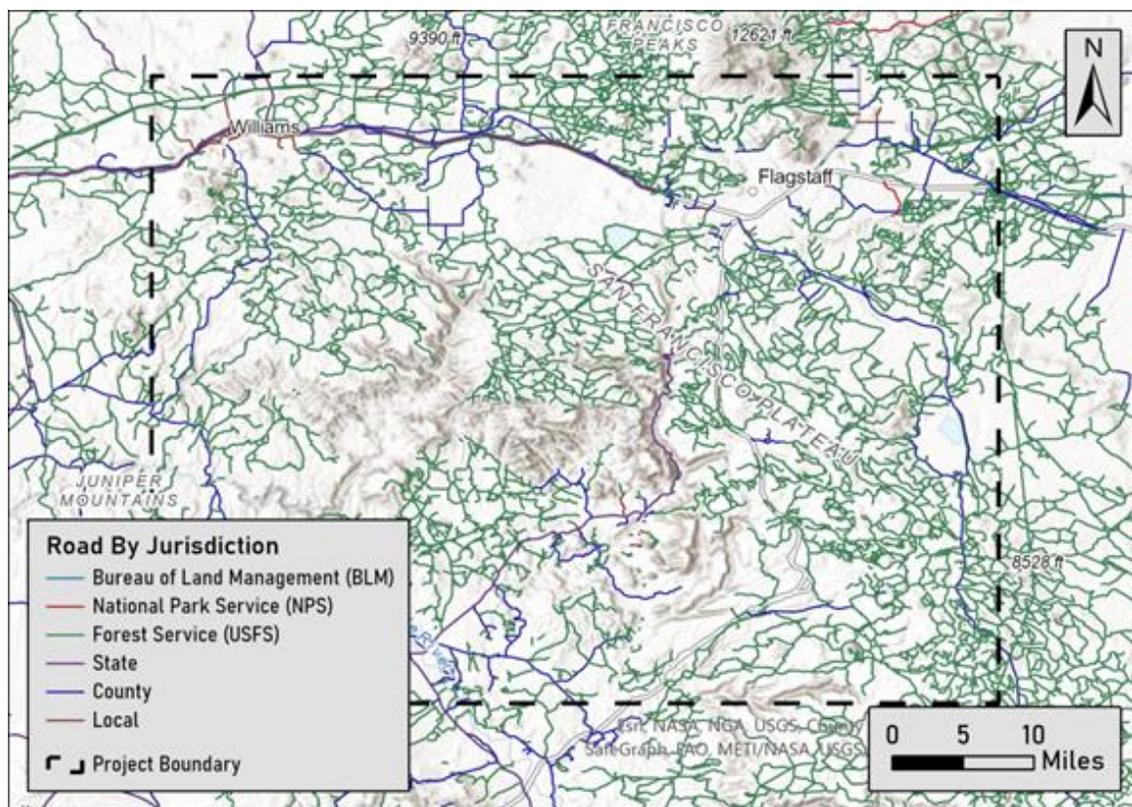
Figure 6: *Federal roads dataset symbolized by jurisdiction.*

4.1.2 City of Flagstaff Route Recommendation

The SCT route I describe in this project is based on the route recommended by Smath (2021), which was broken into two sections: Sedona to Flagstaff and Flagstaff to Williams. However, Smath (2021) does not suggest a route through the City of Flagstaff, which would ultimately connect both sections. In order to map a continuous route from Sedona to Williams, a route through the City of Flagstaff needed to be developed.

The recommended route for this section begins at the end of Smath's (2021) Sedona to Flagstaff recommended route, at the intersection of Lake Mary Rd. and J.W Powell Rd. This route enters Lake Mary Trail; this northwest parallel to Lake Mary Rd. Lake Mary Trail is travelled for about 0.4 miles until reaching the Chevron gas station, which is the first location to access food and water since Mormon Lake Village. From here, the trail moves onto the dedicated bike lane on Lake Mary Rd for about a quarter mile, then briefly turns left onto S Nicholas Street before reaching another paved bike path on the right called the Ponderosa Trail. Ponderosa Trail moves northwest for another half mile, which passes under I-17 and reaches Beulah Boulevard. The crosswalk is taken that runs perpendicular to Beulah Boulevard (continuing straight), then the second crosswalk is taken that runs perpendicular to W University Heights Drive.

The route then enters the Sinclair Wash Trail, offering impressive views of the San Francisco Peaks. The Sinclair Wash Trail is travelled northwest for 0.3 miles until it crosses over S Woodlands Village Boulevard, allowing trail users to access multiple grocery stores and restaurants directly off the trail to the west. Once crossing S Woodlands Village Boulevard and travelling for 0.2 miles, the route crosses W McConnell Drive to the north and S Beulah Boulevard to the west, both using crosswalks, to continue west on the Sinclair Wash Trail. The route then enters the southern portion of the NAU campus and travels west for about 0.75 miles

until turning left onto the San Francisco Trail. This portion of the route offers beautiful views and shade along Sinclair Wash with access to a Starbucks and the South Quad immediately to the south, making this a great rest spot for trail users. The San Francisco Trail is then travelled north for about 0.6 miles until reaching the northern border of the NAU campus. There is a short climb that offers breathtaking views of the peaks, which descends into north campus with access to the NAU Bookstore and the Health and Learning Center with several food options. The San Francisco Trail ends at the intersection of S San Francisco Street and Franklin Avenue.

From here, trail users will transition north onto S San Francisco Street for about a half mile, crossing Butler Avenue. This portion of the route enters Flagstaff's Southside district with several iconic bars, breweries, and cafes directly on-route as well as the Flagstaff Visitor Center. The route then crosses Old Route 66 onto N San Francisco Street, entering downtown Flagstaff. This area showcases several historic buildings, such as Hotel Monte Vista and the Weatherford Hotel along with a plethora of food, entertainment, and lodging options. N San Francisco Street is travelled for about 0.15 miles before turning left onto E Birch Avenue, which is travelled for about a quarter mile before reaching Wheeler Park to the south. Wheeler Park contains a large grassy area and shade making for another great rest spot for SCT users. Although there are 'share the road' ethics implemented, including signage and street markings, it should be noted that the portion of the route from S San Francisco Street until Wheeler Park does not contain dedicated bike lanes or paths. It is recommended that trail users dismount at the northern border of NAU campus and walk their bikes on dedicated sidewalks to avoid shared use roads should they feel the need to.

The route turns right onto the Karen Cooper Trail near the intersection of W Birch Avenue and N Kendrick Street, reentering the Flagstaff Urban Trail System. The Karen Cooper

Trail is travelled northwest for about 0.54 miles. This portion of the route travels through a shady corridor, crossing N Bonito Street at the crosswalk and continuing northwest. Here, the trail user will find Frances Short Pond to the right, which is a relaxing rest spot with benches and scenery. Directly north of the pond will be a trail fork, which continues left onto the Mars Hill Trail. Immediately after this fork is a left turn onto a paved portion of the trail, which is travelled for about 0.15 miles before reaching Thorpe Dog Park, connecting directly to the start of Smath's (2021) Flagstaff to Williams route recommendation.

      I recommend this route through the City of Flagstaff due to its high usage of the well-developed Flagstaff Urban Trail System as well as the route's direct access to amenities, local food, and entertainment. Although the route briefly travels through areas without a dedicated bike lane, the roads I chose are frequented by bike commuters with appropriate signage, warning drivers of shared lanes. These roads also feature some of the highest-rated eateries in the city as well as several culturally important buildings. This route recommendation aligns well with the goals of the SCTA and would certainly benefit the City of Flagstaff's tourism economy by highlighting local businesses via a downtown route section.

Mars Hill Trail
Karen Cooper Trail
Birch Ave.
Flagstaff
San Francisco St.
San Francisco Trail
89A
Cogdill Center
Northern Arizona University
E Route 66
E Butler Ave
Sinclair Wash Trail
89
W Kaibab Ln
W University Ave
W Route 66
W Kiltie Ln
staff Ranch olf Club
I-40
I-40
Ponderosa Trail
NF-532
89
E Zuni Dr
Pine Canyon
Lake Mary Trail
Thorpe Park

N

Esri, NASA, NGA, USGS, County of Yavapai, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

City of Flagstaff Route Recommendation
Smath's Route Recommendations

0   0.5   1 Miles

4.1.3 Queries & Data Removal

Figures 4-6 show how expansive the three datasets are. 'All Roads Network 2021' extends throughout the entire state of Arizona and the 'Road' dataset from the Forest Service covers most of the American Southwest. However, the SCT will only utilize a fraction of the roads and trails these datasets contain, so they were manipulated to remove extraneous roads and trails.

The process started with loading all three datasets onto a blank map from the InitialDatasets geodatabase, then projecting the map using a WGS 1984 datum. The Select by Attributes tool was opened and the 'FS_Roads' dataset was loaded in as the Input Rows parameter of the tool. From here, the process started by selecting specific roads (using the RTE_NO field) starting at US Route 179, marking the beginning of the SCT section. This process continued in the order of the
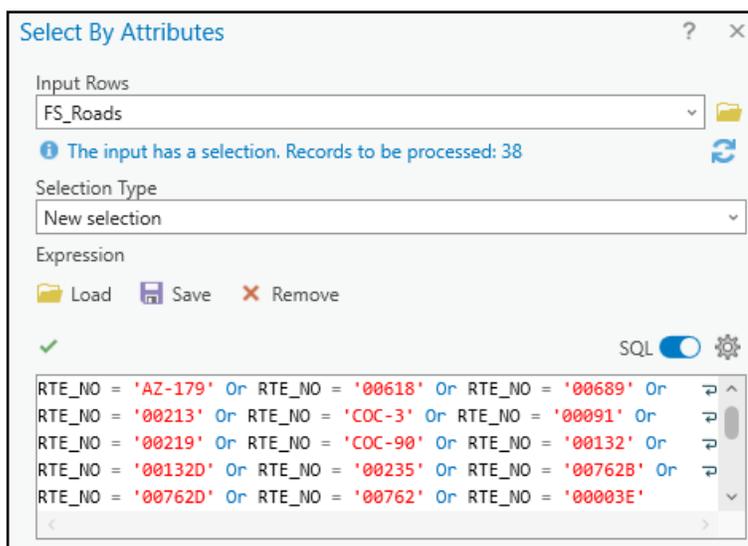
Figure 7: FS_Roads dataset query

northbound traveler (Figure 7). Smath's (2021) Sedona to Flagstaff route recommendation (pp. 34-36) was used to start this process. Smath (2021) describes in detail how the route moves from US Route 179 to Flagstaff and each of the roads he describes was selected using the Select by Attributes tool. Thirty-eight roads were selected from the FS_Roads dataset. Using the Export Features tool, the selected roads were exported as a new feature class titled 'FS_Roads_SedtoFlag', then imported into a new file geodatabase titled 'IntermediaryData'.

This process was repeated using Smath's (2021) Flagstaff to Williams route recommendation (pp. 44-47), starting from the western portion of the Flagstaff City limits in the Mars Hill area,

Figure 8: Intermediary datasets
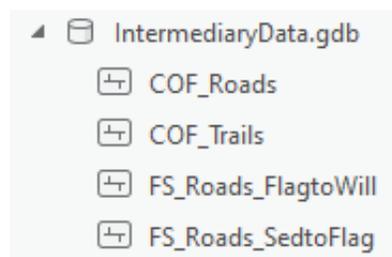
moving west into downtown Williams.

The City of Flagstaff route recommendation outlined in section 4.1.2 contains a combination of both roads and trails. To obtain the data necessary for this portion, the same query process was performed on both the ARN_2021 and FUTS datasets.

There are only three roads utilized in the City of Flagstaff portion of the route: S Nicholas Street, San Francisco Street and E Birch Avenue. The three roads were selected using the Select by Attributes tool, exported as a feature class titled 'COF_Roads', then imported into the IntermediaryData geodatabase. The FUTS dataset contains all trails that are part of the Flagstaff Urban Trail System but also includes planned trails that don't exist yet. Some of the planned portions are extensions of trails that already exist, so the query selecting these trails needed to reflect this. As performed in the previous queries, each trail outlined in section 4.1.2 was selected using an 'OR' operator. However, in order to only include trail portions that are existing, an 'AND' operator was nested between each 'OR' statement that selected the status of those trails to 'Existing'.
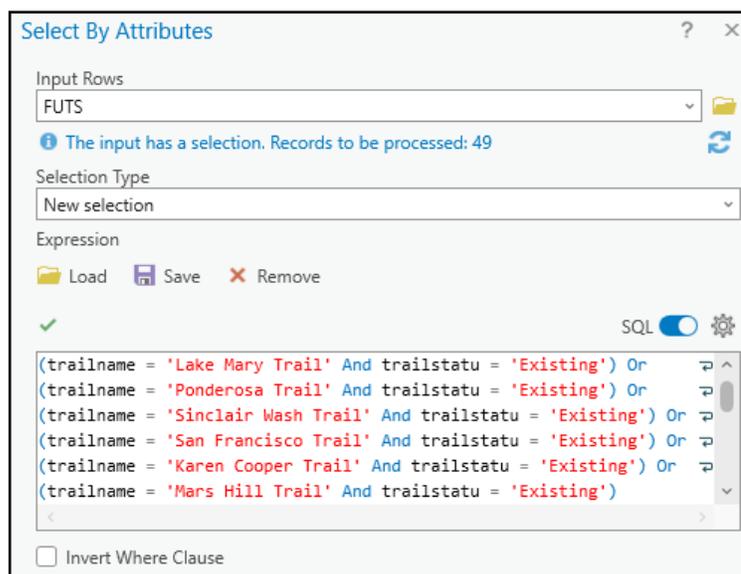

Figure 9: FUTS dataset query
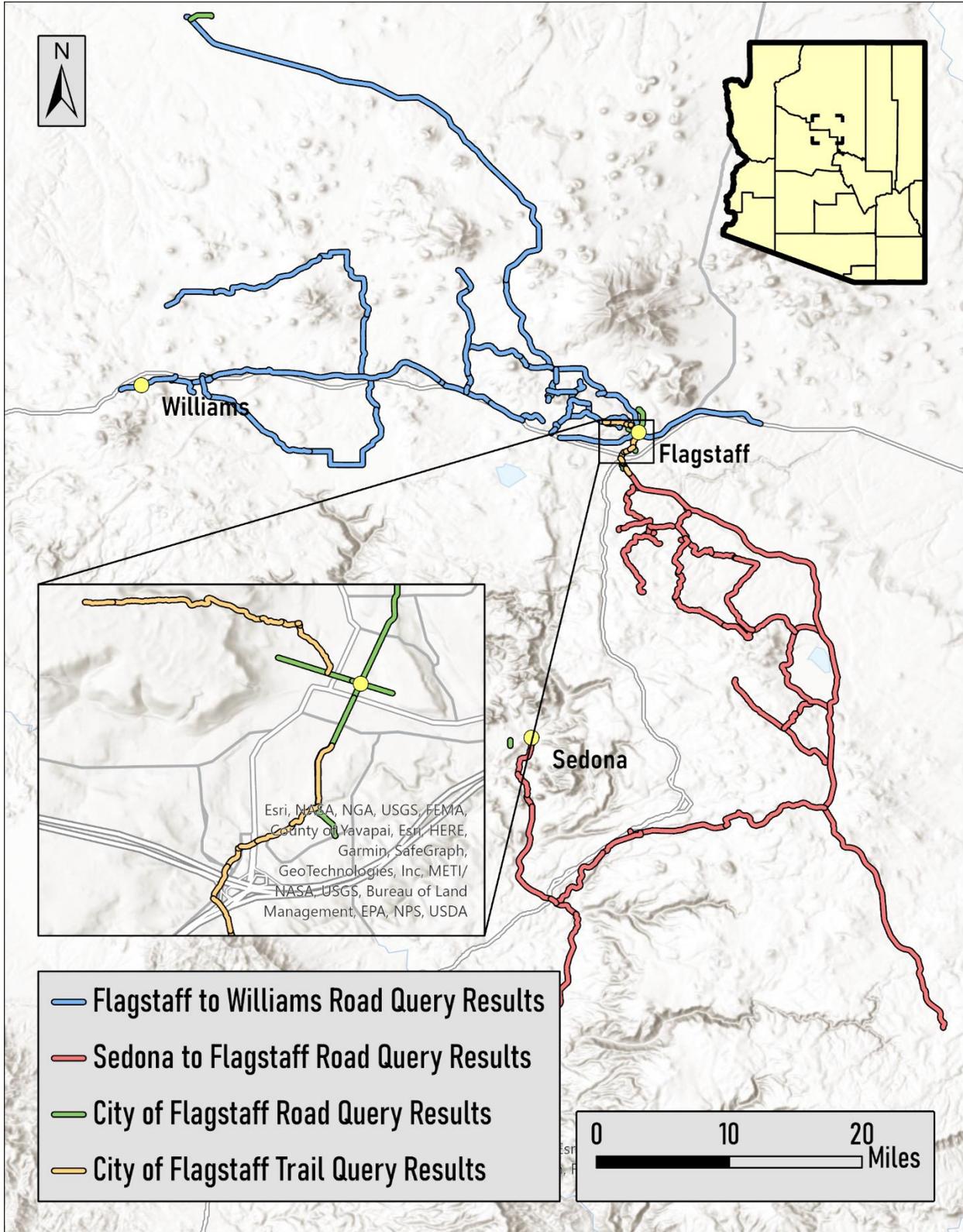
Figure 10: *Resulting datasets from all queries performed.*

4.1.4 Route Line Editing

The queries performed in the previous section selected the entire portion of each road the SCT travels on between Sedona and Williams. However, the SCT does not utilize the entirety of those roads, but rather a smaller portion; this is why Figure 10 shows extraneous road portions instead of a single, consolidated route line. Each of the datasets in the 'IntermediaryData' geodatabase needed to be manually edited to get rid of every section of road or trail that is not outlined in the overall route recommendation.

To maintain consistency, the process began at the southern terminus of this SCT section in downtown Sedona. The route line starts down US Route 179, eventually transitioning onto a dirt road called Beaver Creek Road. The route has the trail user turn left (northeast) onto Blue Grade Road, but Beaver Creek Road continues south (Figure 11). This portion of the road was still present in the FS_Roads_SedtoFlag feature class, so this layer was brought into the Editor ribbon for analysis.

The Editor ribbon contains a multitude of tools to modify feature class geometries. Since the line

Figure 11: Splitting road segment at vertex.

representing Beaver Creek Road extends beyond the turn onto Blue Grade Road, the Split tool was used to separate the line segment into two parts. With Vertex Snapping enabled, the line was split at the Beaver Creek Road/Blue Grade Road Junction. The portion of the line that was not

used for the SCT route was then deleted. Once again following the associated Route

Recommendation (Smath, 2021), this process continued following the route northbound.

There were several gaps that occurred in the data, resulting in blank sections between

route segments. The first instance of this occurred on Forest Service Road 235 in the Priest Draw

area (Figure 12). Although it is technically a continuation of the same road, this portion of the
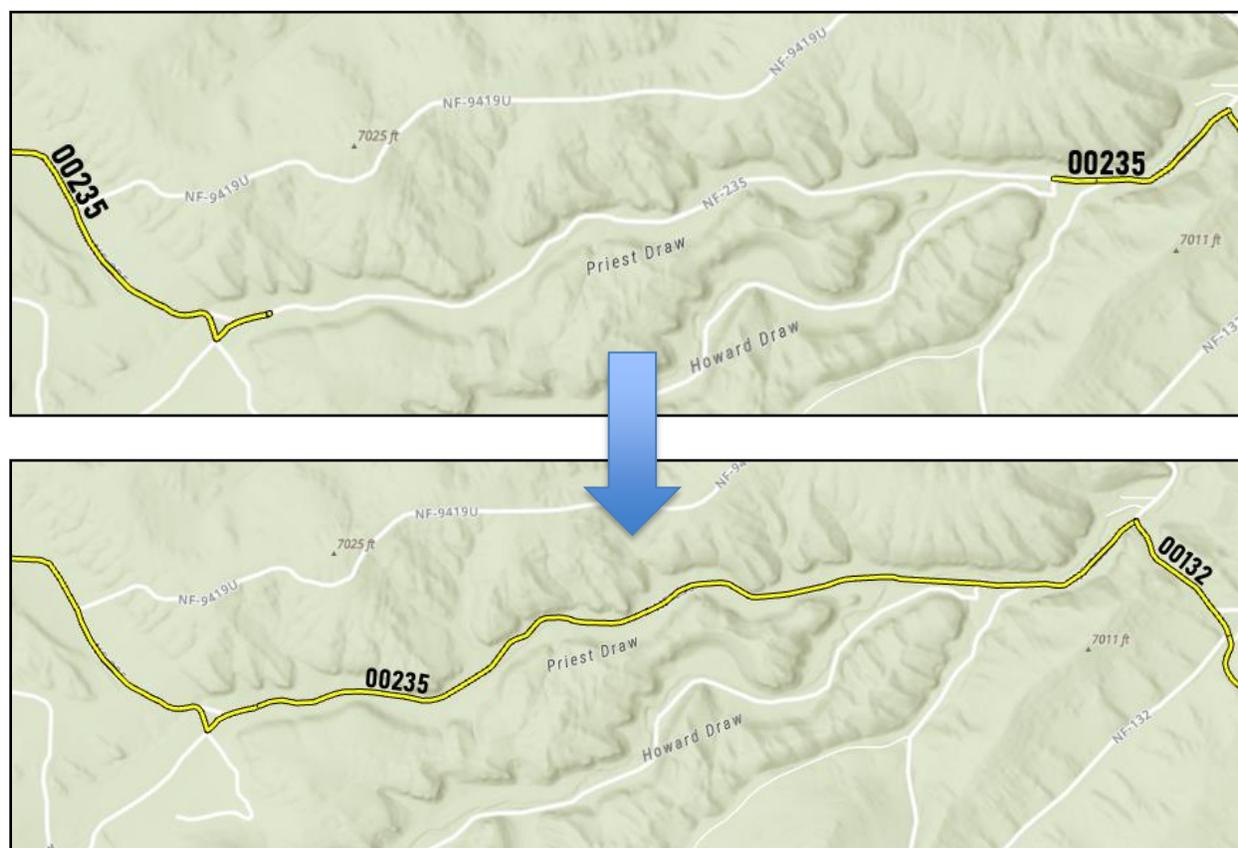
Figure 12: Extending Forest Service Road 235to fill in gap at Priest Draw

road transitions to a single-track trail, which is why it is not included in the data. Using the base

map with the road as reference, the route line was manually drawn from east to west using the

Line tool within the Create Features pane. With end snapping enabled, the line was seamlessly

drawn to connect both ends together. This also occurred on a short portion of Rudd Tank Road

just northwest of Flagstaff and the same process was repeated.

With each of the four layers from the IntermediaryData geodatabase properly edited, they all needed to be merged. At this point, there were still gaps between each dataset due to inconsistencies in topological connections between the COF_Trails, COF_Roads, FS_Roads_SedtoFlag and FS_Roads_FlagtoWill datasets. An example of a gap like this occurred where San Francisco Trail transitions onto S San Francisco Street (Figure 13). To fix these

Figure 13: Fixing gaps between different datasets.

gaps, the Edit Vertices tool was used in conjunction with End Snapping to create a seamless route line. Gaps like this occurred at most instances where the different datasets met, and each gap was fixed using the same process.

Once all gaps were fixed and the topology was correct throughout the entire route line, the Merge geoprocessing tool was used to merge all four datasets together (Figure 14). The result was a continuous route line connected by 76 different route segments. This would translate to many different connected route segments if converted to a GPX file at this state, so the Dissolve geoprocessing tool was used, which merged all the connected road and trail segments into a continuous route line (Figure 15). I exported the completed route line from Sedona to Williams as a feature class titled 'SCT_SW' in the 'SCTSegments' file geodatabase.
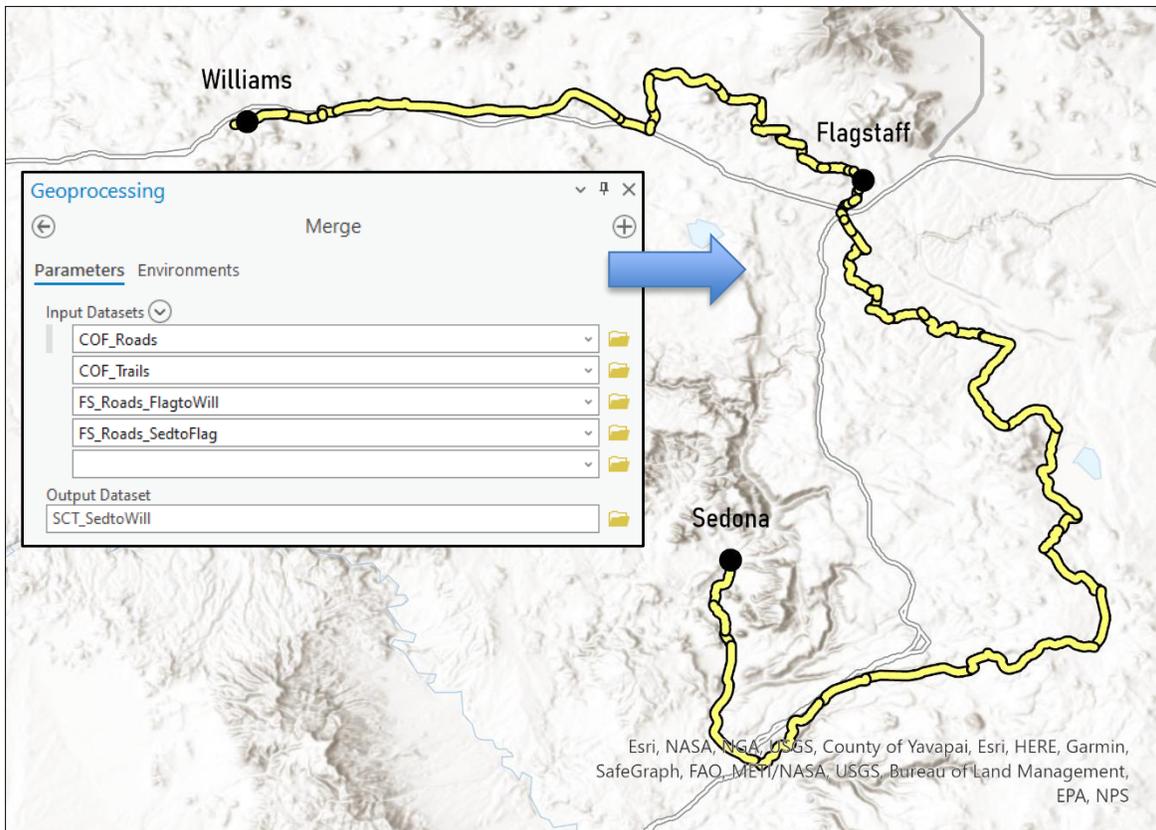
Figure 14: *Output from Merge tool*
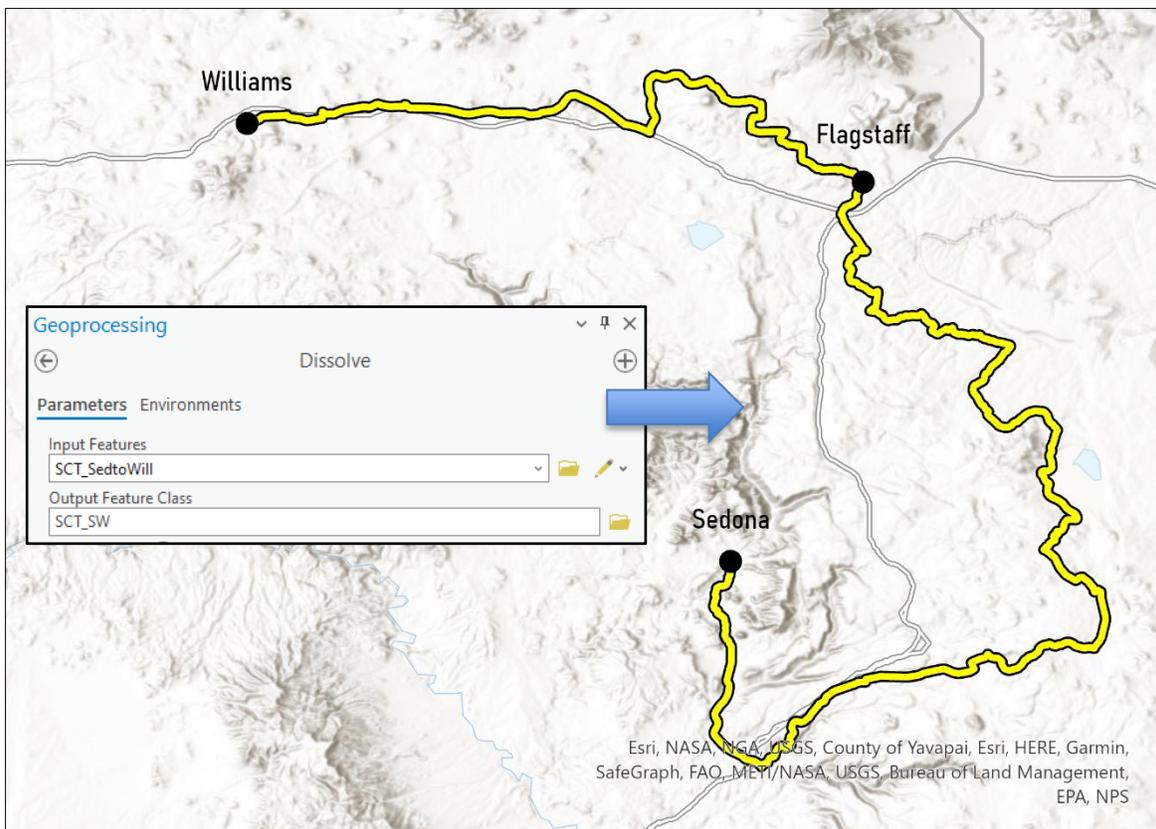
Figure 15: *Output from Dissolve tool*

As stated previously, this route line will be broken down into Section 1 (Sedona to Flagstaff) and Section 2 (Flagstaff to Williams). A copy of the 'SCT_SW' feature class was created and then split at the intersection of N San Francisco Street and E Birch Avenue using the Split tool, thus giving the SCT_SW dataset two parts. Each part was then selected and exported as their own feature class files named 'SCT_S1' (S1: Section 1) and 'SCT_S2' (S2: Section 2) respectively, then placed into the 'SCTSegments' file geodatabase.
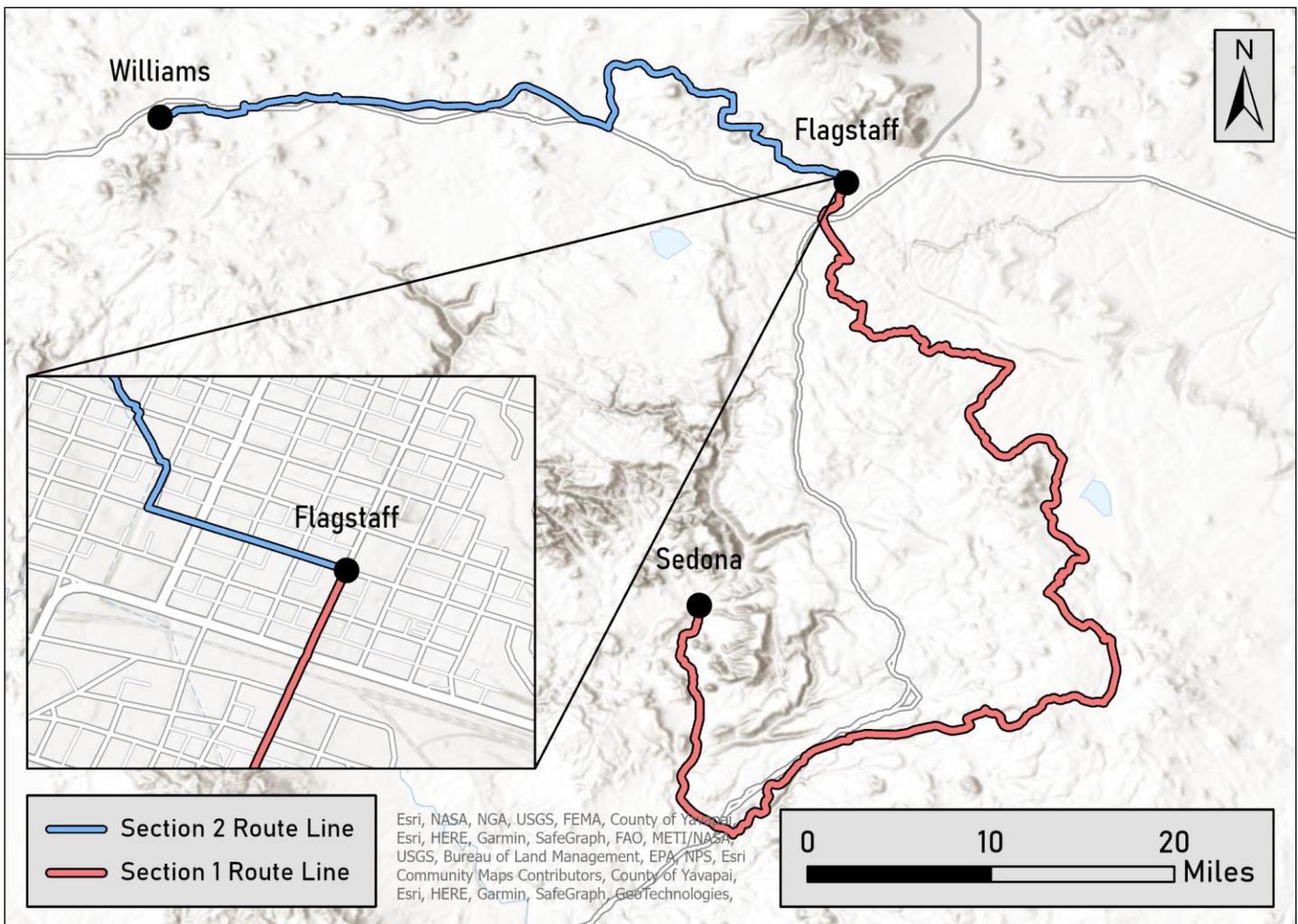
Figure 16: *Result from splitting SCT_SedtoWill -- SCT_S1 and SCT_S2 datasets*

4.2 Waypoint File Creation & Results

4.2.1 Data Acquisition, Creation & Framework

One of the main ways that users can feel safe and confident on-trail is for them to know exactly where to obtain basic amenities such as food, water, and shelter as well as locate highlights and attractions. As bikers use the route files for navigation, they will need additional information to know where to access those amenities. To fulfill this need, waypoints were created. Waypoints are a point based GPX file feature that represents a specific physical location connected to a coordinate pair. There are three main features associated with waypoints: coordinates, names, and descriptions. Each waypoint is associated with a latitude-longitude pair and like the route line, is stored using a WGS 1984 datum, which is standard amongst GPS-based use cases. Names represent the name or title of the location while the description field explains the location in more depth. To determine which specific locations are necessary and useful for the guide, a specific set of inclusion/exclusion criteria was created as a framework for all waypoints included in the files (outlined in Section 4.2.2). Once the criteria were established, the process of creating the waypoints was started. Each waypoint type, except for Route Junctions and Service Warning Gaps, originated from Google Maps. Google Maps contains a feature where you can right click on a location and pull a set of

***Figure 17:** Pulling coordinate pairs from Google Maps.*

latitude and longitude coordinates (Figure 17). The Google Maps interface is also projected using

a WGS 1984 datum, so the location will translate accurately to my two SCT route segments. The

coordinate pairs were brought into a new Google Sheets workbook titled 'SCT_X_Y_Data' with

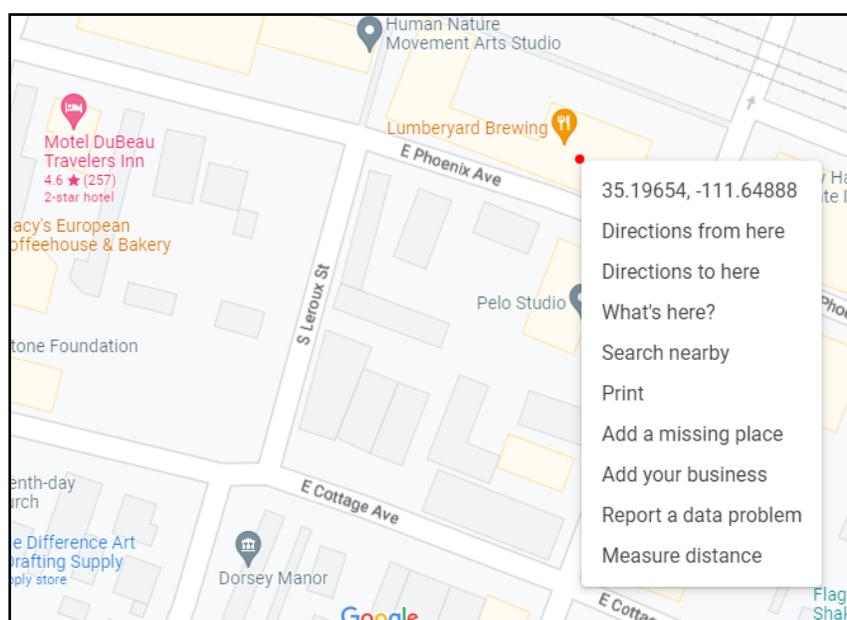each individual spreadsheet representing a different waypoint type. The coordinate pairs were

placed into 'X' (latitude) and 'Y' (longitude) columns. A 'Name' column was created for the

name or title of the location as well as a 'Description' column for more information. The name

field was populated with the name of that location directly from Google Maps to maintain

continuity amongst all waypoints. I created the descriptions for most waypoint classes and each

waypoint class has a unique description format (discussed in the following subsections).

Column Names			
X	Y	Name	Description
Latitude coordinates in decimal degrees	Longitude coordinates in decimal degrees	Name/title of location	Description of location

Table 2: Framework for each waypoint type spreadsheet (excluding Route Junctions and Service Gap Warnings)

Once each spreadsheet was populated with entries, they were downloaded individually as

Comma Separated Values (CSV) to import into ArcGIS Pro. CSV Files are simple text files that

use commas to indicate different column and row entries. ArcGIS Pro does not accept Excel or

Google Sheets file types, so CSV files were needed for further analysis. Each CSV file was

imported into ArcGIS Pro using the XY Table to Point geoprocessing tool. This tool takes an

input table (the CSV file) and converts it into a feature class using the associated latitude and

longitude data. A new file geodatabase titled 'Waypoints' was created to store each of the output

files from this tool. Within this geodatabase, three feature datasets were created:

'Waypoints_S1', 'Waypoints_S2' and 'Waypoints_SW' to contain all waypoints from Section 1,

Section 2, and the entirety of Sedona to Williams, respectively. Since each spreadsheet from the

SCT_X_Y_Data Google Sheets workbook contained every waypoint from Sedona to Williams,

all outputs from the geoprocessing tool were placed in the Waypoints_SW feature dataset and

ended with '_SW' to match the naming scheme. Route Junctions and Service Gap Warnings

were both created as their own point type feature class using the Create Feature Class

geoprocessing tool. Both were set as point type geometries, projected in a WGS 1984 geographic

coordinate system, and saved into the 'Waypoints_SW' feature dataset. Both feature classes were

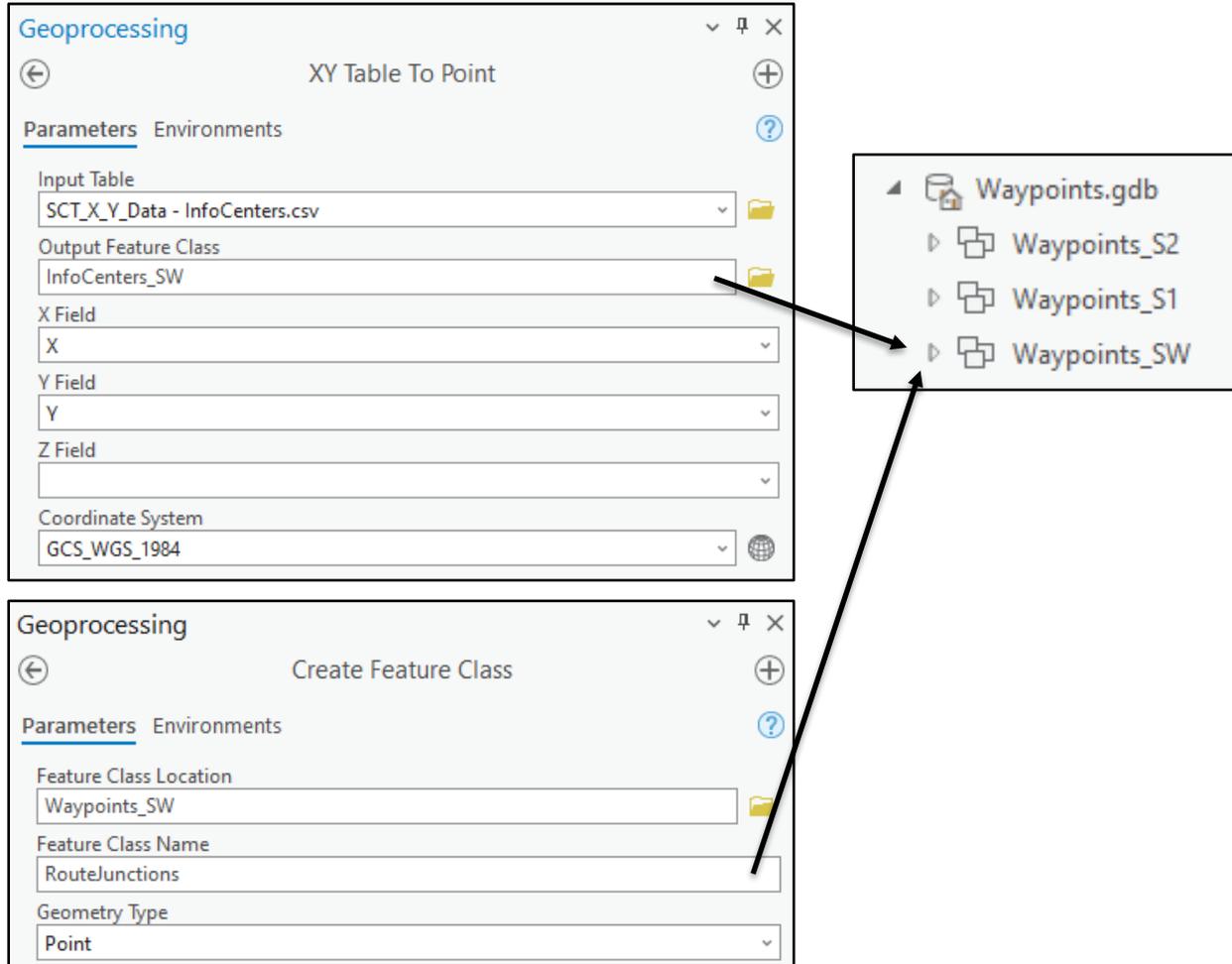empty at this point and were further developed in Sections 4.2.3 and 4.2.11.

Figure 18: *Feature class creation process for all waypoint types*

4.2.2 Inclusion/Exclusion Criteria

To help reduce subjectivity, as well as to create a guideline for consistency, I created a specific set of inclusion/exclusion criteria for waypoints. The following criteria were created to match the goals of the SCTA, as articulated in the Sun Corridor Trail Alliance Plan (Anderson et. al, 2021) Lodging options and restaurant waypoint types are all framed to highlight local and ideally non-chain businesses to help boost local economies while also recognizing businesses with a good reputation that have been integrated into the local culture for some time. Google Reviews were used to determine the legitimacy of each business highlighted, with a minimum of 50 or more reviews for Lodging and Restaurants. It should be noted that this is not a perfect method as those who leave reviews are often more opinionated than others who don't, which can introduce bias in this process (Beaton, 2018). More integral waypoint types, such as Grocery/Convenience Stores, Information Centers, and Bike Shops, I have deviated from the stricter criteria set for local businesses so that the trail user has the most convenient access to those amenities. Each waypoint type will be systematically defined and explained in the following sections.

Table 3: Inclusion/Exclusion Criteria for all waypoints

Waypoint Type	Criteria for Inclusion	Exceptions
Route Junctions	• Placed each time a road/trail continues or turns onto a different road/trail • Placed when a single road/trail takes a sharp turn and could confuse the trail user • Terrain changes (major road to Forest Service Road, road to trail, etc.) • Crosswalks • Traffic circles	
Lodging	• Independently owned • Must have dedicated space for bike storage OR can be brought into rooms • 50 or more Google reviews	• Include chains if established lodging options are not present in a 10+ mile section

	• Average review of 4.0 stars or higher on Google • Must be within one mile of trail corridor • Four to six options within each town or city boundary • Must be established for at least two years	• Can be within 0.5-1 miles from trail corridor if there are not options within a 10+ mile section
Grocery/ Convenience Stores	• Every convenience store within a 0.25-mile radius of the route line will be included • Every grocery store within a 0.5-mile radius of the route line will be included • Must be established for at least two years	• Location not included if route enters high motor vehicle use area
Restaurants	• 50 or more Google reviews • Average review of 4.0 stars or higher on Google • Business established in area for at least 2 years • If restaurant is a chain, the chain cannot exceed the Arizona state boundary • Must be within a 0.5-mile radius of route line • No more than five options within each city/town boundary	• Can be within 0.5-1 miles from trail corridor if there are not options within a 10+ mile section
Information Centers	• Every library, visitor center and forest service information center within five miles of the trail corridor will be included	
Attractions	• Needs to highlight history/culture of the given area	
Bike shops	• Every dedicated bike shop within a five-mile radius of the route line will be included • Independently owned • Not a chain	• Include chains if local bike shop options are not present in a 5+ mile radius
Outdoor Sports Stores	• Every outdoor sports store within a 0.5-mile radius of the route line will be included • Independently owned • Not a chain	
Service Warnings	• Every gap in services (restaurants, lodging, bike maintenance and/or access to basic amenities) of over 25 miles will be included	

4.2.3 Route Junctions

The SCT utilizes different Forest Service roads and urban trails to create its path. Because of this, the trail takes many turns and operates on various types of terrain. The Route Junctions waypoint type includes a set of coordinate points along the route line that represents a turn or transition on the route and each waypoint adheres to my inclusion criteria (Table 3).

Table 4: *Framework for Route Junctions waypoint type*

	Junctions Feature Class Field Name		
	Number	**Name** (X/Y)	**Description**
Junction #	Order of the junction, starting in Sedona, AZ and ending in Williams, AZ	Name of the junction. Crosswalks and traffic circles are self-titled, while all other junctions follow the naming scheme above, where X represents the path already travelled and Y represents the path the route is entering onto. Ex: (FR 618/Blue Grade Rd.)	Directions on how to navigate the junction, whether it's to continue on the same path or to turn onto a different one.

The process of creating Route Junction waypoints started by importing the 'Junctions_SW' feature class into an empty map in ArcGIS Pro. Three different fields were created in the attribute table using the Add Fields geoprocessing tool: Number, Name, and Description (Table 4). Within the Features group, I opened the Create Features pane to place points. With edge snapping enabled, points could be placed along the route line and fully intersect with it to maintain topological consistency.
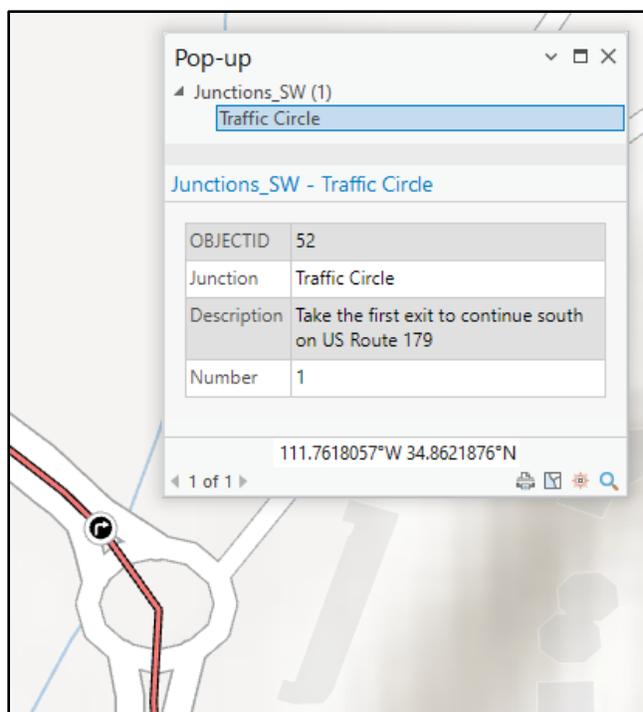
Figure 19: Placing initial Route Junction waypoint.

The junction points placed are all based on Smath's (2021) route recommendations, where he describes in detail the order of the route line. The route line starts in downtown Sedona at the northern terminus of US Route 179. The route starts by travelling south and almost immediately enters a traffic circle. The first route junction waypoint was placed right before the traffic circle using the Point tool (Figure 19). This action places a single point along the route line but does not automatically populate it with any information. Within the Editor tab, the Attributes pane was opened, allowing me to populate the empty fields. This process was repeated following the route line northbound until the last route junction in Williams, AZ.

The SCTA aims to have services available within a short distance of the trail every 30-40 miles. However, this section of the SCT contains one of the largest expected service gaps on the whole trail. Between the southern border of Village of Oak Creek and Mormon Lake Village, there are no services available on route for approximately 42.5 miles. On Route Junction #11, a note was added warning the trail user about the services gap (Table 5). To mitigate this issue, a route detour was suggested within the same description to detour 5.4 miles down Beaver Creek Rd. to access amenities, resulting in the choice of a 10.8-mile workaround to access amenities before Mormon Lake Village. Additionally, there is another 32.8-mile service gap between

Mormon Lake Village and the Chevron convenience store located on Lake Mary Rd. just south

of Flagstaff. On Route Junction #19, an additional note was added warning the user about the

service gap. There are no obvious workarounds or detours to mitigate the service gap so there

were no suggestions made for this in the description.

Table 5: *Route Junctions waypoint attribute table*

Number	Name	Description
1	Traffic Circle	Take the first exit to continue south on US Route 179
2	Traffic Circle	Take the first exit to continue south on US Route 179
3	Traffic Circle	Take the second exit to continue south on US Route 179
4	Traffic Circle	Take the second exit to continue south on US Route 179
5	Traffic Circle	Take the second exit to continue south on US Route 179
6	Traffic Circle	Take the second exit to continue south on US Route 179
7	Traffic Circle	Take the second exit to continue south on US Route 179
8	Traffic Circle	Take the second exit to continue south on US Route 179
9	Traffic Circle	Take the second exit to continue south on US Route 179
10	Rt 179/FR 618	Continue straight onto Forest Service Rd. 618
11	FR 618/Blue Grade Rd	Turn left onto Blue Grade Rd. No services will be available on route until Mormon Lake Village in 42.5 miles. To access services through a detour, turn right here on Beaver Creek Rd. and continue for 5.4 miles until you reach Beaver Creek Gas Mart.
12	Turn	Turn left to continue onto Blue Grade Rd.
13	Blue Grade Rd/Stoneman Lake Rd	Turn right onto Stoneman Lake Rd.
14	Turn	Turn left to continue on Stoneman Lake Rd.
15	Stoneman Lake Rd/Lake Mary Rd	Turn left onto Lake Mary Rd.
16	Lake Mary Rd/ FR 91	Turn left onto Forest Service Rd. 91
17	Turn	Turn left to continue on Forest Service Rd. 91
18	FR 91/FR 219	Take a sharp right turn onto Forest Service Rd. 219
19	FR 219/Mormon Lake Rd	Turn left onto Mormon Lake Rd. No services will be available on-route for approximately 32.8 miles until the Chevron on Lake Mary Rd.

20	Mormon Lake Rd/FR 132	Turn left onto Forest Service Rd. 132
21	FR 132/FR 132D	Turn right onto Forest Service Rd. 132D
22	FR 132D/FR 132	Veer left onto Forest Service Rd. 132
23	FR 132/FR 235	Turn left onto Forest Service Rd. 235
24	FR 235/Priest Draw Trail	Continue through the parking lot onto Priest Draw Trail
25	Priest Draw Trail/FR 235	Continue straight onto Forest Service Rd. 235
26	FR 235/FR 762B	Turn right onto Forest Service Rd. 762B
27	FR 762B/FR762D	Turn left onto Forest Service Rd 762D
28	FR 762D/FR 762	Turn left onto Forest Service Rd. 762
29	Turn	Turn left to continue on Forest Service Rd. 762
30	FR 762/FR 3E	Turn right onto Forest Service Rd. 3E
31	FR 3E/Frontier Rd	Turn Right onto Frontier Rd.
32	Frontier Rd/Lake Mary Rd	Turn Left onto Lake Mary Rd.
33	Lake Mary Rd/Lake Mary Trail	Veer to the gravel path on the right and cross the crosswalk across J.W Powell Rd to enter Lake Mary Trail
34	Lake Mary Trail/Lake Mary Rd.	Enter back onto the bike lane on Lake Mary Rd. at the Chevron gas station
35	Lake Mary Rd/Ponderosa Tr	Cross the road at S Nicholas St to continue on the paved path on the left (Ponderosa Trail)
36	Crosswalk	Enter the crosswalk across S Beulah Blvd.
37	Crosswalk	Enter the crosswalk across W University Heights Dr. to enter the Sinclair Wash Trail
38	Road Crossing	Carefully cross over S Woodlands Village Blvd. to continue onto Sinclair Wash Trail
39	Turn	Turn right to continue on Sinclair Wash Trail
40	Crosswalk	Turn left and cross the crosswalk to stay on Sinclair Wash Trail
41	Crosswalk	Turn right to cross the crosswalk to stay on Sinclair Wash Trail
42	Sinclair Wash Tr/San Francisco Tr	Cross San Francisco Street and turn left onto the San Francisco Trail (bike path)
43	San Francisco Tr/San Francisco St	Continue straight onto San Francisco St.
44	San Francisco St/Birch Ave	Turn left onto Birch Avenue.

| 45	Birch Ave/Karen Cooper Tr	Turn right onto Karen Cooper Trail.
46	Crosswalk	Enter the crosswalk across W Cherry Ave., turn left on the sidewalk, then immediately turn right to continue on Karen Cooper Trail
47	Karen Cooper Tr/Mars Hill Tr	Turn left onto Mars Hill Trail.
48	Turn	Turn left to stay on Mars Hill Trail
49	Cross Road	Cross the road to continue on Mars Hill Trail
50	Mars Hill Tr/FR 515	Continue straight onto Forest Service Rd. 515
51	FR 515/FR 9113C	Turn right onto Forest Service Rd. 9113C
52	FR 9113C/FR 506	Turn left onto Forest Service Rd. 506
53	FR 506/FR 668D	Turn right onto Forest Service Rd. 668D
54	FR 668D/FR 9014K	Turn left onto Forest Service Rd. 9014K
55	FR 9014K/Rudds Tank Rd	Turn right onto Rudds Tank Rd.
56	Rudds Tank Rd/N Chambers Dr	Turn right onto N Chambers Dr.
57	N Chambers Dr/W Suzette Ln	Turn right onto W Suzette Ln.
58	W Suzette Ln/N Bader Rd.	Turn right onto N Bader Rd.
59	N Bader Rd/US 180	Turn left onto US Highway 180. To access Basecamp at Snowbowl Lodge & Restaurant, turn right onto US Highway 180 and continue for approximately 1 mile.
60	US 180/FR 222	Turn left onto Forest Service Rd. 222
61	FR 222/FS 171	Continue straight onto Forest Service Rd. 171
62	FR 171/Old Route 66	Turn right on Old Route 66
63	Old Route 66/Deer Farm Rd	Turn right on Old Route 66. To access Pilot Travel Station with access to food and drink, turn left onto Old Route 66 and continue for approximately 0.8 miles.
64	Deer Farm Rd/S Garland Prairie Rd	Turn left to cross over US Interstate 40 onto S Garland Prairie Rd.
65	S Garland Prairie Rd/Bearizona Blvd	Turn right onto Bearizona Boulevard (NOTE: There will not be signage for this)
66	Bearizona Blvd/Rt 64	Turn left onto US Route 64
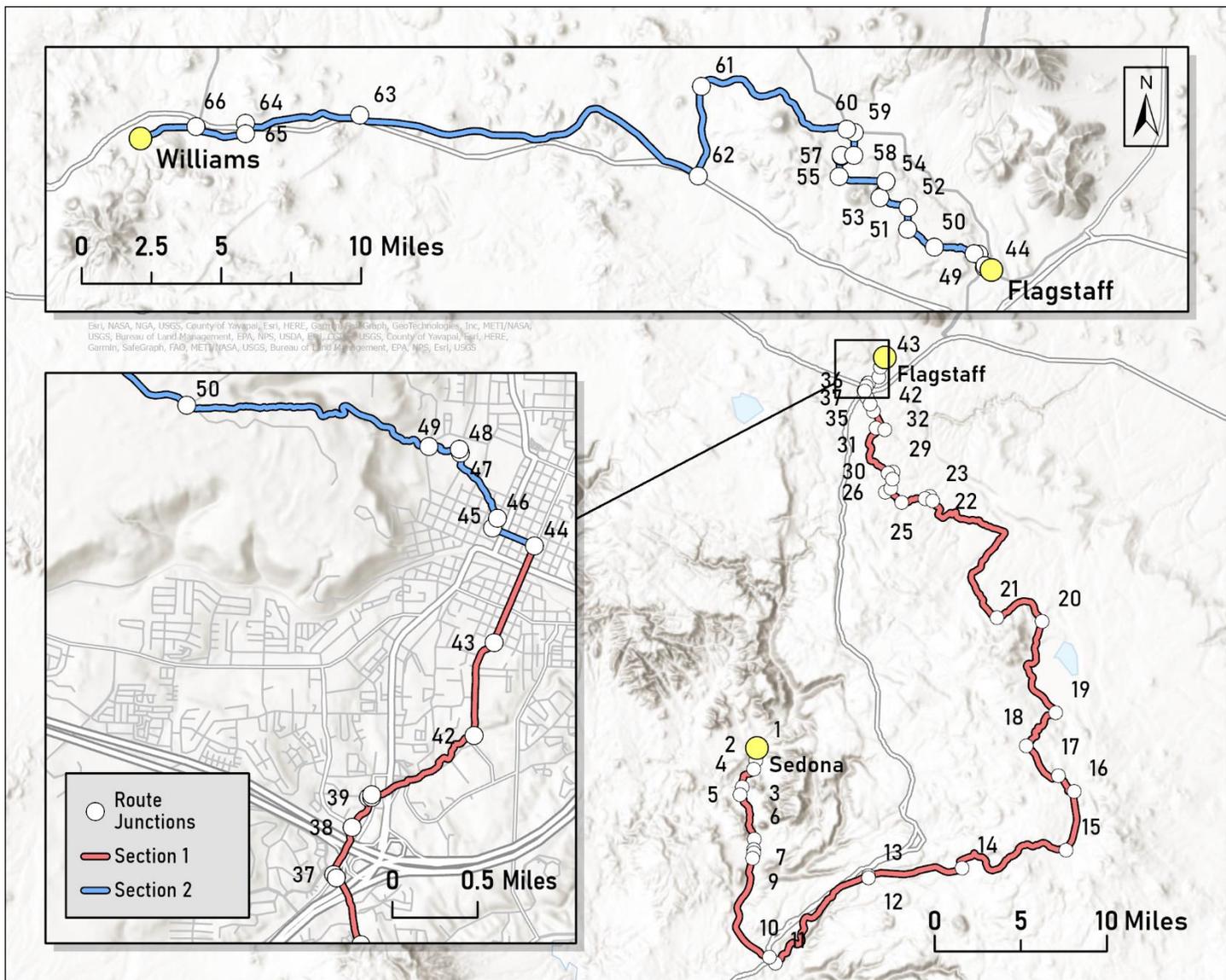
Figure 20: Route Junctions symbolized by order number.

4.2.4 Lodging

As the SCTA intends for this trail to focus on front-country travel, camping and bikepacking-style travel is not encouraged. Instead, the SCTA hopes to boost local economies through increased outdoor recreation tourism, and one way to do that is for trail users to stay overnight in the towns and communities the trail passes through. Lodging options include any hotel, motel, bed and breakfast, resort or cabin that meets the inclusion/exclusion criteria highlighted in Section 4.2.2. Although smartphones could be used to figure out lodging options on-trail, there is no guarantee of cellular service in any section. The inclusion of this waypoint type helps guide trail users that are not as confident with navigating lodging options via smartphone browsers. This waypoint type also points trail users toward independently owned establishments that are more integrated into the local culture.

The description of this waypoint type includes necessary information while being concise. They begin with the star rating based on the hotel star rating system followed by the range of occupants that a single room can provide. They also include information on where to store bikes, whether it be dedicated on-property bike storage, bike racks or brought into rooms. Bike storage options were not listed on any website associated with any of the lodging options, so I called each establishment to obtain the information. Based on a general lack of integrated bike infrastructure in most communities from Sedona to Williams, most lodging options do not have dedicated bike storage. However, every lodging option included allows its occupants to either store bikes in rooms or lock them up securely at some location on the property. Lastly, the description ends with the phone number associated with the establishment so that trail users can optionally book rooms and obtain information about rates via calling rather than on their smartphone web browsers.

Table 6: Lodging Options waypoint attribute table

X	Y	Name	Description
34.86585218	-111.7632734	Cedar's Resort	2-star hotel that can hold 1-4 occupants per room. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 282-7010
34.87035486	-111.7612468	Star Motel	Motel with 1-4 occupants per room. No dedicated bike storage (can be locked up in various spots outside) but they can be brought into rooms if kept clean. Phone: (928) 282-3641
34.86948179	-111.7602785	Orchards Inn Sedona	3-star hotel that can hold 1-4 occupants per room. Up to two bikes can be brought into each room if kept clean. Phone: (855) 474-7719
34.86859422	-111.759959	L'Auberge de Sedona	5-star hotel that can hold 1-6 occupants per room. Valet garage with ample bike storage. Phone: (855) 905-5745
34.86973499	-111.7585857	Amara Resort and Spa	4-star hotel that can hold 1-4 occupants per room. Storage closet located behind front desk that can hold bikes.
34.87178388	-111.759549	The Matterhorn Inn	3-star hotel that can hold 1-8 occupants per room. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 282-7176
34.84413311	-111.7737667	Poco Diablo Resort	3-star hotel that can hold 1-4 occupants per room. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 282-7176
34.78982601	-111.7654885	Red Agave Resort	2-star hotel that can hold 1-5 occupants. No dedicated bike storage but they can be brought into rooms if kept clean (hose available to wash bikes). Phone: (928) 284-9327
34.77320218	-111.7626862	Las Posadas of Sedona	3-star hotel that can hold 1-4 occupants per room. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 284-5288
34.77858369	-111.7634457	Desert Quail Inn	2-star hotel that can hold 1-4 occupants per room. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 284-1433
34.91155093	-111.4672944	Mormon Lake Lodge	2-star lodge that can hold 1-4 occupants per room. Access to a steakhouse, saloon, souvenirs and gas. Phone: (928) 354-2227
35.15746435	-111.656605	Arizona Mountain Inn & Cabins	3-star cabins in the woods that can hold 1-16 occupants per cabin. No dedicated bike storage but they can be brought into the cabins. Phone: (928) 774-8959
35.18713678	-111.6617046	Castle Rock Inn	2-star hotel that can hold 1-4 occupants per room. Up to two bikes can be brought into the rooms if kept clean. Phone: (928) 853-8288
35.19818491	-111.6474696	Hotel Monte Vista	Historic 3-star hotel that can hold 1-4 occupants. Bikes can be stored in rooms and can typically be brought onto higher floors via an elevator. Phone: (928) 779-6971
35.19663811	-111.6505803	Motel DuBeau Travelers Inn	2-star hotel that can hold 1-4 occupants per room. Storage area located on property that bikes can be used with proper notice to hotel personnel. Up to two bikes can be brought into the rooms if kept clean. Phone: (928) 774-6731

35.20149936	-111.6470061	Bespoke Inn	Historic 3-star hotel that can hold 1-4 occupants. Bikes can be stored on a bike rack in the back of the property or brought into rooms if they are kept clean. Phone: (844) 259-7766
35.26800625	-111.7185662	Basecamp at Snowbowl Lodge	2.5-star lodge at the base of Arizona Snowbowl Ski Resort with standalone cabins and hotel-style rooms that can hold 1-4 occupants. No dedicated bike storage but they can be brought into rooms if they are kept clean. Phone: (928) 774-0729
35.25820668	-112.1710948	The Canyon Hotel & RV Park	3-star hotel that can hold 1-4 occupants. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 635-9371
35.25329292	-112.1814847	El Rancho Motel	2-star motel that can hold 1-4 occupants per room. Bikes can be locked up on rear deck of property or brought into rooms if kept clean. Phone: (928) 635-2552
35.25096085	-112.184687	Williams AZ Hostel	Affordable hostel in downtown Williams. No internal bike storage but there are outdoor locations on property for bikes to be locked. Phone: (928) 607-6628
35.25178896	-112.1915416	Grand Canyon Railway & Hotel	3-star hotel that can hold 1-4 occupants. No dedicated bike storage but they can be brought into rooms if kept clean. Phone: (928) 635-4010

Figure 21: *Lodging waypoint type map layout*

4.2.5 Restaurants

The restaurants waypoint type was created to further contribute to local economies as well as highlight the culture of each community through food. Each restaurant waypoint follows the inclusion/exclusion criteria (Table 3) while overall incorporating a variety of styles to suit varying preferences. The descriptions were taken from each business's Google page that allows them to write a short excerpt on their restaurant to maintain accuracy and reflect the business in the way they intended. If a restaurant did not have an excerpt, a short one was written by the researcher in a similar format to maintain consistency of descriptions. This waypoint was saved as 'Restaurants_SW' and saved in the Waypoints_SW feature dataset.
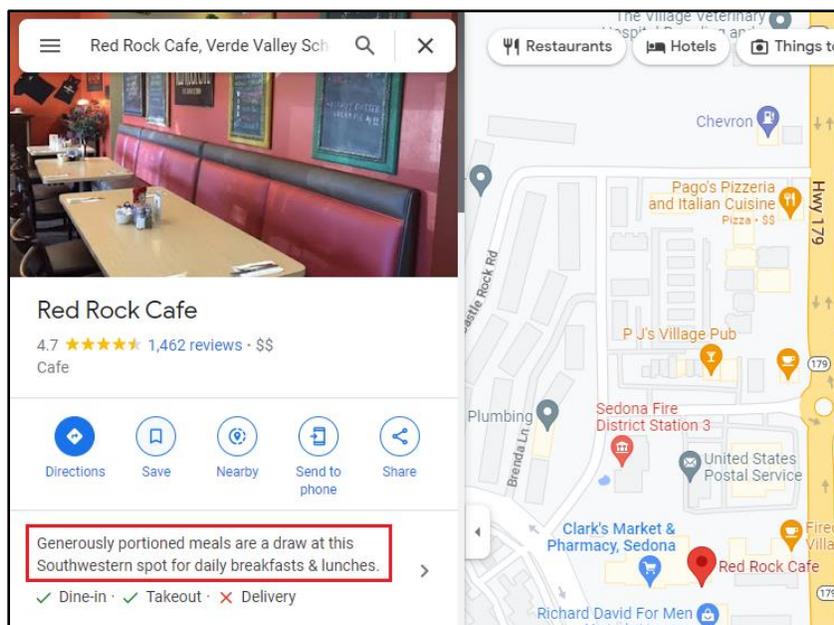

Figure 22: *Google Maps excerpt from Red Rock Café in Sedona, AZ*

Table 7: *Restaurants waypoint attribute table*

X	Y	Name	Description
34.86958177	-111.7615124	Cowboy Club Grille & Spirits	Decked out with cowboy gear, this casual steakhouse offers Southwestern fare such as cactus fries.
34.86445175	-111.763368	Hideaway House	Relaxed eatery featuring sandwiches, pizza & pasta also offers scenic creek & canyon views
34.86320564	-111.7629125	Pump House Station Urban Eatery and Market	Rustic-chic, A-frame eatery offering elevated breakfast, lunch & dinner staples, plus beer & wine.
34.87174074	-111.7604283	Cuptown Coffeehouse	Local coffee shop with coffee, pastries and art available for purchase.

34.78856598	-111.7643039	Red Chopstick	Chinese establishment offering dine-in and delivery options
34.78164238	-111.7633513	Pago's Pizzeria and Italian Cuisine	Neighborhood Italian eatery doling out pizzas & familiar dishes in quaint, informal digs.
34.77825474	-111.7622431	Butterfly Burger	About Butterfly Burger Polished eatery offering upscale burgers, salads & creative sides, plus craft beers.
34.77872993	-111.7642207	Red Rock Cafe	Generously portioned meals are a draw at this Southwestern spot for daily breakfasts & lunches.
34.91149472	-111.4674354	Mormon Lake Lodge Steak House	Steakhouse with American fare and beer alongside a country store and lodge. Seasonal hours can vary so plan accordingly. The Country Store (same building) is open year-round and can provide snacks and microwavable foods.
34.91172124	-111.4681441	Mormon Lake Pizzeria	Pizza shop alongside a country store and lodge.
35.17764105	-111.6677901	Tacos Los Altos - West Side	Casual option for south-of-the-border & Tex-Mex favorites ordered at a counter plus some sweets.
35.17818861	-111.6672249	Delhi Palace Cuisine of India	Cozy Indian restaurant with a sprawling lunch buffet & table service for dinner, plus a full bar.
35.19461079	-111.6495825	Potion Tea & Bakery	Tea house with locally baked goods
35.19478378	-111.6492831	Morning Glory Cafe	Long-running brunch & lunch spot serving organic vegetarian & vegan fare in warm, eclectic digs.
35.19502654	-111.6488141	Historic Brewing Barrel + Bottle House	Easygoing brewpub offering local & imported craft brews, pub fare & a dog-friendly patio.
35.19734594	-111.6483321	Pato Thai Cuisine	Informal Asian diner offering curries & noodle dishes spiced to order plus lunch specials
35.19818559	-111.6480146	Late For the Train Coffee House	Homey coffee shop specializing in dark roasts offers a variety of specialty drinks, plus light fare.
35.199421	-111.649612	Dark Sky Brewing Co.	Inventive house-brewed beers & unique pub fare offered in hip, industrial digs with a cool bar.
35.26800625	-111.7185662	Basecamp Restaurant at Snowbowl	Cozy restaurant at the base of Arizona Snowbowl Ski Resort offering classic American fare along with a full-service bar.
35.26007609	-111.9486965	Parks in the Pines General Store, Deli and Postal Annex	Cozy location with a full-service deli and access to general groceries and postal services.
35.25233143	-112.1833933	Goldies Route 66 Diner	Casual throwback with 1960s styling offering classic American breakfast, lunch & dinner eats.
35.25106548	-112.1882276	Anna's Canyon Cafe	Comfy daytime eatery serving familiar American, Chinese & Mexican plates, plus coffee & milkshakes.
35.25073606	-112.1878314	Fiesta Mexican Grill	Low-key, family-run operation with a folksy atmosphere serving hearty, down-to-earth Mexican dishes.

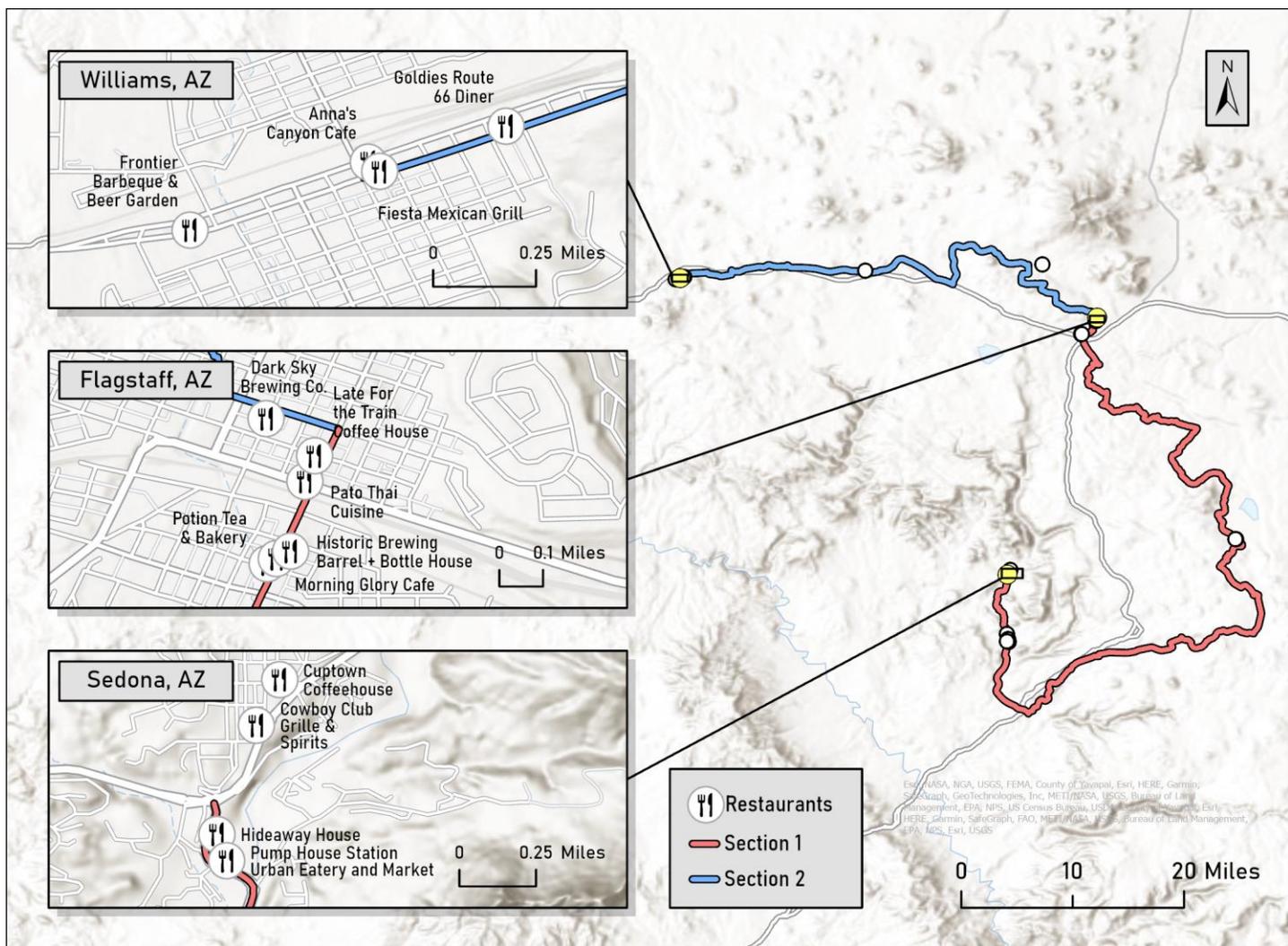|		Frontier Barbeque & Beer Garden	Western-themed restaurant offering a variety of BBQ dishes and local craft brews.
35.24868501	-112.194495		

Figure 23: Restaurants waypoint type map layout

4.2.6 Grocery/Convenience Stores

The Grocery/Convenience Stores waypoint type was created to allow the trail user to access basic amenities quickly and easily. Unlike Lodging and Restaurants waypoint types, Grocery/Convenience Stores deviated from the stricter criteria of being local/non-chain to help increase user-friendliness and convenience, as there are not enough independently owned markets to fulfill the needs of SCT travelers. These waypoints can be defined as:

- A grocery store

- A convenience store attached to a gas station

- Corner stores or bodegas

- Farmers markets

These definitions were all congregated into the Grocery/Convenience Stores waypoint type to eliminate overlap and maintain simplicity when using the eventual GPX files. Descriptions within this waypoint type were kept simple and describe the main types of amenities it provides. The Street View feature within Google Maps was used to determine the feasibility of bike storage at each store. If Street View does not show a mounted bike rack on the property, or if Street View imagery is not available in that area, then bike storage information was not provided. This feature class was saved as 'ConvStores_SW' within the Waypoints_SW feature dataset.

Table 8: Grocery/Convenience Stores waypoint attribute table

| X	Y	Name	Description
34.86299953	-111.7993879	Sedona Farmers Community Market	Community farmers market featuring locally sourced food and produce. Open in the summer from 9am-1pm every Sunday from May through October, with winter hours being 11am-3pm every Sunday from October through April.
34.86580335	-111.7641111	76	Gas station with convenience store offering water, snacks and basic necessities.
34.85778224	-111.7635641	Circle K	Gas station with convenience store offering water, snacks and basic necessities.
34.78919101	-111.7626779	Circle K	Gas station with convenience store offering water, snacks and basic necessities.
34.78047849	-111.7624238	Speedway	Gas station with convenience store offering water, snacks and basic necessities.
34.77872544	-111.764673	Clark's Market & Pharmacy	Market with groceries and a pharmacy. Bike rack located outside of store
34.64421943	-111.7857432	Beaver Creek Gas Mart	Gas station with convenience store offering water, snacks and basic necessities.
35.15984342	-111.6608003	Chevron	Gas station with convenience store offering water, snacks and basic necessities.
35.16836892	-111.6641999	Circle K	Gas station with convenience store offering water, snacks and basic necessities.
35.17656091	-111.6671779	Basha's	Market with groceries and a pharmacy. Bike rack located outside of store
35.19168668	-111.6470236	O'Leary Street Market	Small neighborhood market with access to drinks and snacks.
35.1933814	-111.6495427	Speedway	Gas station with convenience store offering water, snacks and basic necessities.
35.19929763	-111.652764	Flagstaff Community Farmers Market	Community farmers market featuring locally sourced food and produce. Open seasonally from the first Sunday in May until the last Sunday in October.
35.19895029	-111.6471967	Hoot Mart	Small neighborhood market with access to drinks and snacks.
35.20751529	-111.6467509	Basha's	Market with groceries and a pharmacy. Bike rack located outside of store.
35.23978664	-111.6717857	Marathon	Gas station with convenience store offering water, snacks and basic necessities.
35.23839473	-111.8219877	Pilot Travel Center	Gas station with McDonald's and Subway locations. Access to water, snacks and basic necessities.
35.25732766	-111.9393154	Parks Feed and Mercantile	Convenience store offering water, snacks and basic necessities, along with animal feed supply.
35.25318087	-112.1810943	Mustang	Gas station with convenience store offering water, snacks, necessities and coin-operated laundry machines.
35.24819082	-112.1937892	Safeway	Market with groceries and a pharmacy. Bike rack located outside of store.
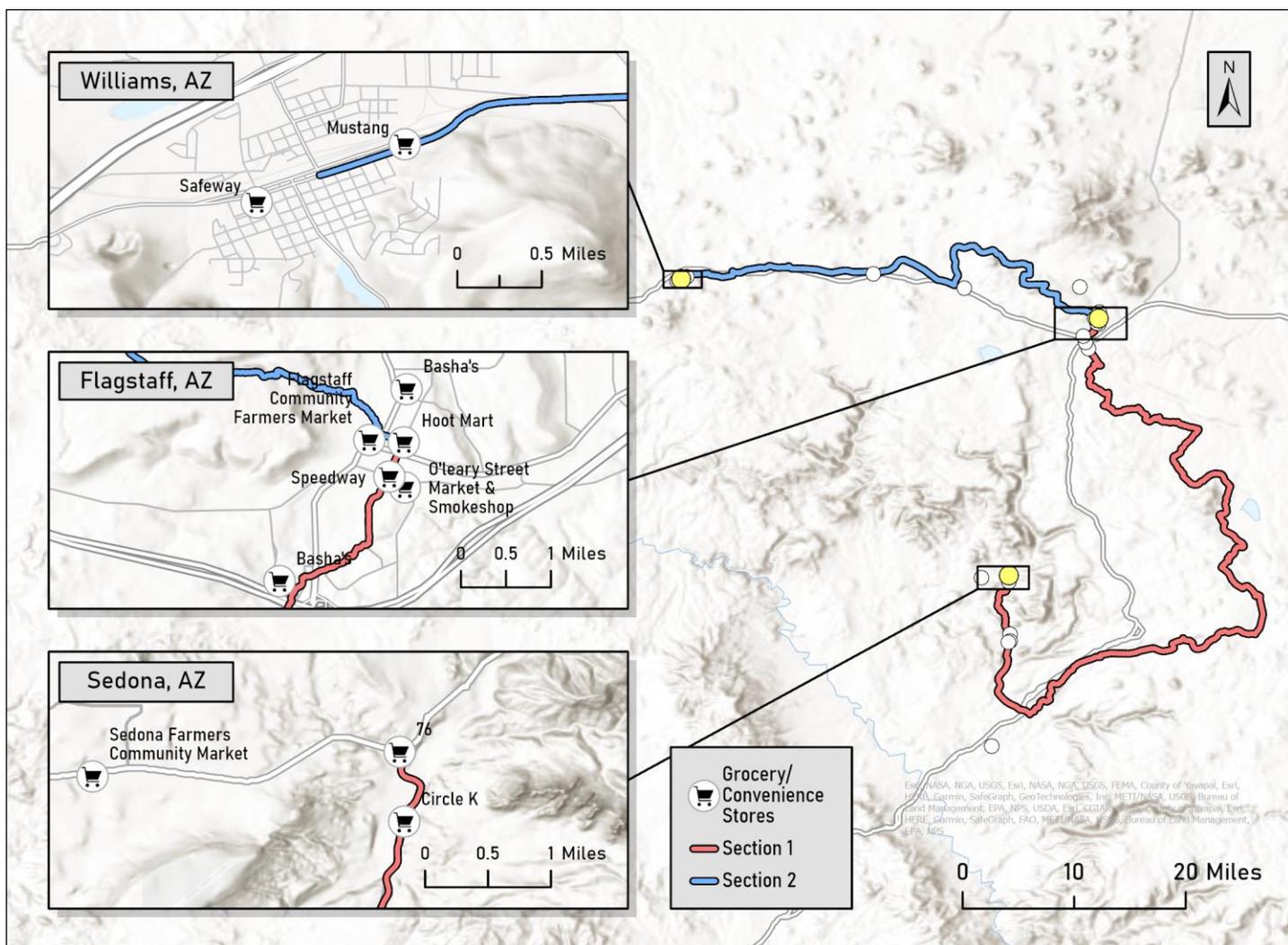
Figure 24: *Grocery/Convenience Stores waypoint layout*

4.2.7 Information Centers

The Information Centers waypoint type was created to help the trail user access important information such as trail closures and Forest Service updates as well as to provide a place to find general information about each community. Although the SCT intends to frequent front-country and urban spaces, this trail moves through rugged terrain and is often well out of cellular service. Additionally, much of this trail travels through Forest Service lands, which means potential closures for maintenance or natural disasters. Trail users that enter each community are also likely to be curious about its history and culture, so the highlighted information centers can be accessed by trail users to understand more about the areas this trail navigates through. Information Centers can be defined as Forest Service offices, visitor centers within each community and local libraries. The descriptions of the Information Centers waypoints briefly list what they offer along with hours of operation and a phone number. The resulting feature class was titled 'InfoCenters_SW' and placed into the Waypoints_SW geodatabase.

Table 9: Information Centers waypoint attribute table

| X	Y	Name	Description
34.86222843	-111.8184428	Sedona Public Library	Library with access to books, movies and computers. Open Monday-Saturday from 10:00am-6:00pm. Phone number: (928) 282-7714
34.86873166	-111.7616826	City of Sedona Visitor Center	Hub for information on tourist attractions & accommodations, with locally themed souvenirs for sale. Open daily from 8:30am-5:00pm, closed Thanksgiving and Christmas Day. Phone number: (928) 282-7722
34.75719551	-111.7641748	Red Rock Ranger District Visitor Center	Information regarding Forest Service lands in the Red Rock Ranger District. Open daily from 8:30am-5:00pm, closed Thanksgiving and Christmas Day. Phone number: (928) 203-2900
34.77801359	-111.778349	Sedona Public Library in the Village	Library with access to books, movies and computers. Open Tuesday-Friday from 10:00am-5:00pm and Saturday from 10:00am-2:00pm. Phone number: (928) 282-7714
35.197232	-111.6488862	Flagstaff Visitor Center	Hub for information on tourist attractions & accommodations, with locally themed souvenirs for sale. Open 8:00am-5:00pm Monday-Saturday and 9:00am-4:00pm on Sunday. Phone number: (928) 213-2951
35.19980487	-111.6521912	Flagstaff Public Library	Library with access to books, movies and computers. Open 9:00am-8:00pm Monday-Thursday, 9:00am-6:00pm Friday, 9:00am-5:00pm Saturday, and 9:00am-1:00pm Sunday. Phone number: (928) 213-2330
35.18621568	-111.6740246	Coconino National Forest Supervisor's Office	Information regarding Coconino National Forest conditions, attractions, and more. Open 8:00am-4:00pm Monday-Friday. Phone number: (928) 527-3600
35.25028865	-112.187091	Williams Public Library	Library with access to books, movies and computers. Open 9:00am-5:00pm Tuesday-Saturday. Phone number: (928) 635-2263
35.25097254	-112.1890189	City of Williams Visitor Center	Hub for information on tourist attractions & accommodations. Open daily from 8:00am-5:00pm. Phone number: 928-635-4061
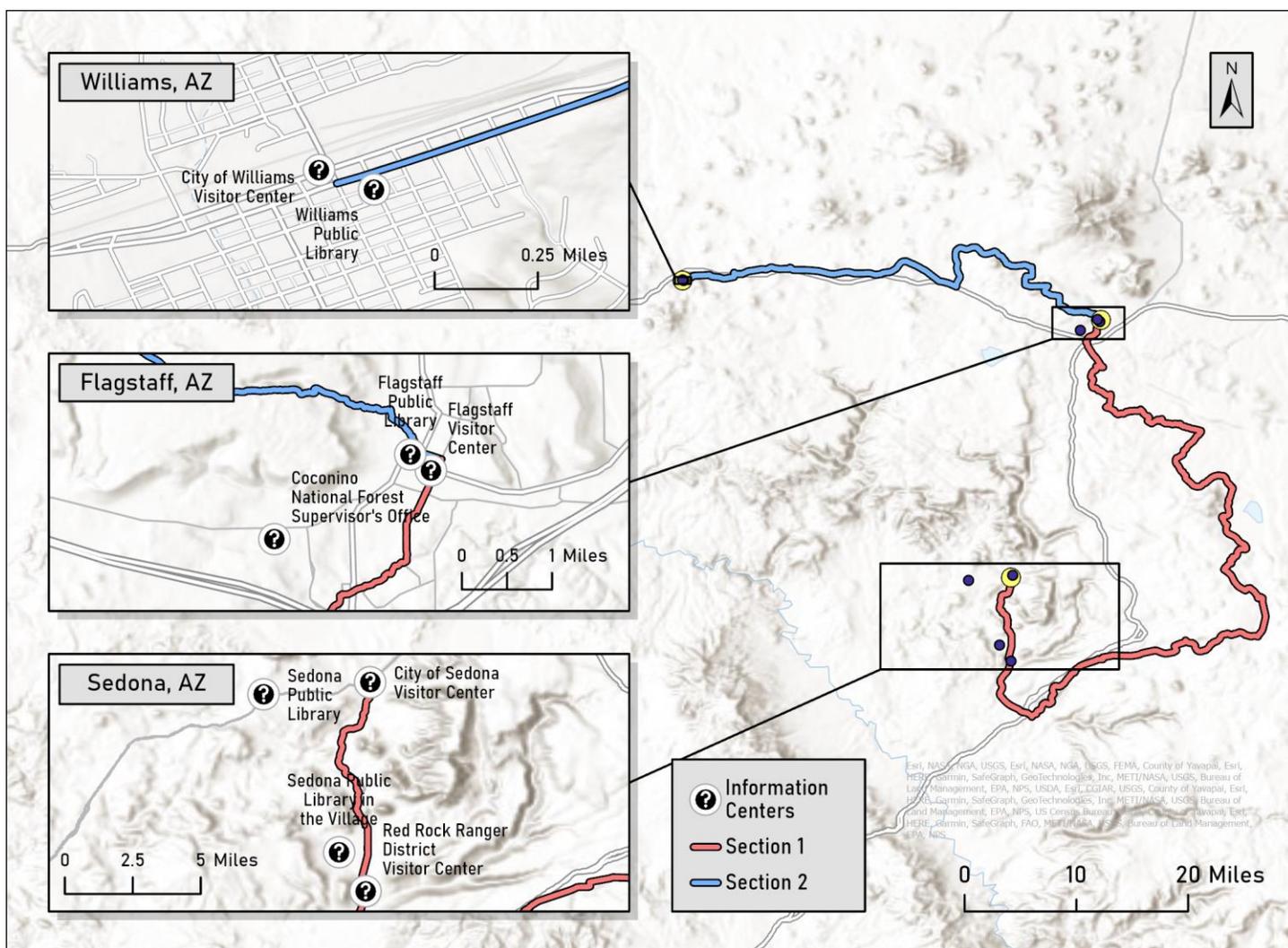
Figure 25: Information Centers waypoint map layout

4.2.8 Attractions

The SCT provides a plethora of attractions for the trail user in both backcountry and urban settings. The attractions waypoint type was created to highlight some of the most significant attractions within and between each community. These attractions showcase some of the defining characteristics of each community but also serve to break up trail sections with rest spots. Attractions can be defined as museums that showcase local culture and history, significant viewpoints, rest areas for trail users, local parks, and other notable local attractions. As attractions can and should be researched prior to travelling on the SCT, this waypoint type serves to point out ones that are most significant and unique to each area or are useful for someone travelling the trail. The descriptions of this waypoint type are concise and give a brief description of the location and potential amenities associated with it.

Table 10: *Attractions waypoint attribute table*

| X	Y	Name	Description
34.87802143	-111.7624486	Sedona Heritage Museum	Center for regional history, events & education in a preserved family farmstead.
34.83207625	-111.7664586	Chapel of the Holy Cross	Modern 1950s chapel with a striking location atop red rock buttes & wide views of the Sedona area.
34.79186559	-111.7620616	Bell Rock Trailhead	Viewpoint of Sedona's Bell Rock along with a public restroom.
34.72561522	-111.7752377	Red Rock Scenic Byway Sign	Decorative sign commemorating the Red Rock Scenic Byway
34.66947762	-111.7142619	Beaver Creek Picnic & Day Use Area	Day use areas with picnic tables, pit toilets, and access to creek swimming. Potable water is accessible from one of 18 picnic sites.
34.7781188	-111.5250858	Stoneman Lake Overlook & Picnic Area	Great spot to relax, eat, and take in scenic views of Stoneman Lake.
35.18769308	-111.6582909	Riordan Mansion State Historic Park	Circa-1904 historic mansion with art nouveau touches covering 13,000 sq. ft., with guided tours.
35.19991287	-111.6511763	Wheeler Park	Mature trees & park benches line the 2.5 acres of this public picnic & festival destination.
35.20613938	-111.6550669	Frances Short Pond	Small fishing pond surrounded by trees, wildlife, hiking trails & a basic outhouse.
35.20279031	-111.6646945	Lowell Observatory	Founded in 1894, this hilltop center with giant telescopes offers tours, solar viewing & stargazing.
35.23483546	-111.6656243	Museum of Northern Arizona	Museum chronicling the Colorado Plateau from 15,000 B.C. to the present via exhibits & artifacts.
35.26569389	-112.0572081	Grand Canyon Deer Farm LLC	Large petting zoo with chances to feed fallow deer, also home to cockatoos, wallabies & llamas.
35.25610051	-112.1538325	Bearizona Wildlife Park	Wildlife park offering a drive-thru experience starring wolves, bears, bison, mountain goats & more.
35.25697383	-112.1690062	The Gateway to the Grand Canyon	Metal arch over Route 66 welcoming tourists to downtown Williams, founded in 1881.
35.25156388	-112.191003	Grand Canyon Railway Depot	Tourist attraction with opportunities to ride the historic railroad to Grand Canyon Village
35.25291108	-112.1833965	Welcome and History Park	City park showcasing the history of Williams and a large Route 66 sign for photo opportunities.
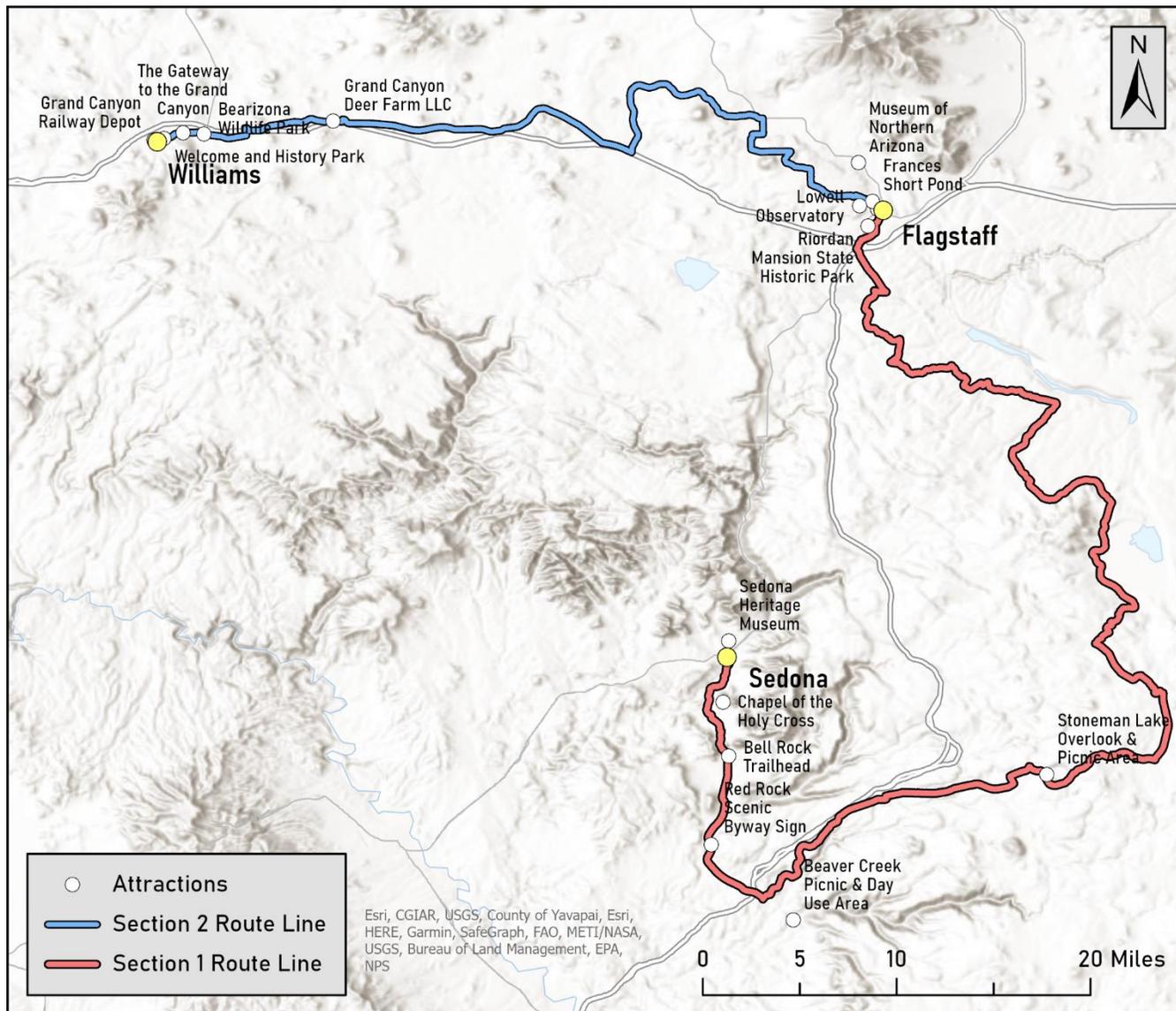
Figure 26: Attractions waypoint map layout

4.2.9 Bike Shops

The resulting GPX files generated from this project are geared toward trail users that plan on bike touring on the SCT. The Bike Shops waypoint type was created to include every bike shop between Williams, AZ and Sedona, AZ that are independently owned, non-chain establishments so that trail users can access bike services easily while supporting local businesses. There are only eight dedicated bike shops within a five-mile radius of this SCT section, so all were included. The description of this waypoint type is simple and briefly explains the services they offer. Given that some trail users have bikes with specialty parts, a phone number is included for each location so that the trail user can communicate this as well as other questions or concerns with the establishment.

Table 11: Bike Shops waypoint attribute table

| X	Y	Name	Description
34.86316428	-111.7897588	Thunder Mountain Bikes	Bike shop offering rentals, service and parts. Phone: (928) 282-1106
34.7880928	-111.7633984	Sedona Bike & Bean	Bike shop offering rentals, service, parts and coffee. Phone: (928) 284-0210
34.7880078	-111.7626357	Absolute Bikes Sedona	Bike shop offering rentals, service and parts. Phone: (928) 284-1242
35.18214233	-111.6609109	Snow Mountain River (SMR)	Local used/new outdoor gear shop with bike service and parts. Phone: (928) 774-1461
35.18965173	-111.6602356	Single Track Bikes	Bike shop offering rentals, service and parts. Phone: (928) 773-1862
35.19695653	-111.6522772	Flagstaff Bicycle Revolution	Bike shop offering rentals, service and parts. Phone: (928) 774-3042
35.19694996	-111.6467664	Absolute Bikes Flagstaff	Bike shop offering rentals, service and parts. Phone: (928) 779-5969
35.19977168	-111.6506389	Cosmic Cycles	Bike shop offering rentals, service and parts. Phone: (928) 779-1092
35.19365289	-111.6477703	Bici-Mundo Bicycle Sales & Service	Bike shop offering discounted/used parts and service. Phone: (928) 779-3121
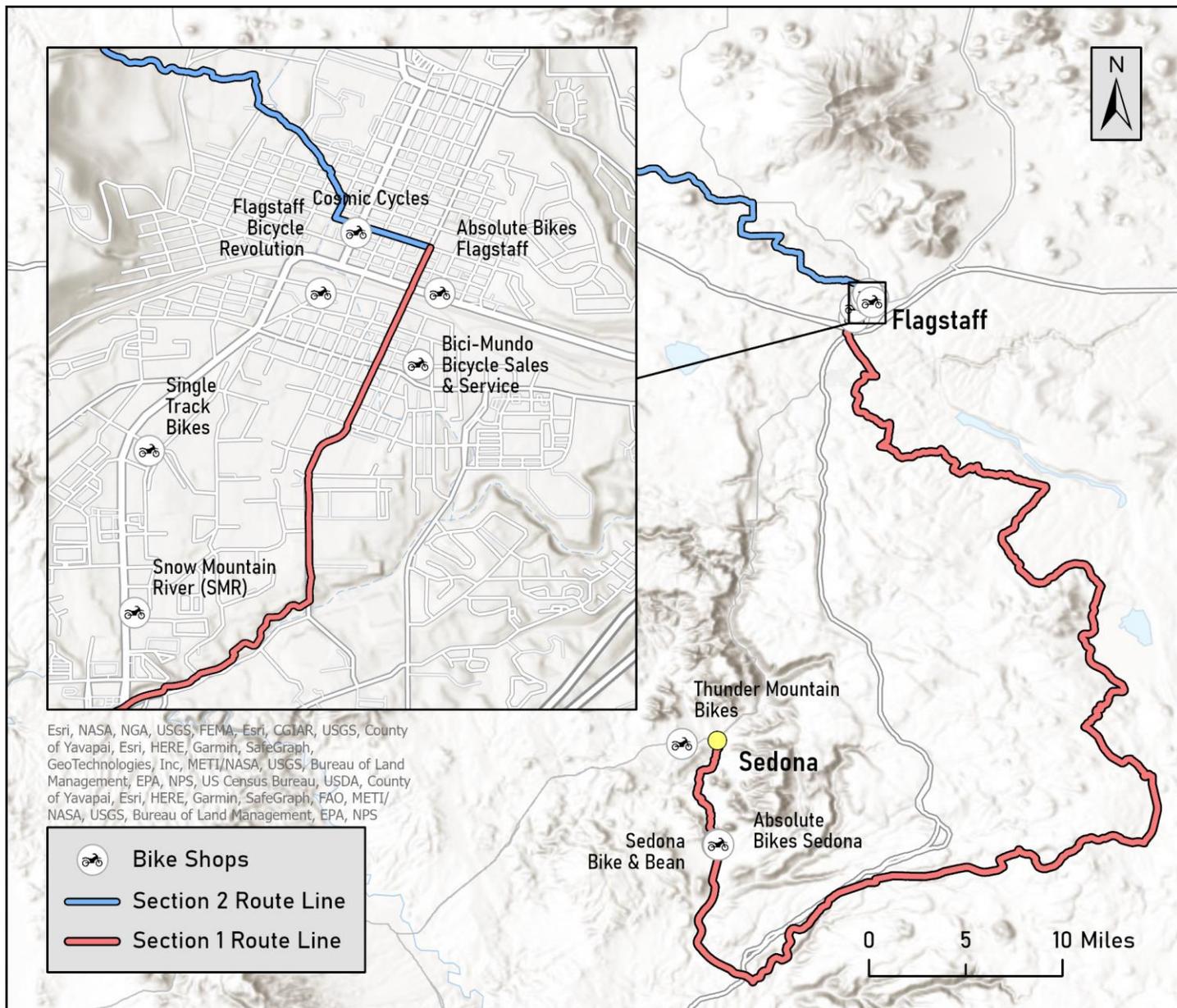
Figure 27: *Bike Shops waypoint map layout*

4.2.10 Outdoor Sports Shops

The Outdoor Sports Shops waypoint type was included to show locations of outdoor sports retailers providing general athletic wear, gear, and fitness-focused snack items. As with Bike Shops, the Outdoor Sports Shop waypoint type only includes local businesses. There are only six of these that exist within a one-mile radius of the route line, so all that met the criteria were included.

Table 12: Outdoor Sports Shops waypoint type attribute table

X	Y	Name	Description
34.87049503	-111.7609227	Sedona Outdoors	Retailer carrying a variety of outdoor gear including shoes/boots, maps, apparel and backpacks.
34.86137287	-111.7615468	The Hike House	Retailer and coffee shop carrying a variety of outdoor gear including shoes/boots, maps, apparel, backpacks and more.
35.197846	-111.6496218	Peace Surplus	Retailer carrying a variety of outdoor gear including shoes/boots, maps, apparel, backpacks and more.
35.19778695	-111.6478732	Aspen Sports	Retailer carrying a variety of outdoor gear including shoes/boots, maps, apparel, backpacks and more.
35.19823192	-111.6476659	Babbitt's Backcountry Outfitters	Retailer carrying a variety of outdoor gear including shoes/boots, maps, apparel, backpacks and more.
35.24982249	-112.1907547	Mountain Man Mercantile Outdoor Store	Retailer carrying a variety of outdoor gear including shoes/boots, maps, apparel, backpacks and more with a selection of various local brews to go.
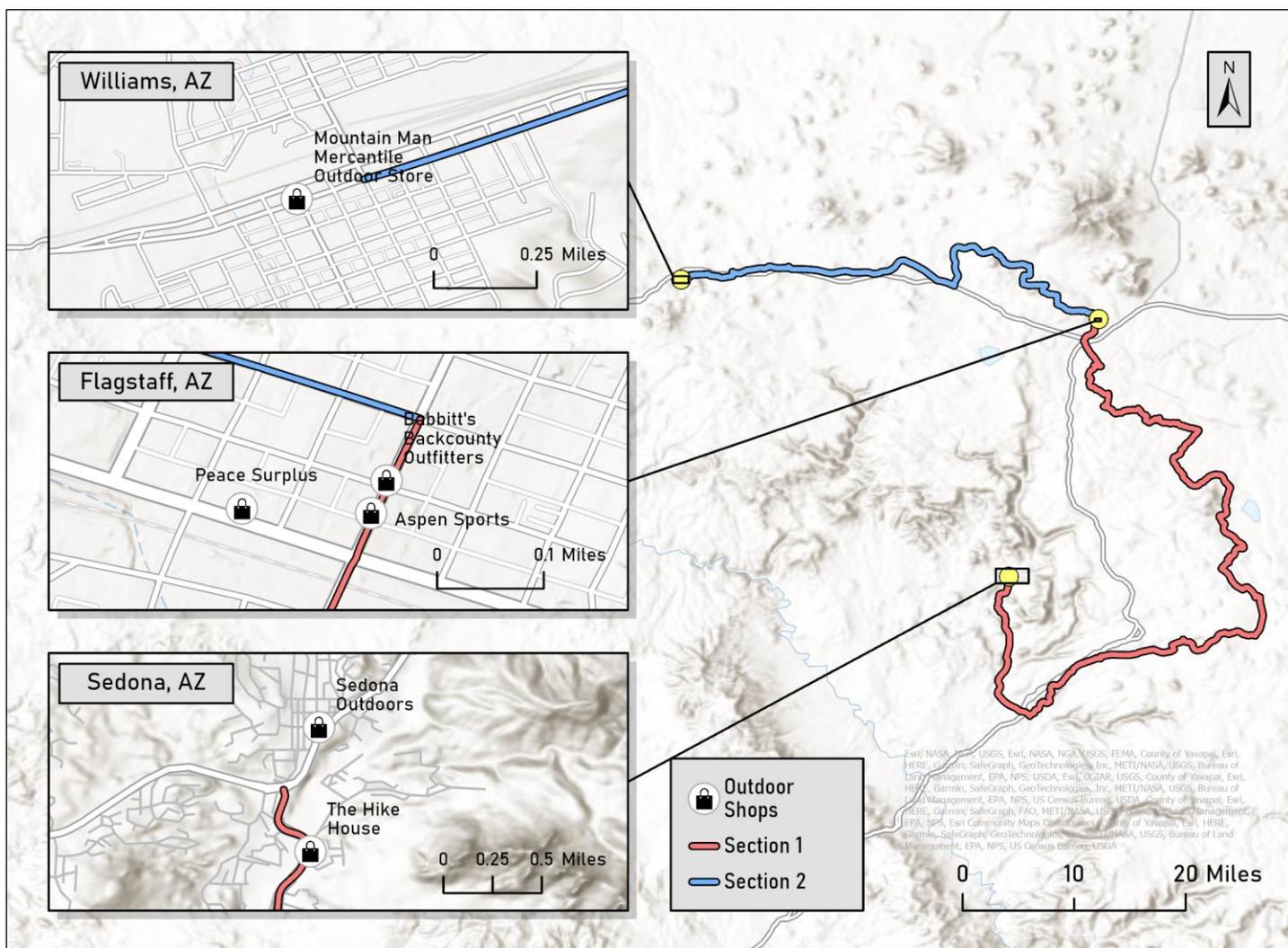
Figure 28: *Outdoor Sports Shops waypoint map layout*

4.2.11 Service Gap Warnings

Route Junctions #11 and #19 include a short description of the service gaps of about 42.4 miles and 32.8 miles, respectively. For most travelling the trail, these service gaps will likely be an inconvenience, and most would stay overnight at Mormon Lake Village to minimize time without available amenities. It is of utmost importance to warn the trail user of these service gaps, so the Service Gap Warnings waypoint type was created. This waypoint type follows a similar format to Route Junctions and was created using the same method of creating an empty point feature class and placing a point along the route line using edge snapping to maintain topological correctness. Compared to the brief description of the service gaps in the Route Junctions waypoint type, the description here gives more specific details about mileage and how to access workarounds. The first Service Gap Warning waypoint was placed on the southern edge of Village of Oak Creek, which is the last place to access amenities before reaching Mormon Lake Village without taking the detour. The second point was placed on the northern edge of Lake Mormon village, where amenities cannot be accessed until the Chevron on Lake Mary Rd.

Table 13: Service Gap Warnings waypoint attribute table

Name	Description
Service Gap Warning	There are no services south of this traffic circle for about 42.4 miles until Mormon Lake Village while on-trail. You can access services via a 5.4-mile one-way route detour at the junction of Forest Service Rd. 618 and Blue Grade Rd. in about 7.5 miles.
Service Gap Warning	There are no services after Mormon Lake Lodge for about 32.8 miles until the Chevron on Lake Mary Rd. just south of Flagstaff.

Mileages for service gaps were calculated by trimming the route line feature class between areas with service gaps, then measuring the mileage of the trimmed segment. To do this, I made a copy of the completed route line feature class to not manipulate the completed segment. The first distance measured resulted in 42.43 miles. This process was repeated with the second service gap, which resulted in 32.80 miles.
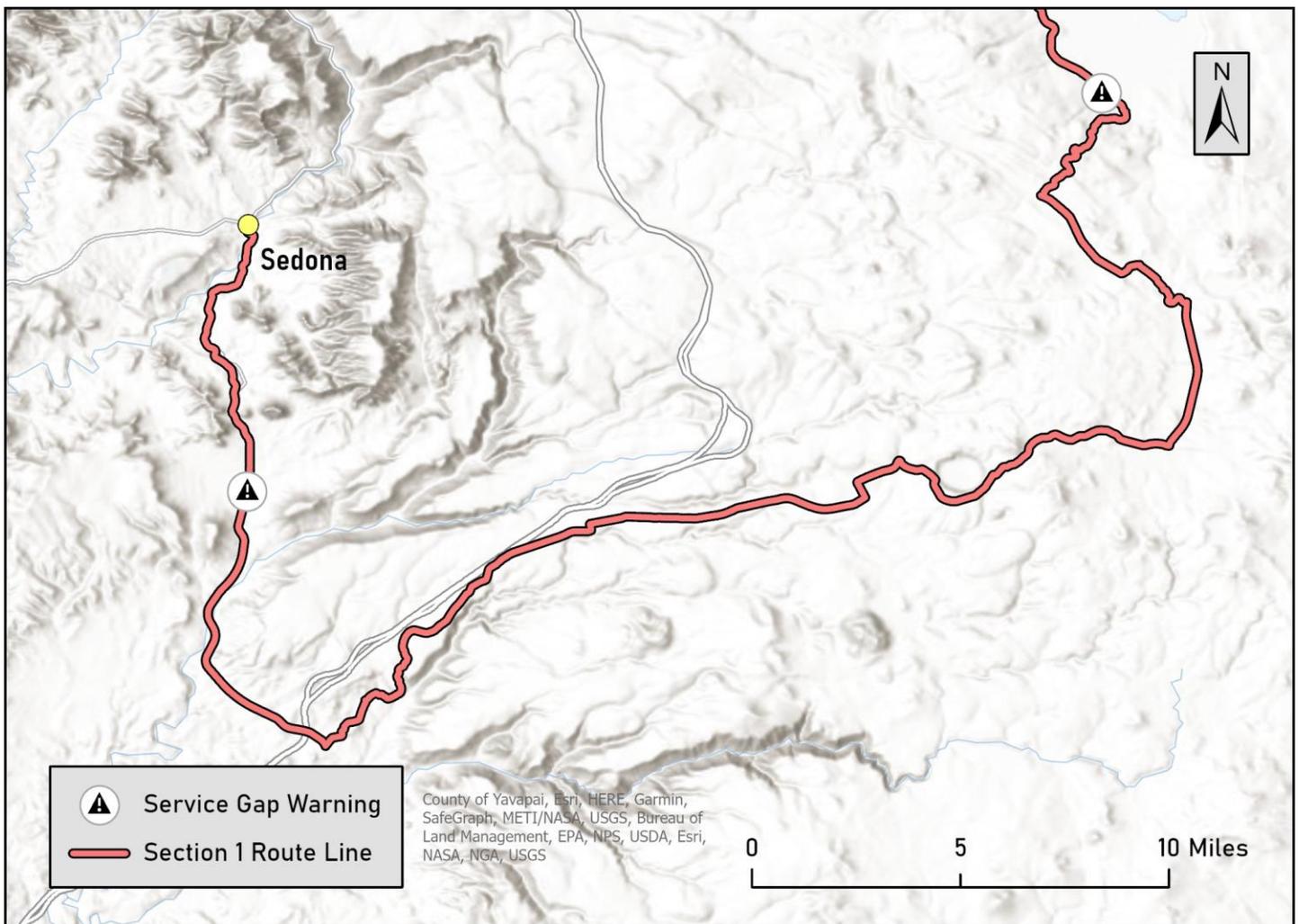
Figure 29: *Service Gap Warnings waypoint map layout*

4.3 GPX File Creation & Results

4.3.1 Data Preparation & Conversion

The previous methods resulted in the completion of the Section 1 (SCT_S1) and Section 2 (SCT_S2) route line feature class as well as nine completed waypoint feature classes. The process of converting the route line files to GPX was simple and started by loading the SCT_S1 dataset into the Features to GPX geoprocessing tool. This tool has several parameters: Input Dataset, Output Dataset, Name Field, Description Field, Z Field, and Date Field. The route line feature classes do not contain any attribute information, so all parameters other than Input and Output Dataset were left blank. The output GPX file was titled the same as the feature class to maintain consistency in the naming scheme. This process was repeated for SCT_S2 and followed the same naming scheme.
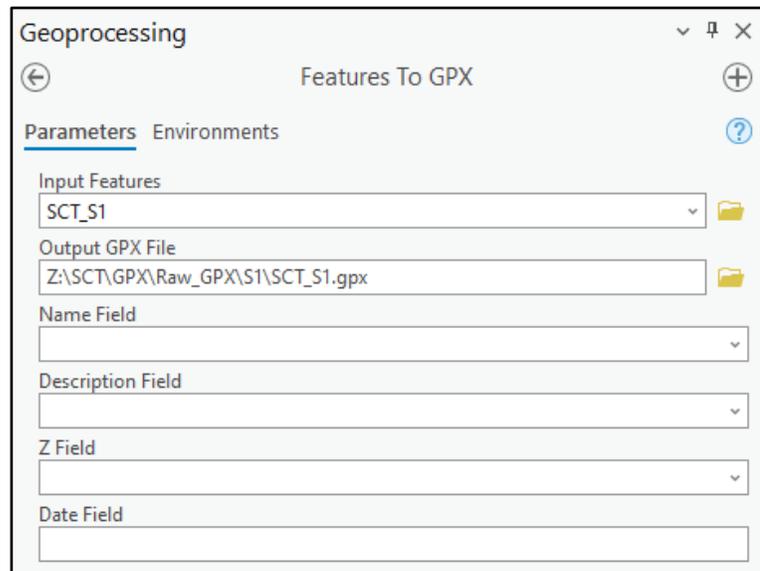
Figure 30: Converting SCT_S1 feature class to a GPX file.
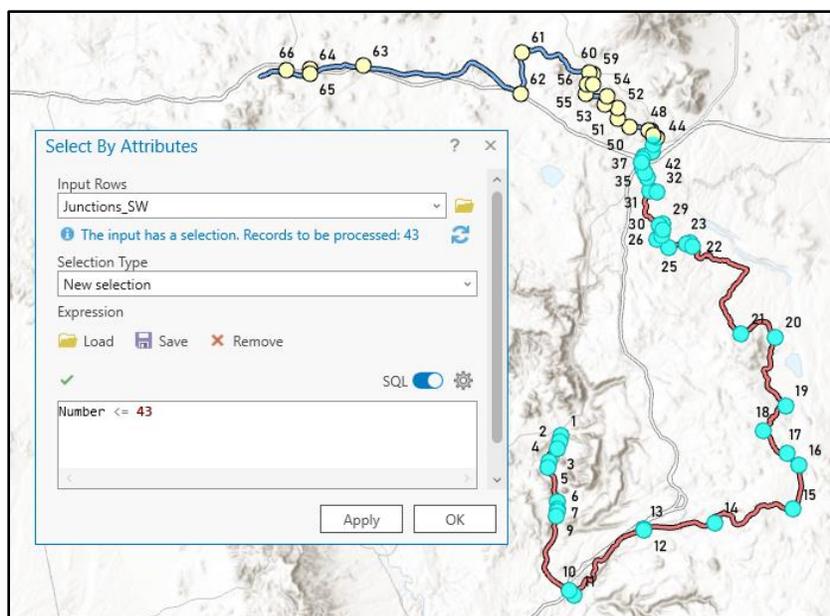
Figure 31: Separating Route Junctions into Section 1 and 2

Before the waypoint feature classes are converted to GPX format, the existing data needs to be split into Section 1 and Section 2. This process started by loading the SCT_S1 and SCT_S2 datasets onto a blank map as well as the Route Junctions feature class. It was determined that Route Junctions #1-43 fell within Section 1, so the first 43 attribute tables were selected using a Select by Attributes query (Figure 31). This data was then exported as its own feature class and renamed 'Junctions_S1' and placed into a new 'Waypoints_S1' feature dataset, which will contain all waypoints that fall within Section 1. This process was repeated for Route Junctions #44-66, with the data exported as a feature class titled 'Junctions_S2' and placed within a new 'Waypoints_S2' feature dataset, containing all waypoints that fall within Section 2.

Figure 32: Completed Waypoints geodatabase.

This process was repeated for the rest of the waypoint types and followed the same naming scheme. Unlike Route Junctions, every other waypoint type included overlap in the greater Flagstaff area to maintain information in this area for both sections. Service Gap Warnings only exist within Section 1, so this data was only exported into the Waypoints_SW and

Waypoints_S1 feature datasets. Once this process was completed, each waypoint feature dataset contained all waypoints for each section.

All waypoint feature class to GPX conversions were completed using the Features to GPX geoprocessing tool, starting with Junctions_S1. This tool only takes one dataset at a time, so all datasets for each section were exported individually. All waypoints had the 'Name' and 'Description' field of their attribute tables set to the Name Field and Description Field parameters, respectively (Figure 30). None of the datasets had elevation associated with them yet, so the Z Field parameter was left blank. The Date Field parameter was also left blank because GPX time tags were not relevant in this project. This process was repeated for every waypoint in the Waypoint_S1 and Waypoint S2 feature datasets (Figure 32).
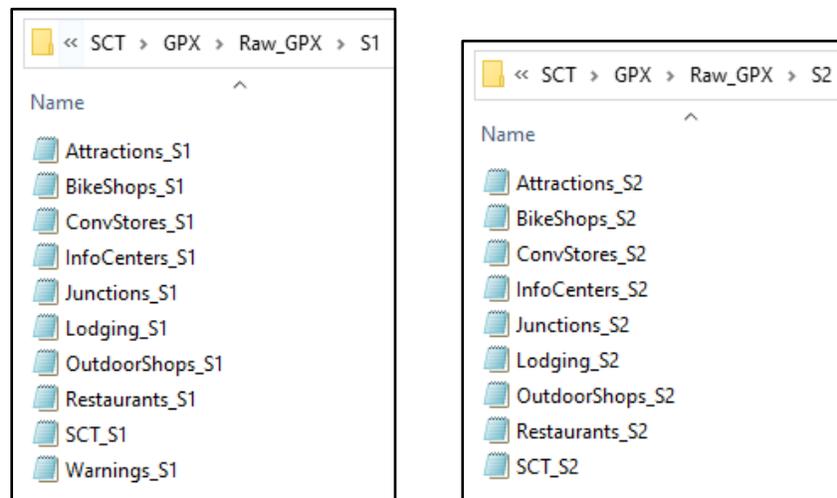
Figure 33: GPX folder layout with all exported datasets

4.3.2 GPX File Editing & Merging

All waypoint types and route lines for the two their own GPX files. Now, they needed to be merged to create one GPX file for each section. Starting with Section 1, all ten GPX files outlined inFigure 34 were loaded into gpx.studio, which is an open-source, web-based GPX file editor, and merged

Figure 34: NoElev_GPX folder

(gpx.studio, 2021). This process was repeated for Section 2, thus creating one merged GPX file for each section with all waypoints and the route line. The files were saved as 'SCT_GPX_S1_NoElev' and 'SCT_GPX_S2_NoElev' to signify that elevation data had not been applied to them yet (Figure 34).
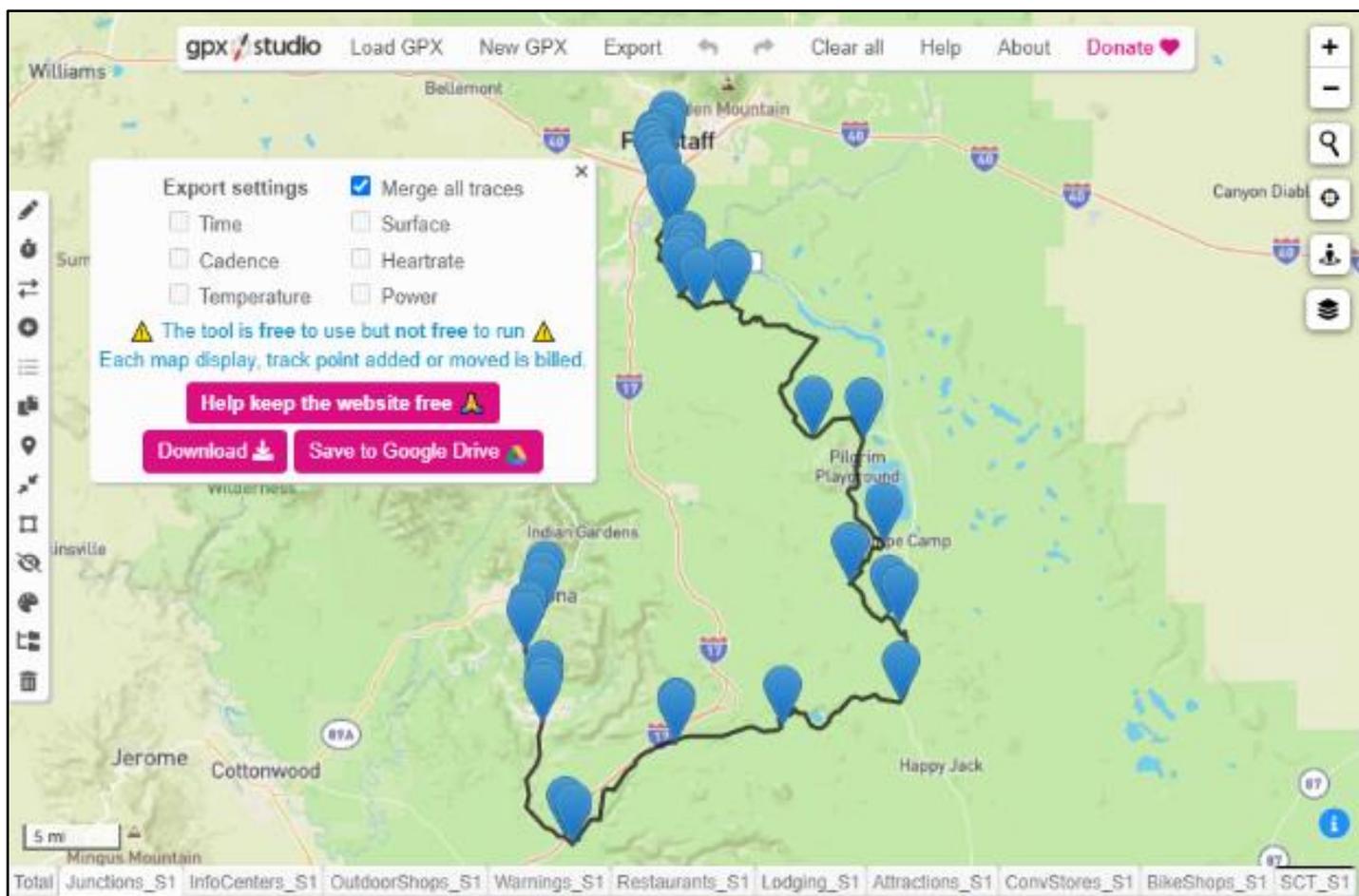
Figure 35: *gpx.studio interface showing Junctions_S1 and SCT_S1 GPX Files and the exporting process.*

Elevation data is integral to GPX file use as it will give the user information on slope gradients, climbs, and elevation change. To add elevation data, each merged file ('SCT_GPX_S1_NoElev' and 'SCT_GPX_S2_NoElev') was uploaded to GPS Visualizer, which is another open-source, web-based GPX file editor that takes GPX files and populates the elevatgion attribute (shown as <ele></ele>) within its file structure (Schneider, 2003). GPX Visualizer sources its elevation data from the U.S. Geological Survey's (USGS) National Elevation Dataset (NED), which contains 1 arc-second (~30-meter) resolution elevation values across the United States, Canada, and Mexico (Gesch et al., 2018). The new files with elevation data were saved as 'SCT_GPX_S1' and 'SCT_GPX_S2'.

Figure 37: GPS Visualizer conversion process

Figure 36: Final GPX output files

Figure 38: Waypoint entry with elevation value populated

The last edit done to the main GPX files was adding a type attribute to each waypoint. The type attribute (shown as <type></type>) attribute allows GPS applications to read each waypoint type (Route Junctions, Attractions, etc), rather than just an unsorted collection of waypoints. As these are an optional parameter in the file structure, the GPX files did not contain them yet. To start, each output file from GPS Visualizer was opened using Notepad. Then, the type attribute manually entered in the first waypoint entry (Figure 41), which happened to be the 76 gas station within the Grocery/Convenience Stores waypoint type. The type attribute was populated with the text 'Grocery/Convenience Stores' and was applied to every waypoint in that category. This process was repeated for every GPX file, thus completing the GPX file creation process.

```
<wpt lat="34.762119806" lon="-111.645117392">
    <ele>1665.6</ele>
    <name>Blue Grade Rd/Stoneman Lake Rd</name>
    <desc>Turn right onto Stoneman Lake Rd.</desc>
    <type>Route Junctions</type>
</wpt>
```
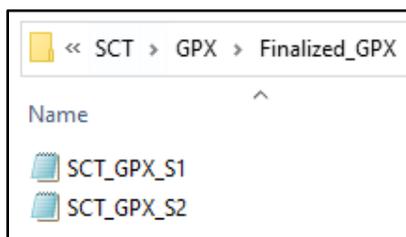
Figure 39: Waypoint entry from Figure 40 with the type attribute populated.

4.3.3 Ride with GPS Optimization

Not all programs read GPX files the same and certain parameters are ignored when uploaded. This is the case with Ride with GPS (RWGPS), which does not recognize the 'type' attribute in it's GPX file structure (Ham & King, 2007). Because of this, all waypoints show up as the same category and contain the same icon. Since RWGPS is one of the most popular bike navigation applications, both Section 1 and Section 2 GPX files were edited to be optimized for

Figure 40: *RWGPS upload page.*

RWGPS. To begin, I made a copy of the completed Section 1 GPX file (SCT_GPX_S1.gpx) and removed all Route Junction waypoints using Notepad. RWGPS automatically provides directions when navigating a route line, so having waypoints for this would be redundant for those who wish to navigate the trail using this program. After the Route Junctions were removed, the file was renamed to 'SCT_S1_RWGPS.gpx' to signify that this GPX file was optimized for RWGPS. After this was completed, I created a Ride with GPS account (Premium Subscription),
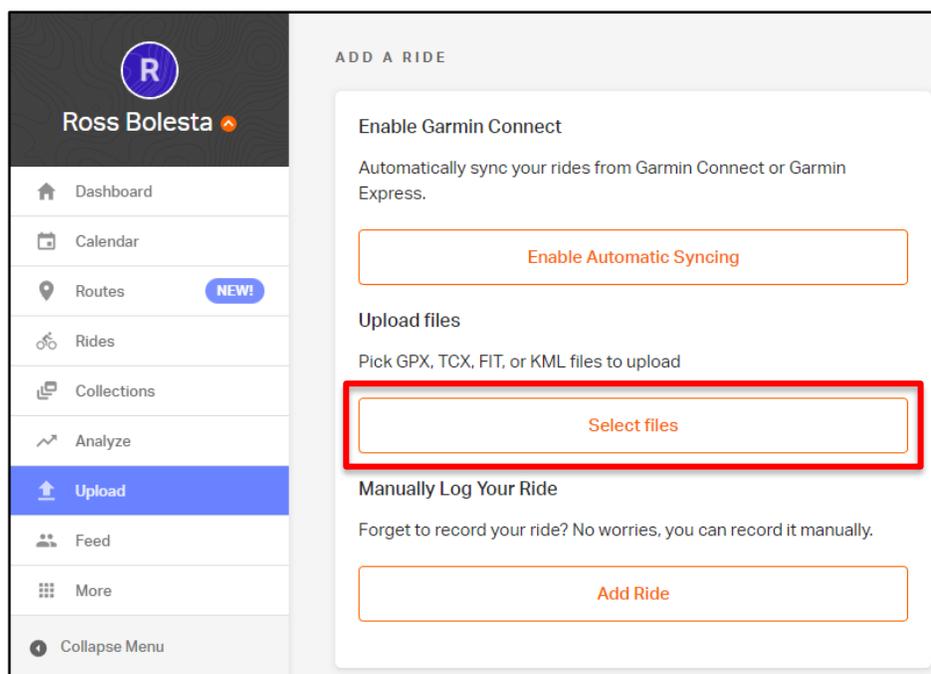
Figure 41: SCT_S1_RWGPS.gpx shown with default icons in the RWGPS editor interface.

which allowed me to fully edit any uploaded route files. RWGPS accepts multiple different file extensions including GPX files. SCT_S1_RWGPS.gpx was uploaded to the RWGPS web application, which allowed me to see the completed route line and all 126 waypoints associated with Section 1 (Figure 41). As expected, all waypoints showed up as the same waypoint type. To fix this, I clicked the 'Edit' tab, which directed me to the editor tool within the RWGPS interface.

The editor within RWGPS contains a variety of tools to alter route lines and waypoints, generate elevation profiles, detect gradient changes, and much more. To optimize this for use in the RWGPS interface, the waypoint icons needed to be edited manually. This was because each waypoint was symbolized by the 'i' icon, which is a 'Generic' waypoint type. As an example, Figure 44 shows the first waypoint, the Sedona Public Library within the Information Centers waypoint type, which was located west of the southern terminus in the West Sedona area. Once clicked, the waypoint pops up and lists the Name and Description fields along with an icon drop down on the tops were automatically populated with the 'Generic' waypoint icon upon

Figure 42: Changing waypoint icons in RWGPS web editor.

Table 14: *Waypoint types with RWGPS icon match*

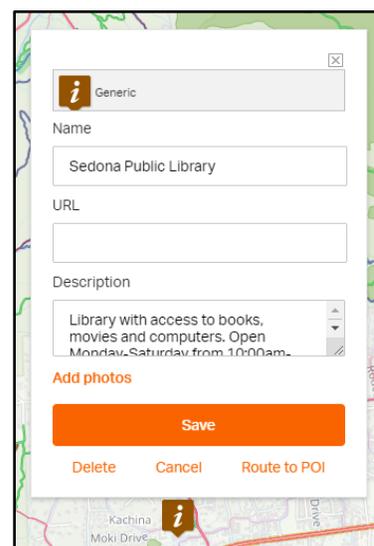| Waypoint Type	RWGPS Icon Match
Lodging	'Lodging'
Restaurants	'Food'
Grocery/Convenience Stores	'Convenience Store'
Information Centers	'Library'
Attractions	'Viewpoint, Monument, Park'
Bike Shops	'Bike Shop'
Outdoor Sports Stores	'Shopping'
Service Gap Warnings	'Caution'

uploading. The RWGPS software contains default waypoint icon types, which were closely matched to the waypoint types I created in this project (Table 13). Lodging, Restaurants, Grocery/Convenience Stores, Bike Shops, Outdoor Sports Stores and Service Gap Warnings all had very close matches. I symbolized Information Centers with the Library icon as this was the most accurate fit amongst all RWGPS waypoint icons. No single RWGPS icon fit well with my Attractions waypoint type, so I used the Viewpoint, Monument and Park icons to symbolize these. Once all icons were updated, I renamed the route 'Sun Corridor Trail: Sedona, AZ to Flagstaff, AZ' (Figure 46 and 47). This process was repeated for Section 2 (Figure 48 and 49). Both routes are accessible to the public using the links in the table below.

Table 15: *RWGPS Routes with accessible URL*

RWGPS Route Title	URL
Sun Corridor Trail: Sedona, AZ to Flagstaff, AZ	https://ridewithgps.com/routes/42346397
Sun Corridor Trail: Flagstaff, AZ to Williams, AZ	https://ridewithgps.com/routes/42346557

5. Discussion

5.1 Recommendations to the SCTA

Section 1 contains a service gap longer than the SCTA's anticipation of a maximum of 30-40 miles between communities with access to amenities. This section is from the southern edge of Village of Oak Creek to Mormon Lake Lodge, spanning for 42.4 miles. The service gap also contains the longest and steepest climb between Sedona and Williams, which climbs 3,706 ft and lasts for 20.8 miles. Due to the compounding difficulties of this section, the SCTA should recommend that trail users stay the night in the Village of Oak Creek area before attempting this section. Although Sedona is a popular tourist destination, attempting to travel to Mormon Lake from there could add approximately 15 miles to the overall trip, which could put those who are less experienced at risk of exhaustion in areas without access to amenities. Additionally, Sedona receives and overwhelming amount of tourism during peak seasons, resulting in overcrowding, and has increased in popularity since the start of the COVID-19 pandemic (Pearson, 2022). This makes for a great opportunity for the SCTA to encourage tourism in Village of Oak Creek, which can help divert additional tourism to the greater Sedona area.

A major finding from the GPX file production is that each navigation application reads waypoint types differently. The final GPX files from Section 1 and 2 were uploaded onto Ride with GPS, AllTrails, and Gaia GPS and ranged from no waypoint differentiation to recognizing only some waypoint types. Because of these inconsistencies, I would recommend that the SCTA works directly with a navigation application developer to optimize the GPX files specifically for that application. I would recommend Ride With GPS, as it is popular for bike touring purposes and contains several features useful for cyclists.

5.2 Project limitations

All projects have their limitations. In this project, the accuracy of the route lines for both sections are limited to the accuracy of the initial datasets highlighted in Figures 4-6. Most of the roads I utilized in the route line came from the Forest Service Roads dataset, which covers several states in the Southwest. Considering the errors that occur in data, an on-the-ground user might experience some of these data issues firsthand. Because of this, accuracy from a trail user's perspective could be off from the actual road segments and could be reflected in the final GPX file outputs. Ground-testing these files is encouraged for future work to assess their accuracy and usefulness. Unlike the majority of the route lines, most waypoint types, other than Route Junctions and Service Gap Warnings, should have a higher level of accuracy. All coordinates obtained for these came from Google Maps, which uses a WGS 1984 datum just like all components of the GPX file creation, so it is highly unlikely that there will be discrepancies between real-world locations and locations contained on the waypoint portion of the GPX files. However, much of the waypoint information can change and become inaccurate through time. Although Inclusion/Exclusion Criteria was created partly to minimize this, businesses can come and go in correlation with the current economic state. Lodging, Restaurants, Outdoor Shops, and Bike Shops waypoint classes are likely to change in the future because of this.

The final GPX outputs contain much potential for further development into fully fledged guides. Due to several smartphone navigation applications not recognizing waypoint types properly, these files are not meant to be fully-fledged guides as is. Rather, they serve as a great base for them given their relatively high level of accuracy and the large amount of useful information for touring use. They require minimal additional work to get to a point where they're ready to be used on-trail.

5.3 Future work

It is the hope that this report is outlined in such a way that other SCT participants in the future can use this for reference and maintain the framework of digitally mapping this trail with waypoint information. However, as technologies change, the methods outlined in this report should evolve to reflect more efficient methods related to technological advancements in GIS software. GPX files have also been around for more than two decades and could become obsolete in the coming years, thus potentially rendering them useless in newer forms of smartphone or GPS device technology.

As this is the only portion of the SCT that has been digitally mapped, there is much more work to do regarding the completion of this trail. It is recommended that future SCT participants continue Smath's (2021) strategy of field testing a variety of roads and trails to determine their feasibility for future SCT segments. The accuracy of these route lines could be field-tested and recorded using a smartphone. Like Adam Smath's strategy, the recorded ride files could be brought into GIS software programs as GPX files and compared to the accuracy of the route lines created in this project. It is also advised that future SCT participants tour this route using the GPX files and give feedback on their efficiency and usefulness, as none of them have yet been used in the field. There is a potential for redundancy in the waypoints contained in both sections, which could result in an overwhelming amount of information for bike-touring purposes.

Additionally, RWGPS is not only software that can aid in bike touring. It would be beneficial to upload versions of this to different trail databases such as AllTrails and Gaia GPS. The Raw_GPX folder contains all waypoint types and individual route lines, so there is a high amount of flexibility in future renditions of these sections.

The SCT has the potential to strengthen and diversify the outdoor recreation community. This trail can drastically improve the economies of smaller communities through increased bike tourism, as well as increase quality of life through additional outdoor recreation opportunities. In a time where COVID-19 has negatively affected peoples' physical and mental health, bike touring can provide adventure, exercise, and community (Ufnalska, 2020). The creation of these GPS-based files for trail navigation can allow users of all backgrounds in outdoor recreation to explore the SCT in confidence. The waypoint information contained in these files encourages trail users to shop, eat and stay at local businesses, strengthening the SCTA's economic goals. Distributing these files online via RWGPS could help increase public interest in the completion of this trail at an early stage and could potentially expedite the process. The SCT could be one of the first trails of its kind in the United States at its proposed length, and its completion can be accomplished through consistent collaboration, participation, and patience from those involved.

6. Acknowledgements

I would like to sincerely thank both of my academic advisors, Dr. Frank Vernon and Dr. Amanda Stan. Frank introduced this project to me at a critical point during the end of my first semester. After talking with him, I took a risk by completely switching gears from my previous project and wrote the proposal for this one a short time before that semester ended. I want to extend my gratitude to Amanda for speaking with me before I even entered this graduate program and enthusiastically taking me on as one of her advisees. She also supported me through multiple project changes and timeline extensions, which is greatly appreciated. I would also like to thank Cynthia Nemeth for participating on my committee as well as all other members of the SCTA that eagerly brought me onto this project.

Additionally, I would like to thank those part of my small but tight-knit graduate cohort, especially Ailin McCullough for his intellectual curiosity and sense of adventure, Christopher Phair for his constant support and humor, and Anna Vaughn for her festiveness and kind heart. I would also like to thank my other friends Victoria Lewis, Sharon Lopez, and Danielle Juarez for providing a fun and supportive household to live in during this time. Without those listed above, as well as many others I have met since moving to Flagstaff, I would not have been so lucky to experience a life-changing social atmosphere filled with such incredible people. They will remain my friends for life, and I am truly grateful to say that.

7. References

(2021, July 26). *gpx.studio*. computer software. Retrieved May 2, 2023, from
https://gpx.studio/about.

"About Us." FarOut Guides, February 9, 2022. https://faroutguides.com/about-us/.

Anderson et al., "Sun Corridor Trail Alliance Action Plan." American Trails, February 2021.

https://www.americantrails.org/resources/sun-corridor-trail-alliance-action-plan.

Apodaca et al., "Guidelines for road maintenance levels" United States Forest Service, 2012.

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3793545.pdf

Beaton, C. (2018, June 14). Why you can't really trust negative online reviews. The New York

Times. Retrieved May 2, 2023, from https://www.nytimes.com/2018/06/13/smarter-

living/trust-negative-product-reviews.html

Bowker, J. M., Bergstrom, J. C., & Gill, J. (2017, June). Estimating the Economic Value

and Impacts of Recreational Trails: A Case Study of the Virginia Creeper Rail Trail.

Retrieved May 2, 2023, from

https://journals.sagepub.com/doi/abs/10.5367/000000007780823203

Byers, Justin. "Strava Records 1.8B Uploads amid Connected Fitness Boom." Front Office

    Sports. Front Office Sports, December 8, 2021. https://frontofficesports.com/strava-

    records-1-8b-uploads-amid-connected-fitness-boom/.

Curry, David. "Strava Revenue and Usage Statistics (2021)." Business of Apps, November 11,

    2021. https://www.businessofapps.com/data/strava-statistics/.

Czinar, Mare. "Planting the Seeds for the Sun Corridor Trail." PHOENIX magazine, November

    4, 2021. https://www.phoenixmag.com/2021/09/21/planting-the-seeds-for-the-sun-

    corridor-trail/.

Dustin, Daniel, Larry Beck, and Jeff Rose. "Landscape to Techscape: Metamorphosis along the

    Pacific Crest Trail." IJW. International Journal of Wilderness, April 11, 2019.

    https://ijw.org/landscape-to-techscape/.

Foster, Dan. "GPX Explained." Topographix. Accessed December 9, 2021.

    https://www.topografix.com/gpx_for_users.asp.

Gee, Taylor. "How the Guthook App Revolutionized Thru-Hiking." Outside Online. Outside,

    June 12, 2019. https://www.outsideonline.com/outdoor-adventure/hiking-and-

    backpacking/guthook-guides-app-mapping-thru-hiking/.

Gesch, D. B., Evans, G. A., Oimoen, M. J., & Arundel, S. (2018, December 1). The

  National Elevation Dataset. Retrieved May 2, 2023, from

  https://www.usgs.gov/publications/national-elevation-dataset.

Gress, S. & Hall, T. (2017). Diversity in the Outdoors: National Outdoor Leadership School

  Students' Attitudes About Wilderness. Sage Journals. Retrieved May 2, 2023, from

  https://journals.sagepub.com/doi/10.1177/1053825916689267

Ham, Z., & King, C. (2007). Ride With GPS. computer software. Retrieved May 3, 2023,

  from ridewithgps.com.

Hazzard, Cris. "What Is a GPX File?" HikingGuy.com. HikingGuy, July 4, 2021.

  https://hikingguy.com/how-to-hike/what-is-a-gpx-file/.

"History - Explore the Arizona Trail – the Arizona Trail." Arizona Trail Association. (n.d.).

  Accessed December 9, 2021. https://aztrail.org/the-trail/history/.

Korpilo, Silviya, Tarmo Virtanen, and Susanna Lehvävirta. "Smartphone GPS Tracking—

  Inexpensive and Efficient Data Collection on Recreational Movement." Landscape and

  Urban Planning 157 (October 7, 2016): 608–17.

  https://doi.org/10.1016/j.landurbplan.2016.08.005.

Lindsey, Joe, Eben Weiss, The Editors, and Stephanie Pearson. "More People Are Cycling during COVID-19. That Matters." Outside Online, June 27, 2021. https://www.outsideonline.com/outdoor-gear/bikes-and-biking/more-people-cycling-coronavirus-pandemic/.

Mac. "The Pacific Crest Trail Hiker Survey (2021)." Halfway Anywhere, March 12, 2022. https://www.halfwayanywhere.com/trails/pacific-crest-trail/pct-hiker-survey-2021/.

Nudelman, G. (2022, April 11). Bike tourism is quickly becoming luxury travel's Next Big Frontier. Barron's. Retrieved May 2, 2023, from https://www.barrons.com/articles/bike-tourism-is-quickly-becoming-luxury-travels-next-big-frontier-01649702871

Pearson, S. (2022, March 17). Overtourism Has Reached a Dangerous Tipping Point—Am I Part of the Problem? Outside. Retrieved May 3, 2023, from https://www.outsideonline.com/adventure-travel/essays/sedona-overtourism-last-tourist/

Rogers, Andrew G., and Yu-Fai Leung. "Smarter Long-Distance Hike: How Smartphones Shape Information Use and Spatial Decisions on the Appalachian Trail." International Journal of Wilderness, 2020. https://ijw.org/smartphones-shape-information-use-appalachian-trail/.

Schwedhelm, Alejandro, Wei Li, Lucas Harms, and Claudia Adriazola-Steil. "Biking Provides a Critical Lifeline during the Coronavirus Crisis." WRI, April 17, 2020. https://www.wri.org/insights/biking-provides-critical-lifeline-during-coronavirus-crisis.

Smath, Adam. "Sun Corridor Trail Development: Coconino National Forest, Arizona."

Practicum Report, Northern Arizona University, 2021.

"Sporting Goods, Home Fitness, and Cycling Sales Surge in the U.S., Reports the NPD Group."

The NPD Group, July 7, 2021. https://www.npd.com/news/press-releases/2020/sporting-

goods-home-fitness-and-cycling-sales-surge-in-the-us-reports-the-npd-group/.

Schneider, A. (2003, March). GPS Visualizer. computer software. Retrieved May 2, 2023, from

gpsvisualizer.com.

Stragier, Jeroen, Mariek Vanden Abeele, Peter Mechant, and Lieven De Marez. "Understanding

Persistence in the Use of Online Fitness Communities: Comparing Novice and

Experienced Users." Computers in Human Behavior 64 (June 25, 2016): 34–42.

https://doi.org/10.1016/j.chb.2016.06.013.

Ufnalska, Sylwia. "Physical Activity Outdoors as an Alternative to Lockdown: The Three Cs

Strategy." U.S. National Library of Medicine, 2020.

https://www.ejmanager.com/mnstemps/10/10-1604859731.pdf?t=1604903670.