Effective Distance and Visual Connectivity in Glacier National Park, Montana

ANALYSIS OF OPTIMAL PATHS AND VIEWSHEDS FOR EMERGENCY RESPONSE TEAMS

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Glacier National Park. Image: NPS

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Mt. Oberlin, Glacier National Park. Image: Getty

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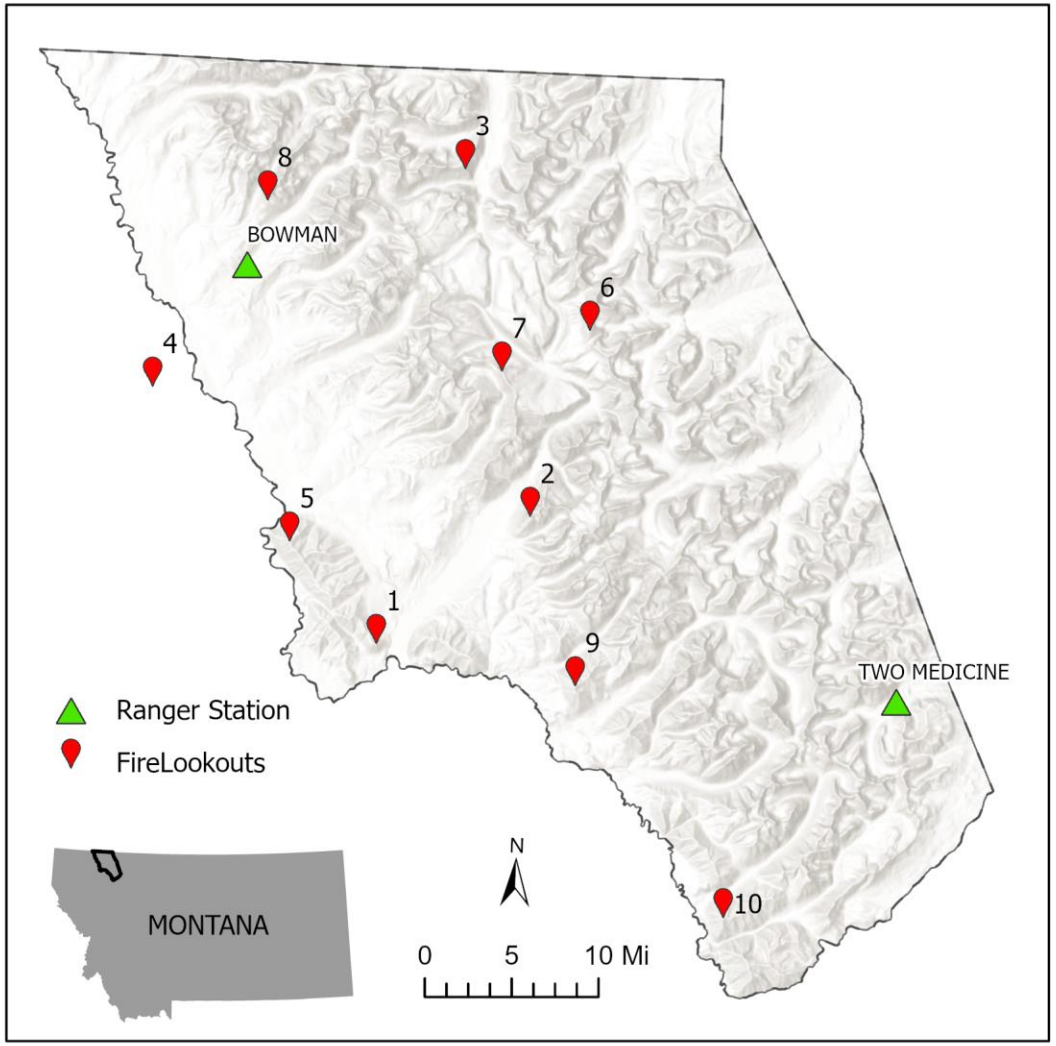
Introduction

The National Park Service is collecting data about ranger stations and fire lookout towers in Glacier National Park to evaluate preparedness and efficacy of emergency response capabilities.

There are currently two ranger stations and nine fire lookout stations located within the park (Fig. 1). NPS has requested analyses to answer the following questions:

1. What is the best path to travel between the two ranger stations?
2. Which areas of the park can be seen from each ranger station and fire lookout tower?
3. Are there any considerable gaps in viewshed coverage from existing infrastructure in the park?

Map 1. Glacier National Park



Note: Tower 4 was excluded from analysis due to it's location outside park boundary.

Context

Fire lookout station. Image: The Billings Gazette

The two ranger stations (Bowman in the north and Two Medicine in the south) serve as headquarters for NPS search and rescue teams. In addition to responding to emergencies like lost or injured hikers, NPS staff monitor the park for signs of natural disasters and severe weather events like wildfires, floods, and avalanches.

NPS is considering construction of an additional fire lookout tower. Managers have requested geospatial analysis to evaluate existing infrastructure in the park. Analysis will examine the location and viewsheds of both ranger stations and all nine fire lookout towers, as well as identify the optimal path for traveling between the two ranger stations.

Methodology: Data Sources

Table 1. Source Data Information

Data	Layer Name	Source	Metadata	Projection	Resolution	Accuracy
Park Boundary	Boundary2003	NPS	XML	NAD 1983 UTM Zone 12N	1:24,000	12m horizontal error
Roads	GLAC_roads_public_Dec2014	NPS	XML	NAD 1983 UTM Zone 12N	1:24,000	12m horizontal error
Facilities	GLAC_Facility_shp	NPS	XML	NAD 1983 UTM Zone 12N	1:24,000	1-2m horizontal error
Elevation	GLAC_10mDEM	NPS	XML	NAD 1927 UTM Zone 12N	10m	10m horizontal error
Vegetation	glacgisdata	NPS	XML	NAD 1983 UTM Zone 12N	1:24,000	80% accuracy
Streams	Glac_streams	NPS	XML	NAD 1927 UTM Zone 12N	1:24,000	12m horizontal error
Lakes	Glac_lakes	NPS	XML	NAD 1927 UTM Zone 12N	1:24,000	12m horizontal error

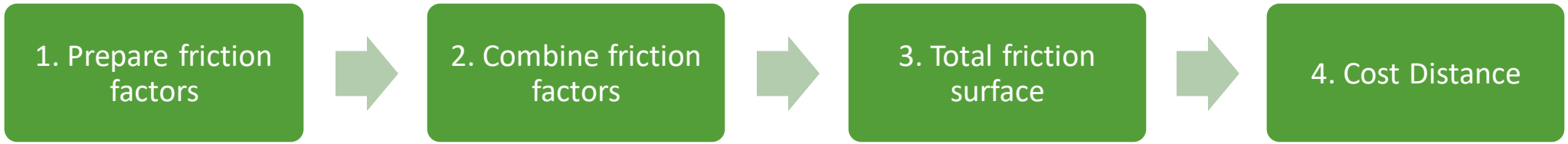
Note: elevation, streams, and lakes reprojected to NAD 1983 UTM Zone 12N.

Methodology: Data Preparation

In order to calculate the lowest cost path (optimal path) between the two ranger stations, it is necessary to create a cost distance surface. This is a layer which incorporates terrain factors that facilitate or impede movement through the park. The source locations (ranger stations) are then added, and cost distance is calculated from each source to every location in the park.

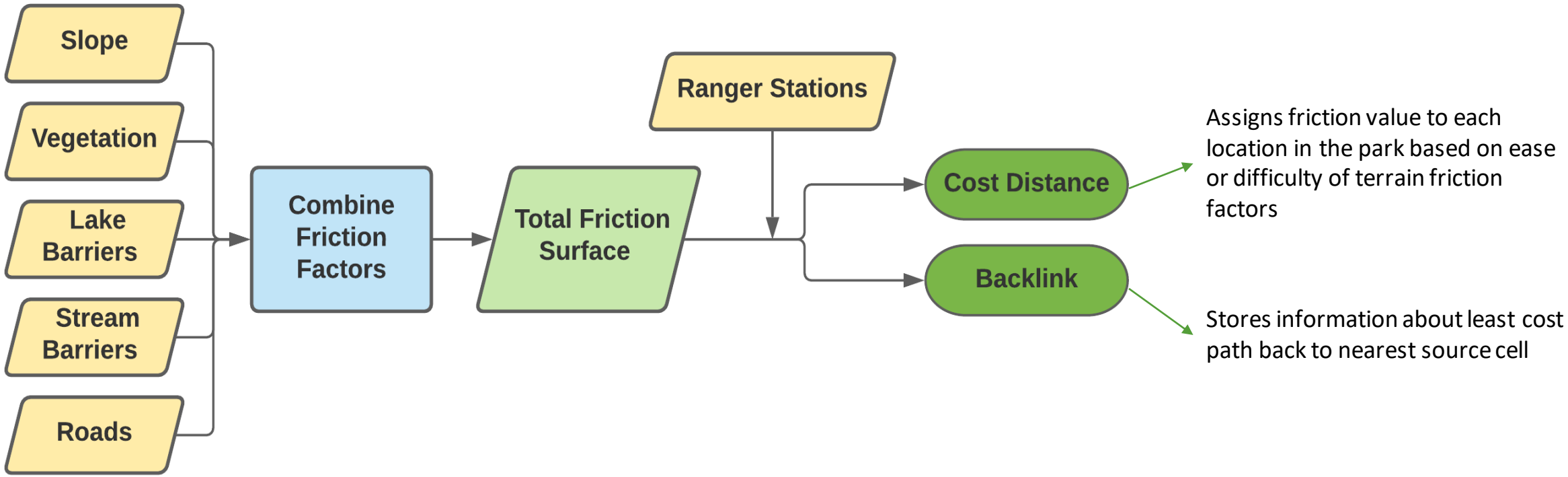
- Friction factors measure how difficult it is to travel throughout the park. In this analysis, friction units were assigned as minutes per meter. Easily accessible areas are assigned low friction values and areas with difficult or impassable terrain are assigned high friction values.

Figure 1. Summary of cost distance process



Methodology: Data Preparation

Figure 2. Terrain factors for cost distance surface



Methodology: Cost Path

Cost path calculates the lowest cost path from one location to another, measured in friction values (in this analysis: minutes per meter).

- Calculation of least-cost path from the Two Medicine ranger station to the Bowman ranger station requires input data about the source location (Two Medicine HQ), the cost to travel across each location in the park (cost distance), and the route or direction to the neighboring lowest cost location (backlink).

Figure 3. Procedure: Cost path

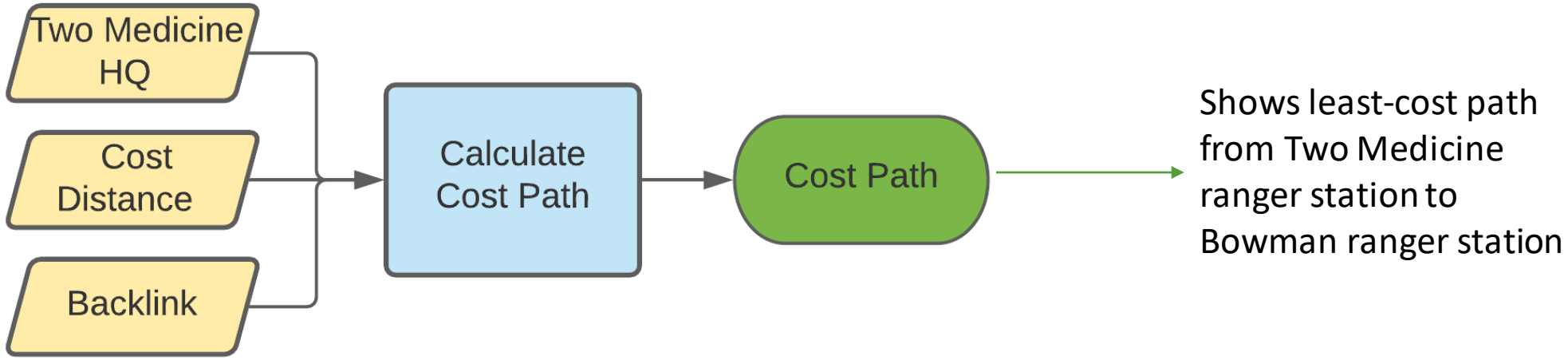


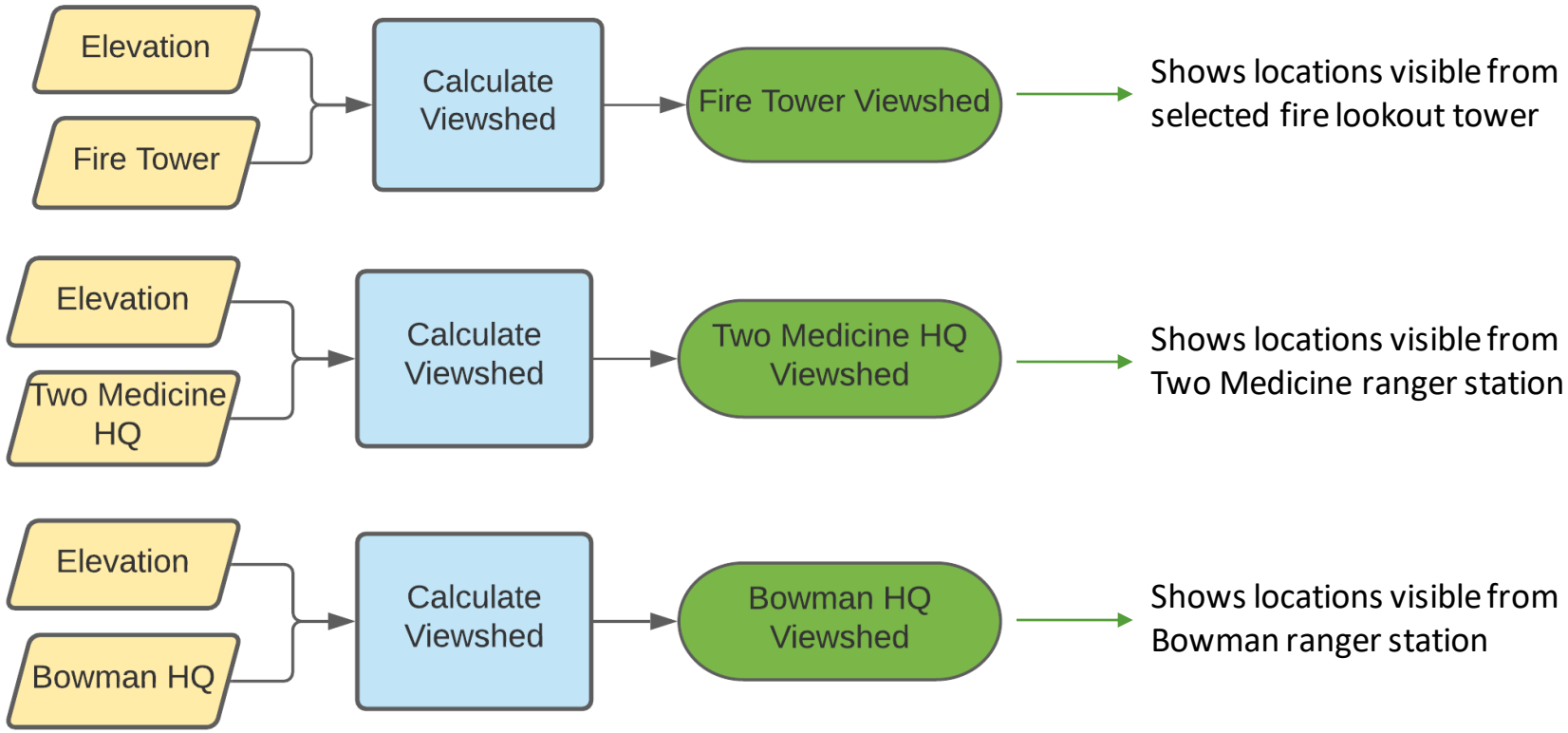
Figure 4. Procedure: Ranger station viewsheds

Methodology: Viewsheds

Viewshed analysis provides information about which locations can be seen by a given observer or observation location.

Calculation of viewsheds for each ranger station requires input data for elevation and source location (location of ranger station or fire tower).

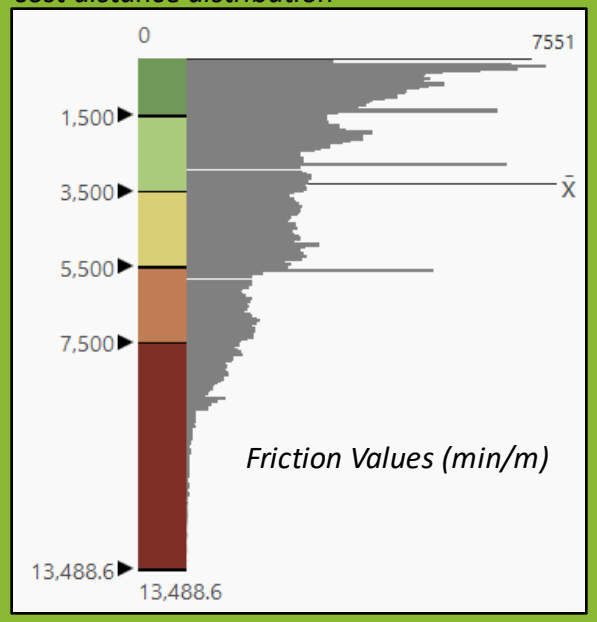
Figure 4. Procedure: Viewshed



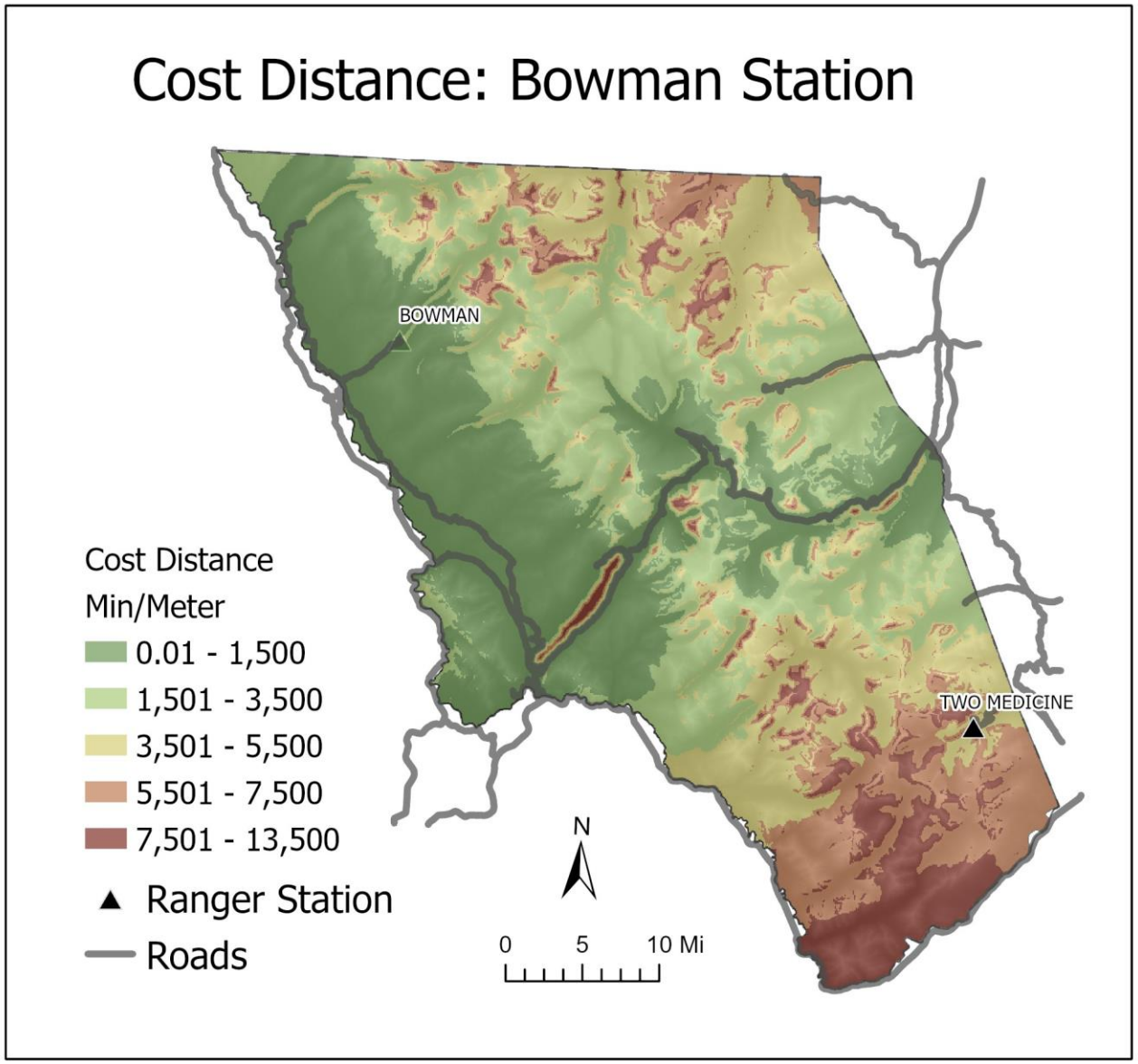
Results: Cost Distance

Map 1 illustrates the cost distance surface as measured from Bowman station. Fig. 5 shows the distribution of values in the cost distance surface.

Figure 5. Histogram: Bowman station cost distance distribution



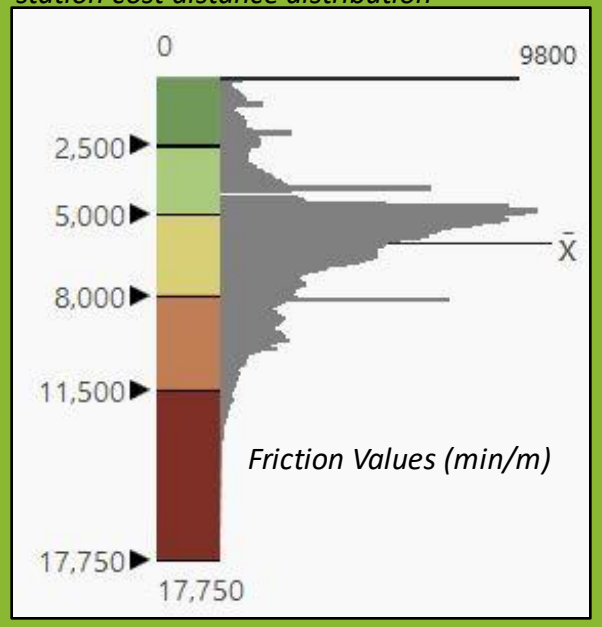
Map 2. Cost distance surface for Bowman station



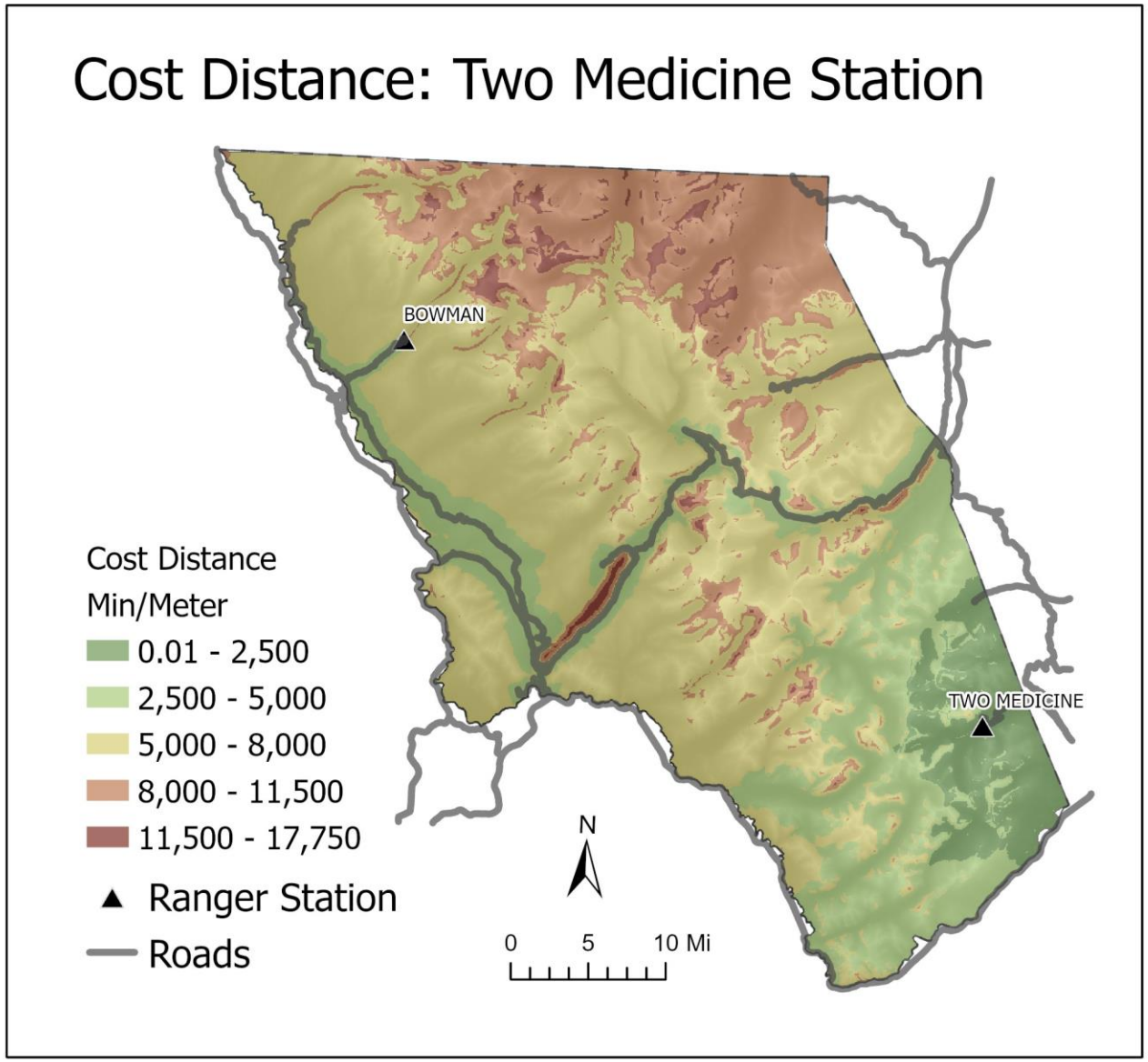
Results: Cost Distance

Map 2 illustrates the cost distance surface as measured from Two Medicine station. Fig. 6 shows the distribution of values in the cost distance surface.

Figure 6. Histogram: Two Medicine station cost distance distribution



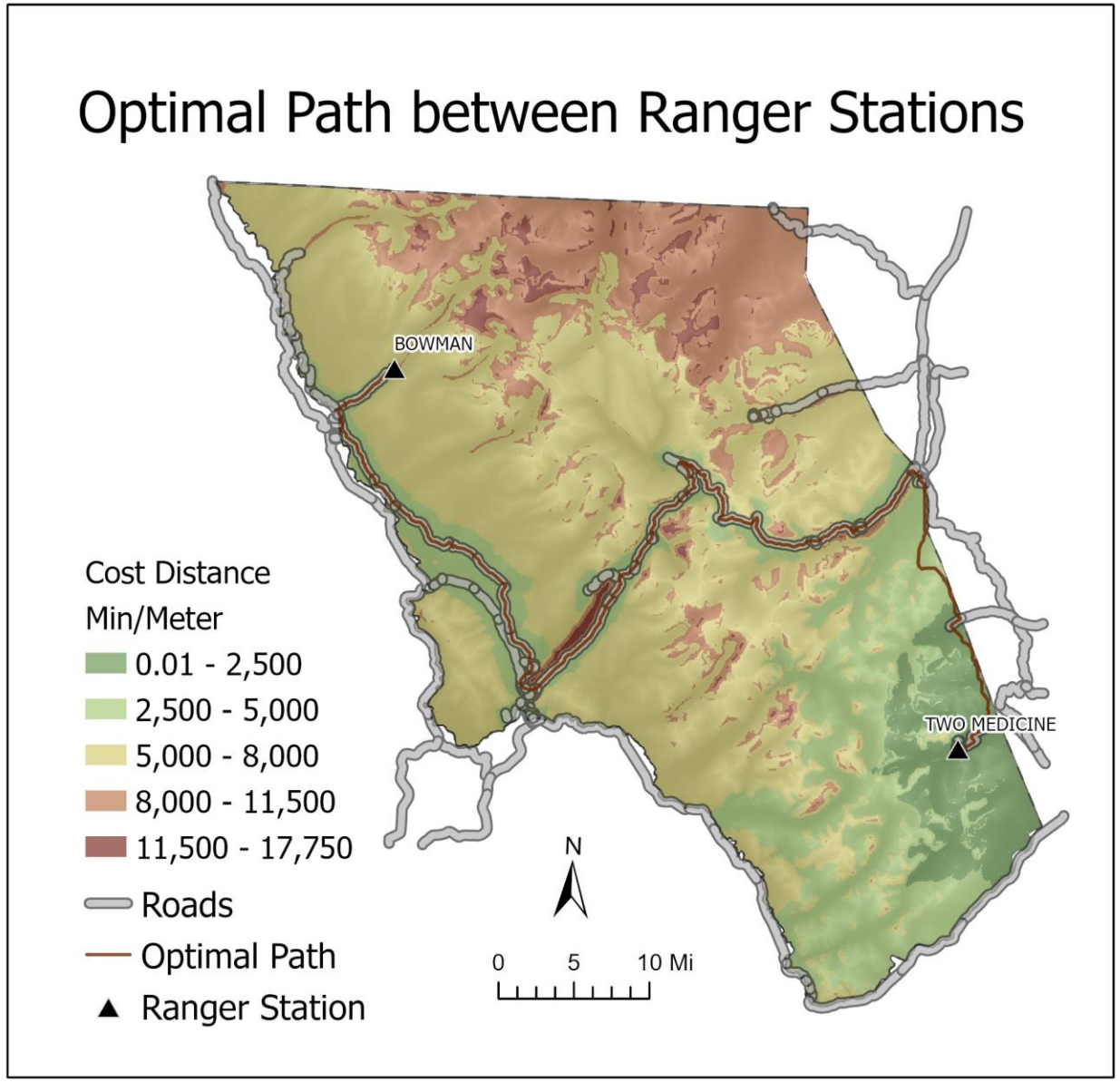
Map 3. Cost distance surface for Two Medicine station



Results: Optimal Path

- Cost Path tool used terrain data from input friction surfaces (cost distance) and stored data about route to neighboring least-cost location (backlink) to create a least-cost path.
- **Least cost path illustrates the optimal route to travel between the two ranger stations.**

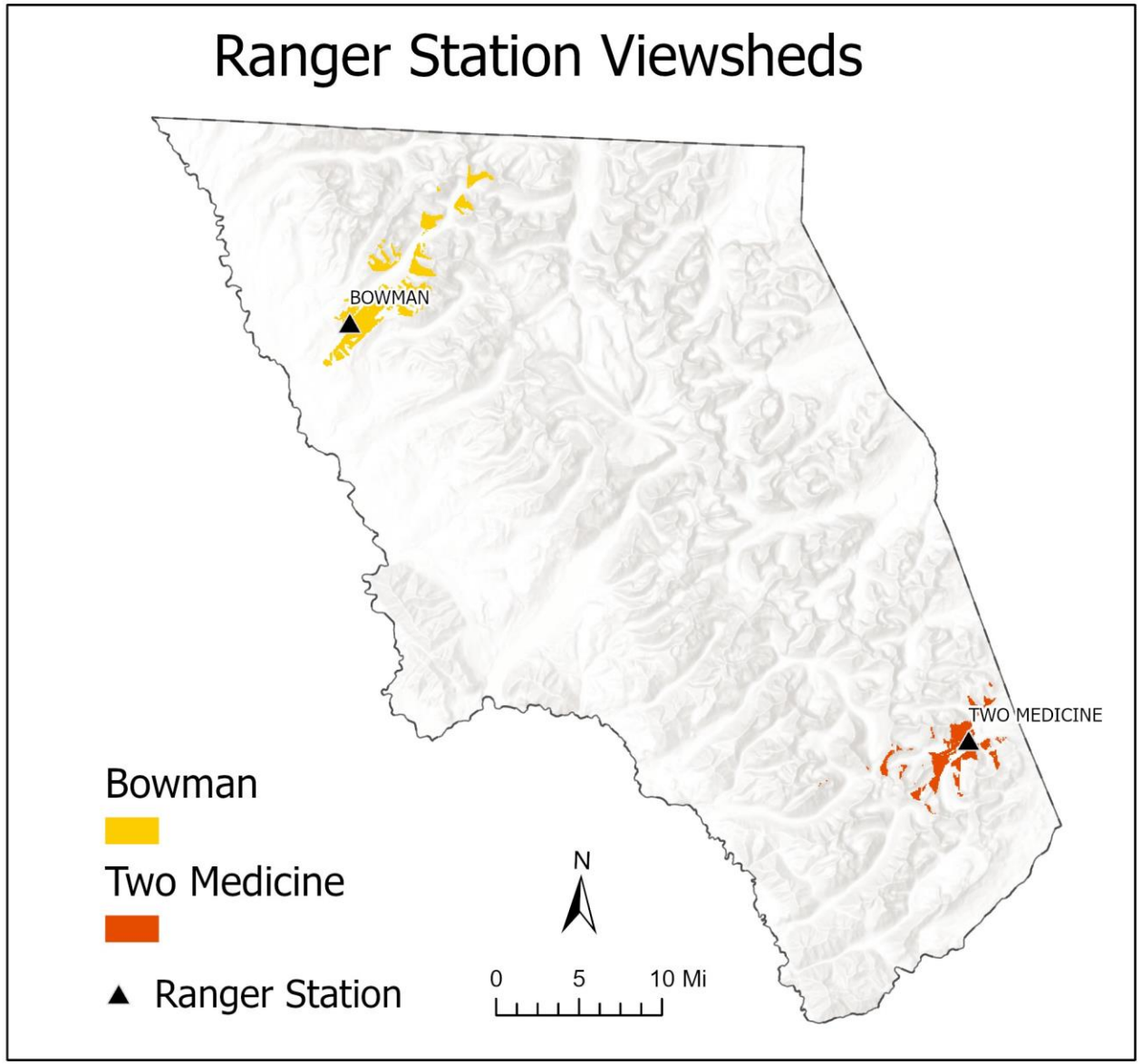
Map 4. Optimal path between ranger stations



Results: Ranger Station Viewsheds

Unlike fire lookout towers, which are elevated and range from 10-20m in height which allows for added view of the surrounding area, ranger stations are built on the ground and thus have viewsheds which are more limited in distance and total area.

Map 5. Ranger station viewsheds

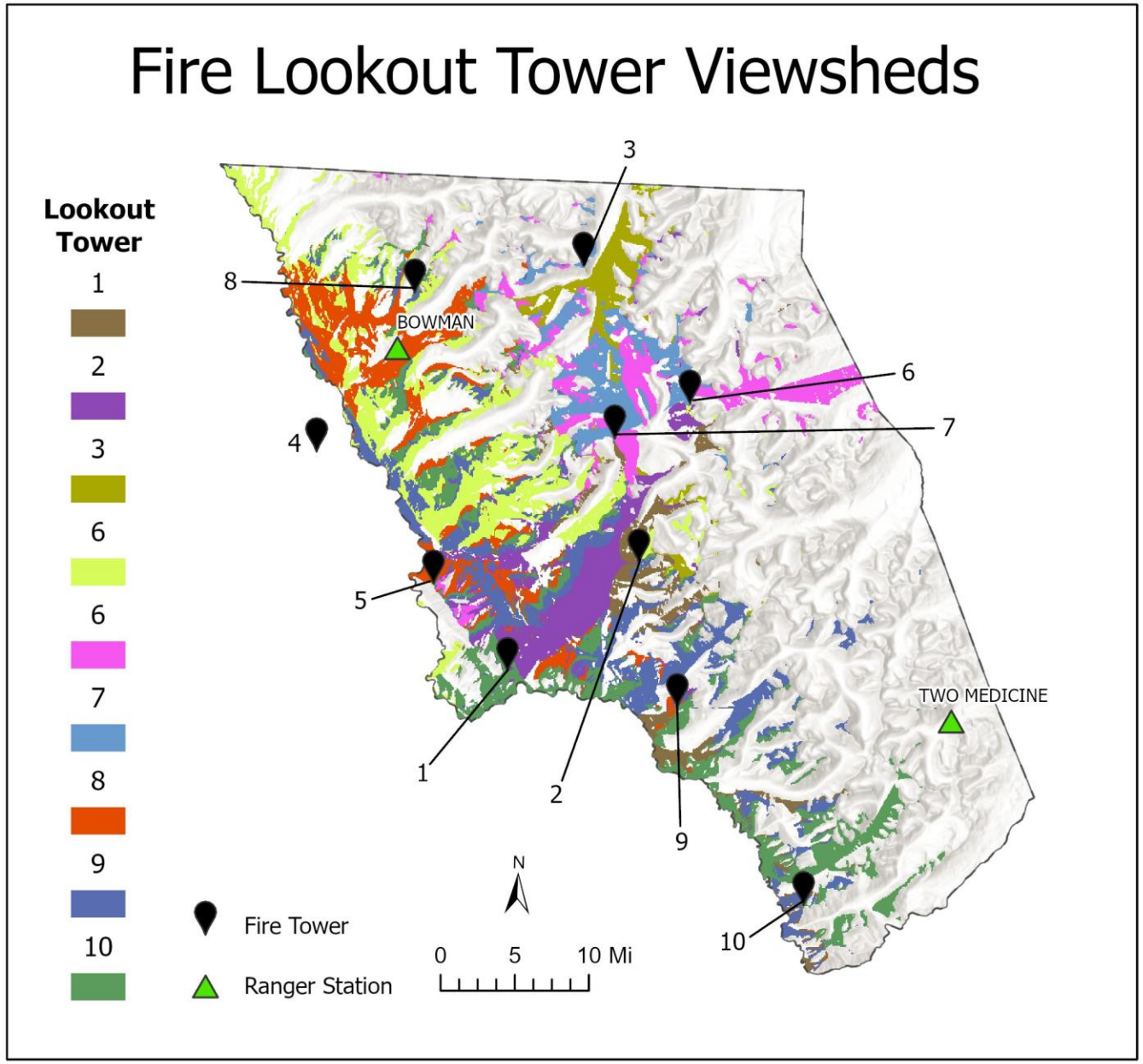


Results: Fire Tower Viewsheds

Table 2. Fire Tower Viewshed Areas

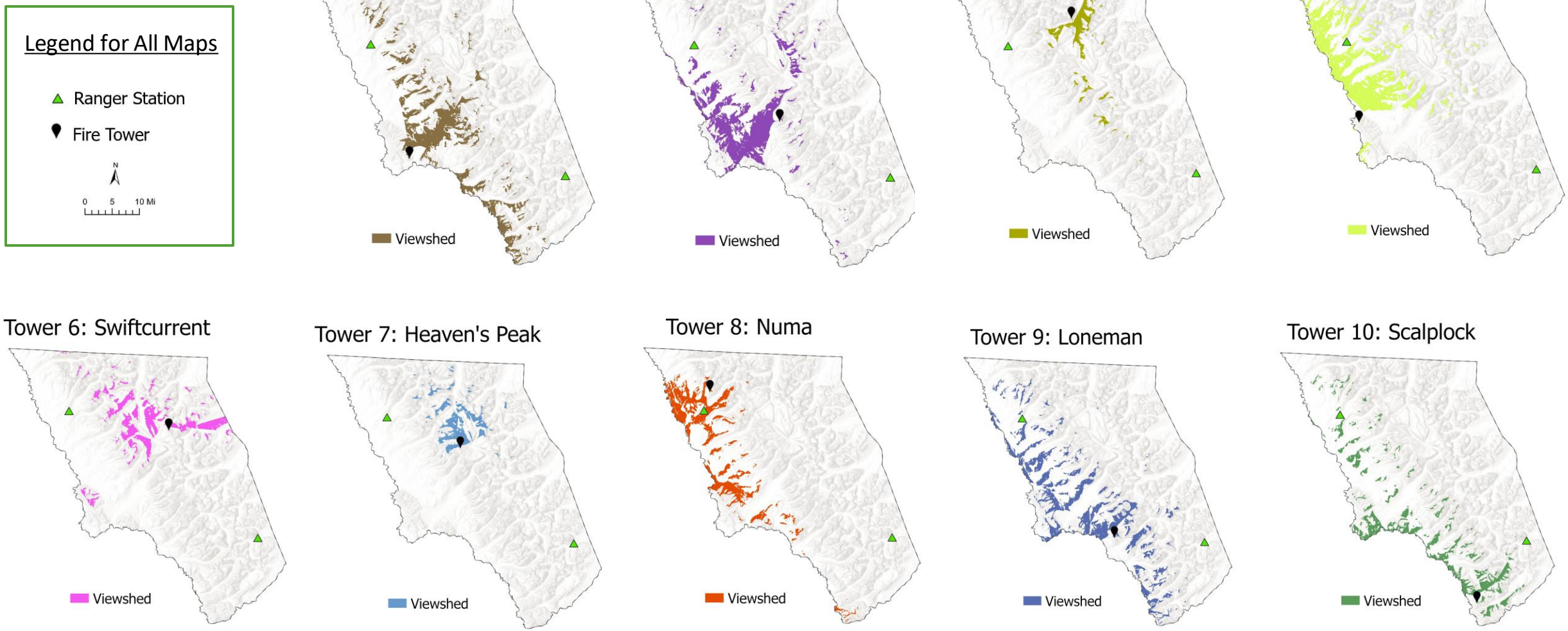
Tower Number	Tower Name	Viewshed Area (ha^2)
1	Apgar	33.03
2	Mt. Brown	32.34
3	Porcupine	8.12
5	Huckleberry	41.82
6	Swiftcurrent	17.67
7	Heaven's Peak	10.16
8	Numa	23.68
9	Loneman	36.28
10	Scalplock	23.41

Map 6. Fire Lookout Tower Viewsheds



Results: Fire Tower Viewsheds

Figure 7. Individual tower viewsheds



Results: Viewsheds Total Area

Figure 8. Ranger Station Viewsheds Summary

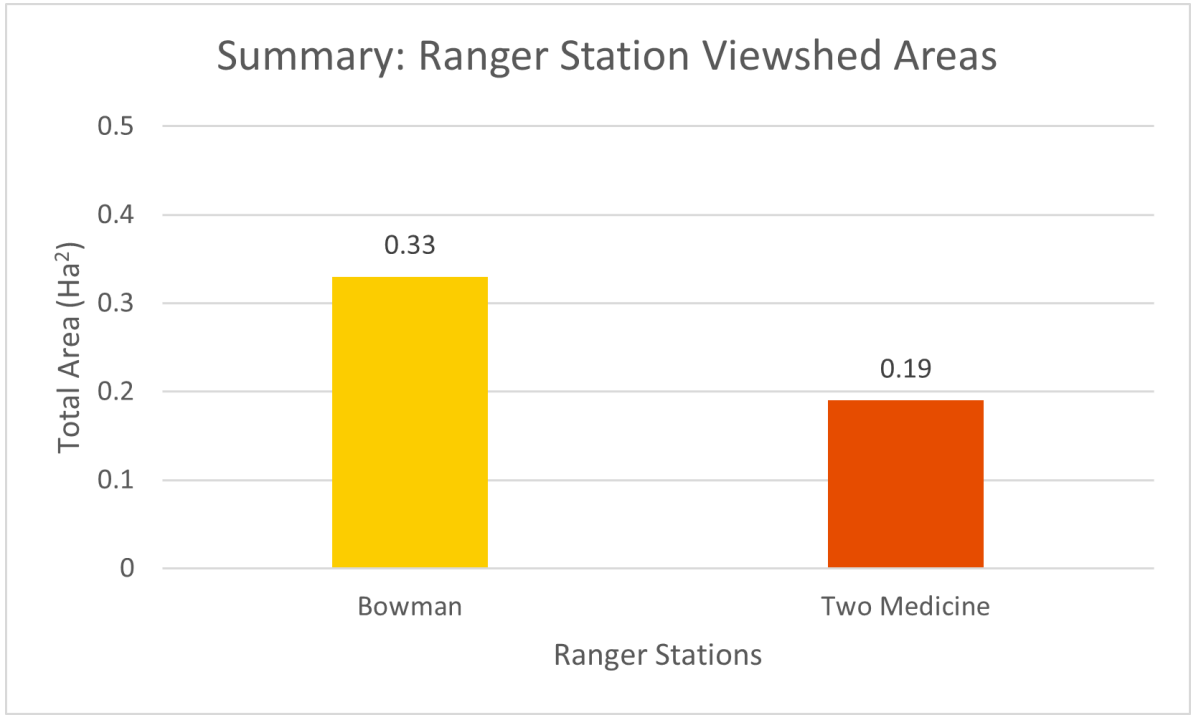
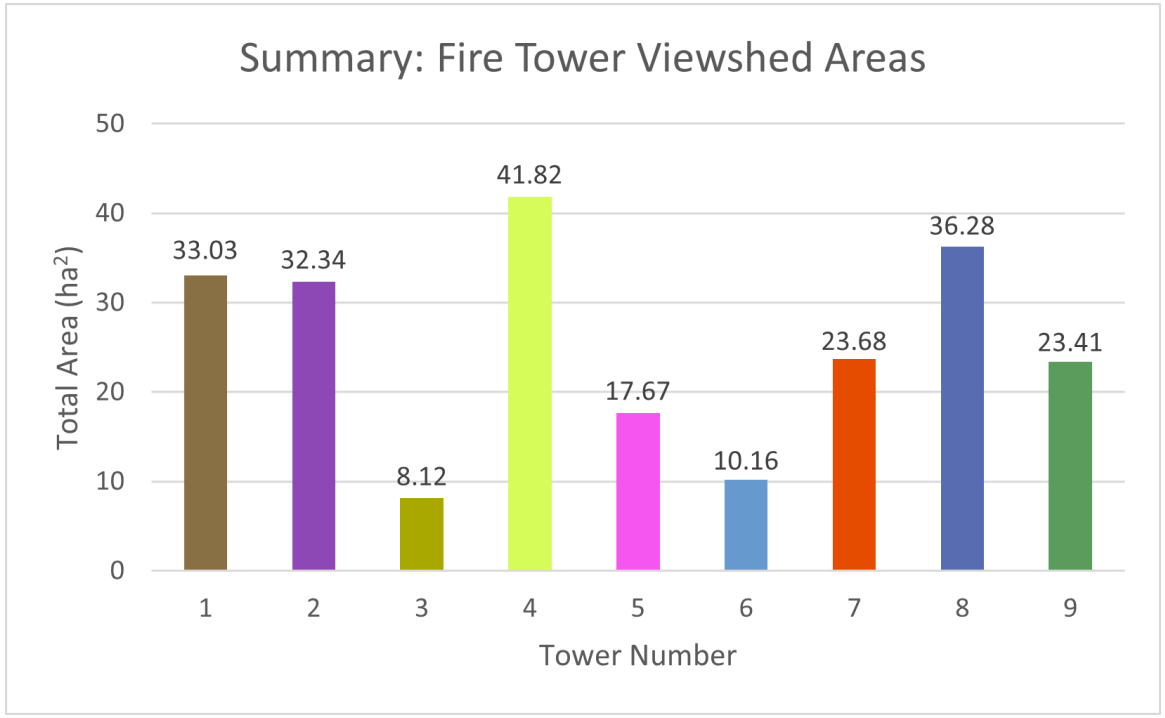


Figure 9. Fire Tower Viewsheds Summary

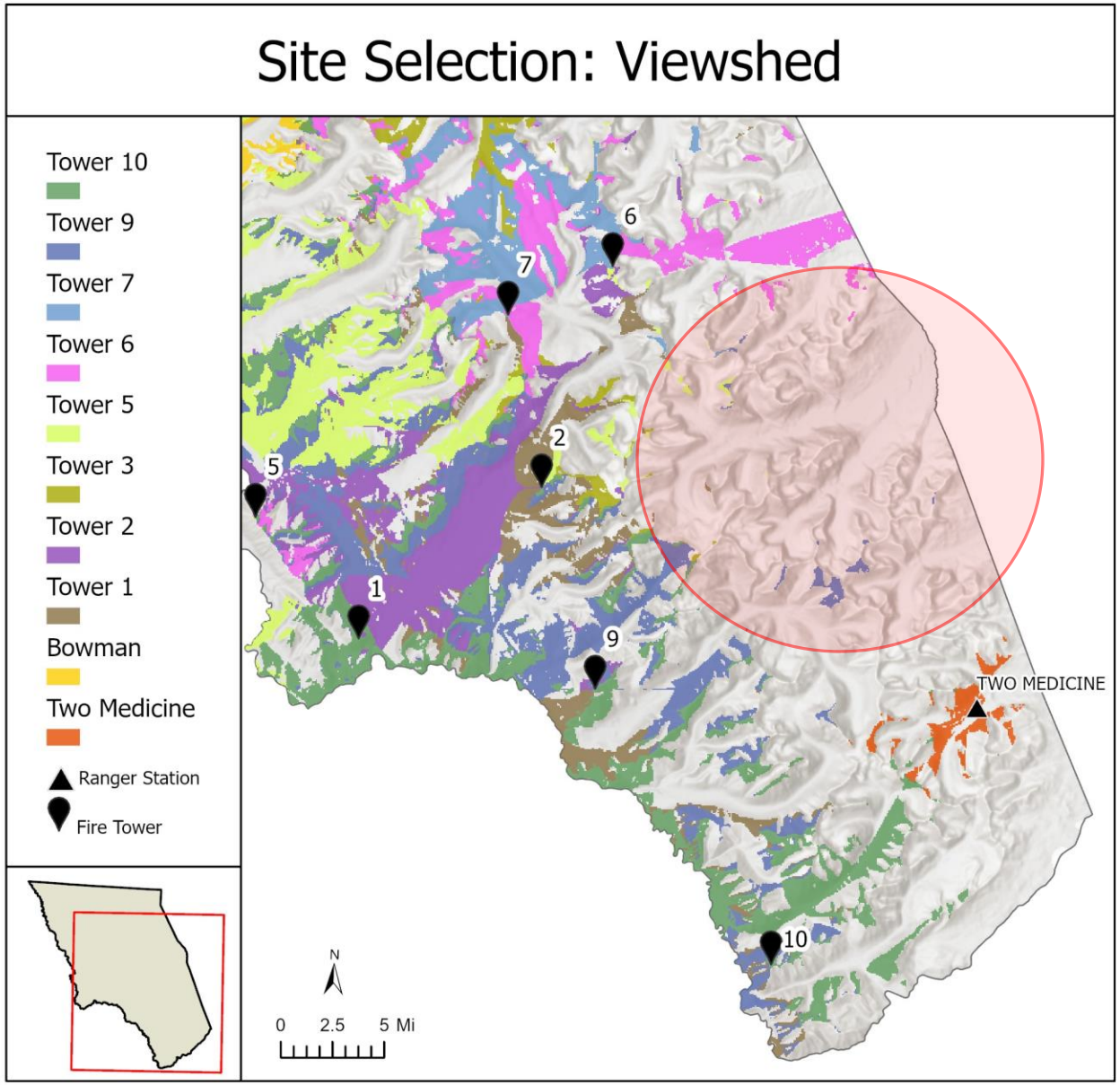


Discussion: Site Selection

Based on viewsheds of existing ranger stations and lookout towers, the new lookout tower should be located centrally in the park and near the eastern border.

- Most fire towers are located along the forested corridor in the northwest region of the park.
- **There is a substantial gap in viewshed coverage from fire towers and ranger stations in the east-central region of the park (Map 7, highlighted in red circle).**

Map 7. Site selection, viewshed

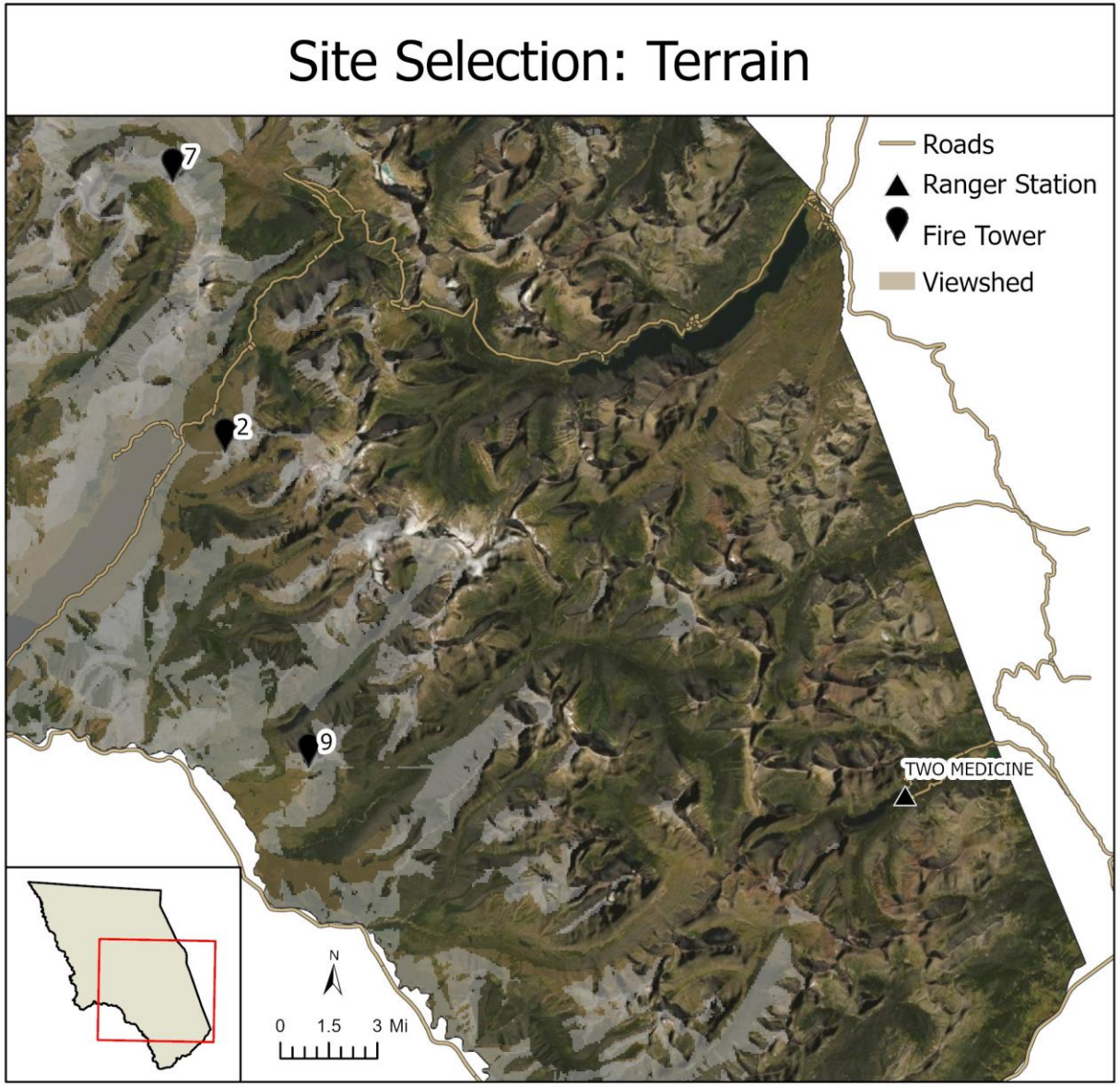


Discussion: Site Selection

Examination of terrain in this region of the park shows a forested valley near Saint Mary Lake (Map 8, northeast corner). This area is an ideal location for a new fire lookout tower:

- Terrain is easily accessible to park rangers on foot or via motor vehicle.
- Lowland valley topography allows for large viewshed if tower is positioned correctly.

Map 8. Site selection, terrain

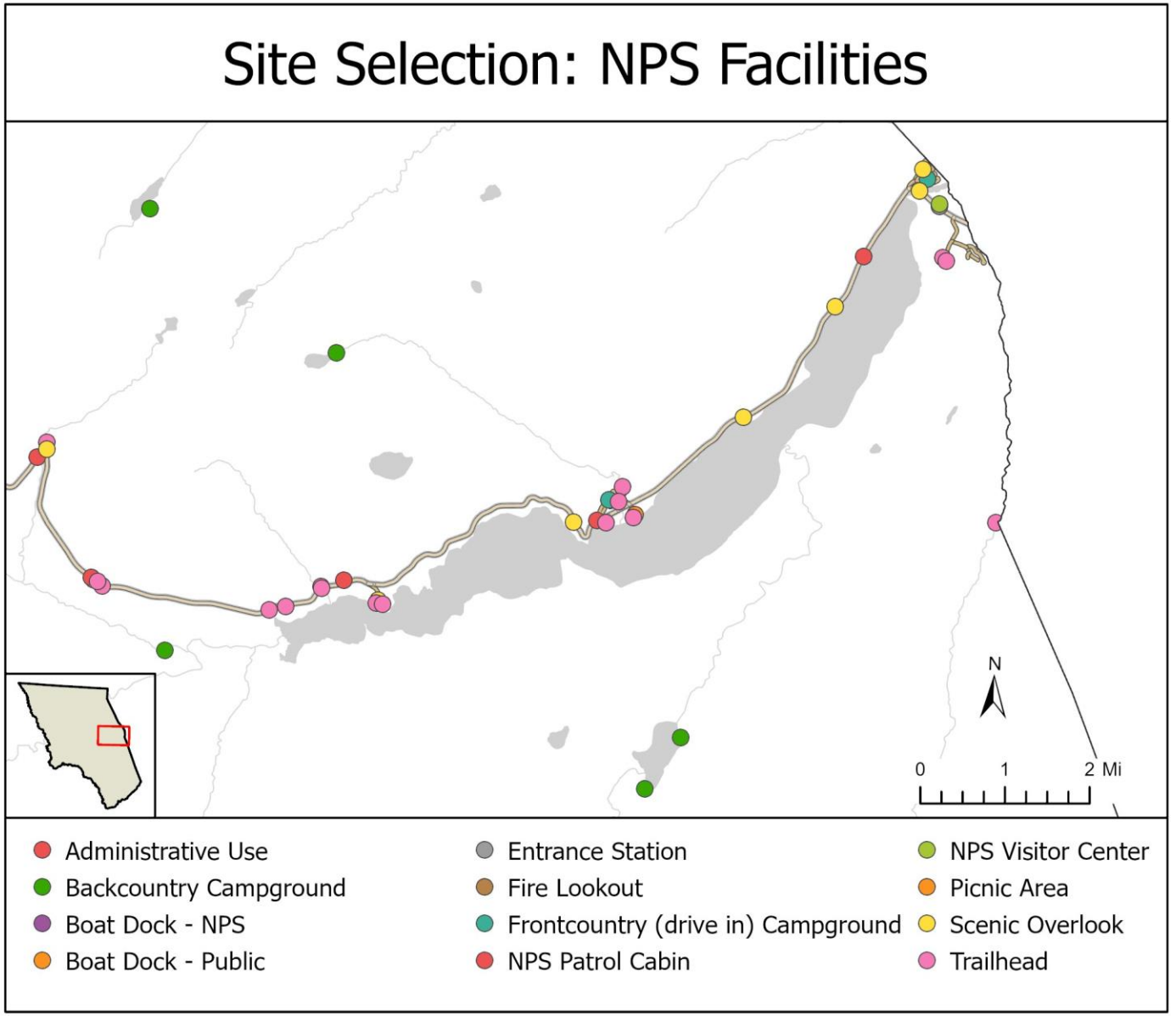


Discussion: Site Selection

Saint Mary Lake is a hub for tourist and NPS staff activity in this are of the park.

- There are a wide variety of facilities in the area, both open for public use and limited to use by NPS staff (Map 8).
- Proximity to administrative buildings provides easy access to new lookout tower built in this area.

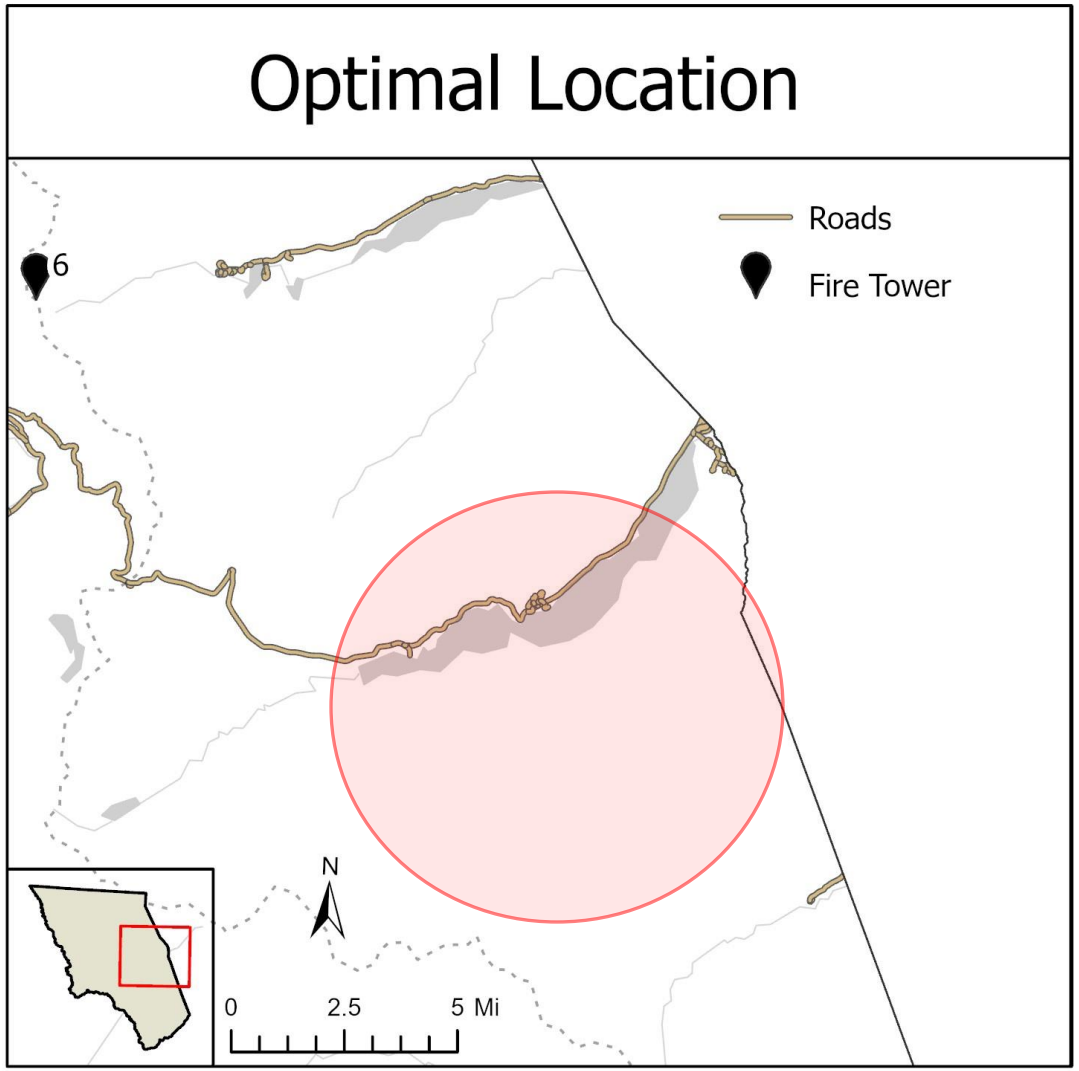
Map 8. Site selection, facilities



Conclusion

- **Based on park terrain and locations of existing fire lookout towers and NPS administrative buildings, the new fire lookout tower should be built near Saint Mary Lake on the eastern border of the park.**
- Considering Swiftcurrent Tower (#6) is positioned to the north, the new tower should be located to the south of the lake (ideal region in red, Map 9).
- This analysis focused on terrain factors and viewsheds from existing fire lookout towers. Further analyses should identify specific locations and examine viewsheds from potential sites to determine the best location.

Map 9. New tower site selection



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Saint Mary Lake. Image: NPS