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Multi-Criteria and Least-Cost Path Analysis for Grizzly Bears (Ursus arctos) in Jasper, Alberta

1.0 Introduction

With the massive post-pandemic increase in national park visitors, there is a significant demand from the federal government of Canada to build wildlife road overpass over highways that would secure connectivity among wildlife habitat patches and avoid road accidents that will harm both humans and animals. Geographic Information System or GIS is a computer-based system that allows users to create, manage, analyze, and plot data onto a map (ESRI, n.d.). With the right data and GIS processing tools, it is possible to conduct multi-criteria and least-cost path analysis to identify the best location to build the wildlife road overpass. Conducting this analysis allows agencies and stakeholders to build a wildlife road overpass that has the lowest cost while still maintain a good connectivity among habitat patches.

Grizzly bear or Ursus arctos is considered as an umbrella species in Canada's 4 contiguous mountain national parks which includes Banff, Kootenay, Yoho, and Jasper (Hood & Parker, 2001). Ursus arctos has a large spatial requirement for their habitat and movements. In addition to that, the presence of highways isolate wildlife populations, which will eventually decrease its genetic diversity (Sawaya et al., 2014). Thus, it is important to secure their movement corridors from human interference especially from high-speed vehicles that passes through highways. The goal of this study is to use multi-criteria and least-cost path analysis to analyze and identify the best possible location for a new wildlife road overpass over one of the two main highways in Jasper, Alberta which are Highway 16 and Highway 93 that would secure connectivity among Ursus arctos habitat patches.

2.0 Study Area and Data

Jasper National Park is the largest of Canada's 4 contiguous mountain national parks (Hood & Parker, 2001). Highway 16 and Highway 93 passes through the Jasper National Park which raises a concern since both highways are major roads that has a high traffic volume. Highway 16 is part of the Trans-Canada Highway connecting Vancouver and Edmonton (Hood & Parker, 2001). Considering the importance of Highway 16 and the large volume of vehicles that uses the highway every day, this investigation will focus on the area surrounding Highway 16 which can be seen in Figure 1.

The main data that is used in this investigation consists of 10 raster layers and were provided by the government for the analysis. The raster layers include elevation of each pixel, terrain ruggedness index, previous fire or burned status from 1984-2015, land cover, Euclidean distance to the nearest riparian feature, Normalized Difference Vegetation Index, Snow Water Equivalent, Euclidean distance to the nearest road, human footprint index, and Euclidean distance to recreational and backcountry trails. There is also several additional datasets such as the habitat patches polygons that represents the 7 habitat patches of Ursus arctos round the Jasper National Park and the road features polygon that represents the roads that exist inside and around Jasper National Park.

3.0 Methods

To identify the best possible location for a new wildlife road overpass, Multi-Criteria and Least-Cost Path analysis is conducted. With the 10 raster layers that represents the spatial characteristics in the study area, it is possible to develop a resistance layer representing the spatial resistance in the area. To build the resistance layer, each of the raster layers needs to be reclassified based on certain characteristics and processed using the to have a weighted sum embedded into the data. Since repeating the same step for all the 10 layers is inefficient, it is essential to use a model which can be seen in Figure 2. The model is built to receive all the 10 raster layers as inputs and reclassify them based on set characteristics. Weighted Linear Combination is then applied into the output of each reclassification to weight and sum all of them into a common scale (0-100) representing low to high resistance). When the model is run, the output of the model would be the resistance layer.

Once the resistance layer exists, it is now possible to conduct the least-cost path analysis. Using the habitat patches polygon as the input raster and resistance layer as the input cost raster, the least-cost path analysis would produce polygons of potential movement corridors from habitat patches with its respective cost. With the existence of the resistance layer and the least cost path polygons, it is now possible to identify the habitat patches that has the lowest and highest resistance and the potential movement corridors that are the least and most costly using zonal statistics as table.

4.0 Results

It is identified that the habitat patch that has the lowest mean resistance would be the habitat patch with FID of 4 with a mean of 9.711808. On the other hand, the habitat patch that has the highest mean resistance would be the habitat patch with FID of 2 with a mean of 31.337898. Both results are supported by the zonal statistic table between the habitat patch and resistance layer, Table 1. It is also identified that the potential movement corridor that is least costly would be the polyline with the Path ID of 12 connecting habitat patch FID 6 and 4 with a path cost of 33564.14. On the other hand, the potential movement corridor that is most costly would be the polyline with the Path ID of 4 connecting habitat patch 3 and 0 with a path cost of 594959. Both results are supported by the least-cost path analysis output, Table 2. The potential movement corridor cost is further supported through the map which can be seen in Figure 3. It is clear that the corridor between habitat patch FID 6 and 4 is represented with the colour dark green which signifies the lowest cost. However, since the goal of this investigation is to identify the best location for wildlife overpass over Highway 16, potential movement corridor that does not passthrough the highway is omitted. Out of all the potential movement corridors that passes through Highway 16, it is identified that the corridor with Path ID of 11 connecting habitat path FID 5 and 4 has the least cost. Hence, it is proposed that the best location to build a wildlife overpass over Highway 16 would be inside the movement corridor with Path ID 11 which can be seen in Figure 4.

5.0 Discussion

There are several factors that make the proposed location to be the best location to build a wildlife overpass for grizzly bears over Highway 16. Highway 16 is a major pathway for travelers to travel on road from the west to the east coast (Hood & Parker, 2001). Considering the amount of traffic and vitality of Highway 16 towards the Trans-Canada Highway, it is important to maintain a good flow of traffic in that specific Highway. Furthermore, out of all the potential movement corridors that passes through Highway 16 and 93, the corridor with Path ID of 11 has the least cost. Thus, the proposed location is believed to be the optimal location to build a wildlife overpass.

Conducting multi-criteria and least-cost path analysis allows stakeholders to find the optimal location to build wildlife overpass while considering the spatial resistance, the cost, and the potential movement corridors. By knowing which movement corridors has the least cost, the federal government can allocate its resources optimally. In addition to that, identifying movement corridors also allows agencies to conduct preventive measures by putting up warnings and traffic signs along the highway to notify road users on potential wildlife crossings in the area. Using the available data, it is possible to extend this investigation by investigating which habitat patches and movement corridors has the highest presence of bears which would increase the accuracy of identifying the best movement corridors to put the wildlife overpass on.

6.0 Tables and Figures

Table 1. Zonal Statistics Table of Patches and its Resistance

FID	Mean
0	22.797053
1	15.352012
2	31.337898
3	19.82215
4	9.711808
5	20.892226
6	11.844483

Table 2. Least Cost Path between Patches

FID	PATH ID	PATH COST	REGION 1	REGION 2
0	3	379739.25	1	0
1	4	594959.00	3	0
2	5	345864.88	4	0
3	6	133027.67	5	0
4	7	434309.31	6	0
5	8	585996.00	1	3
6	9	375895.63	2	3
7	10	107631.99	6	3
8	11	331798.06	5	4
9	12	33564.14	6	4
10	13	179802.39	2	1

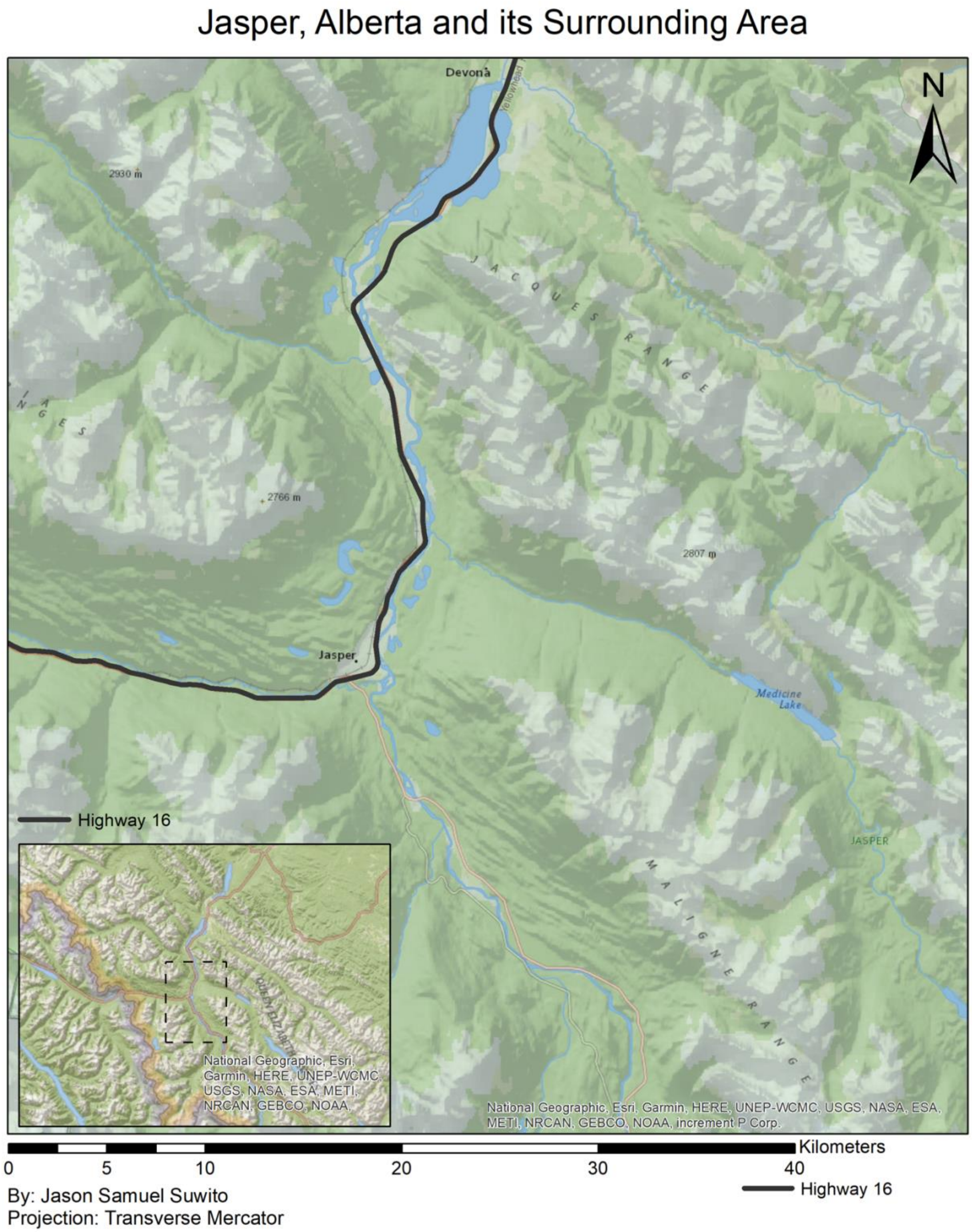

Figure 1. Map of Jasper, Alberta, and its surrounding area with highlight on Highway 16.

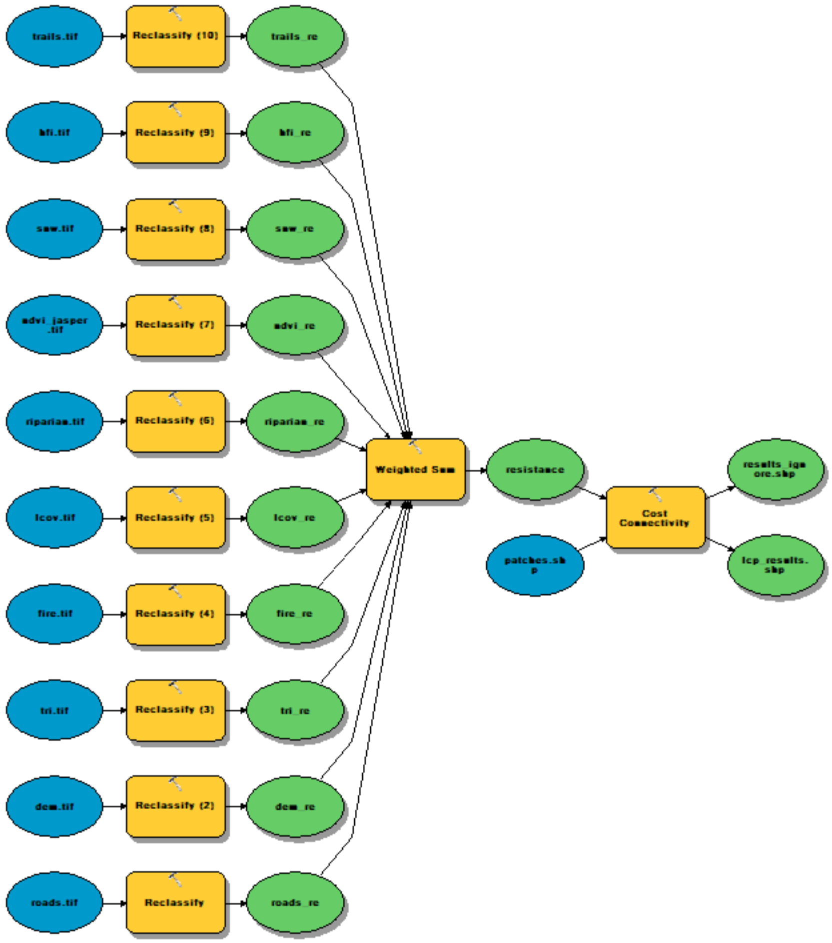

Figure 2. Model that is used to produce the resistance layer and the least cost path polylines.

Movement Resistance, Potential Movement Corridors, and Cummulative Path Cost

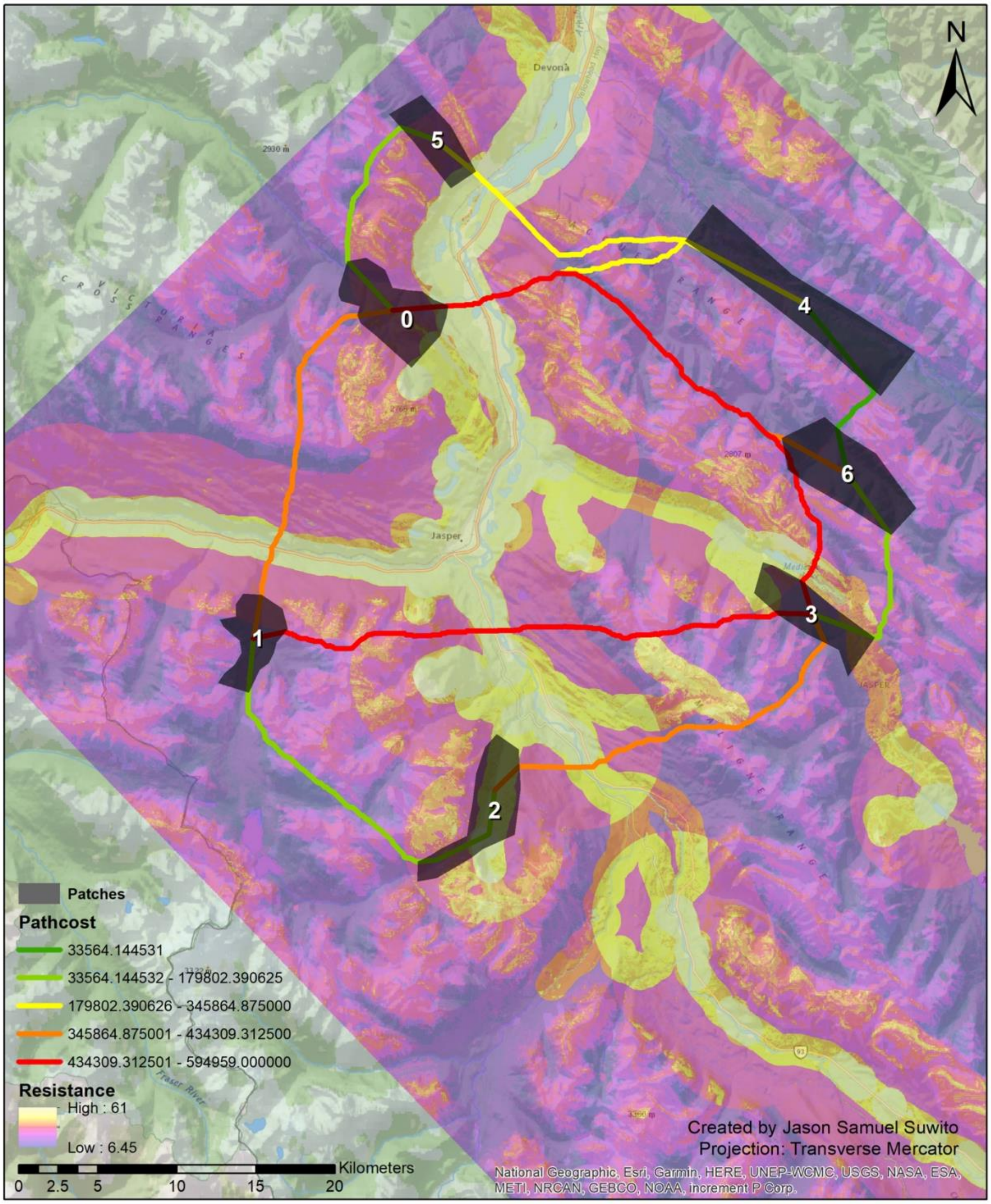

Figure 3. Map of movement resistance, potential movement corridors, and cumulative path costs.

Potential Wildlife Overpass over Highway 16

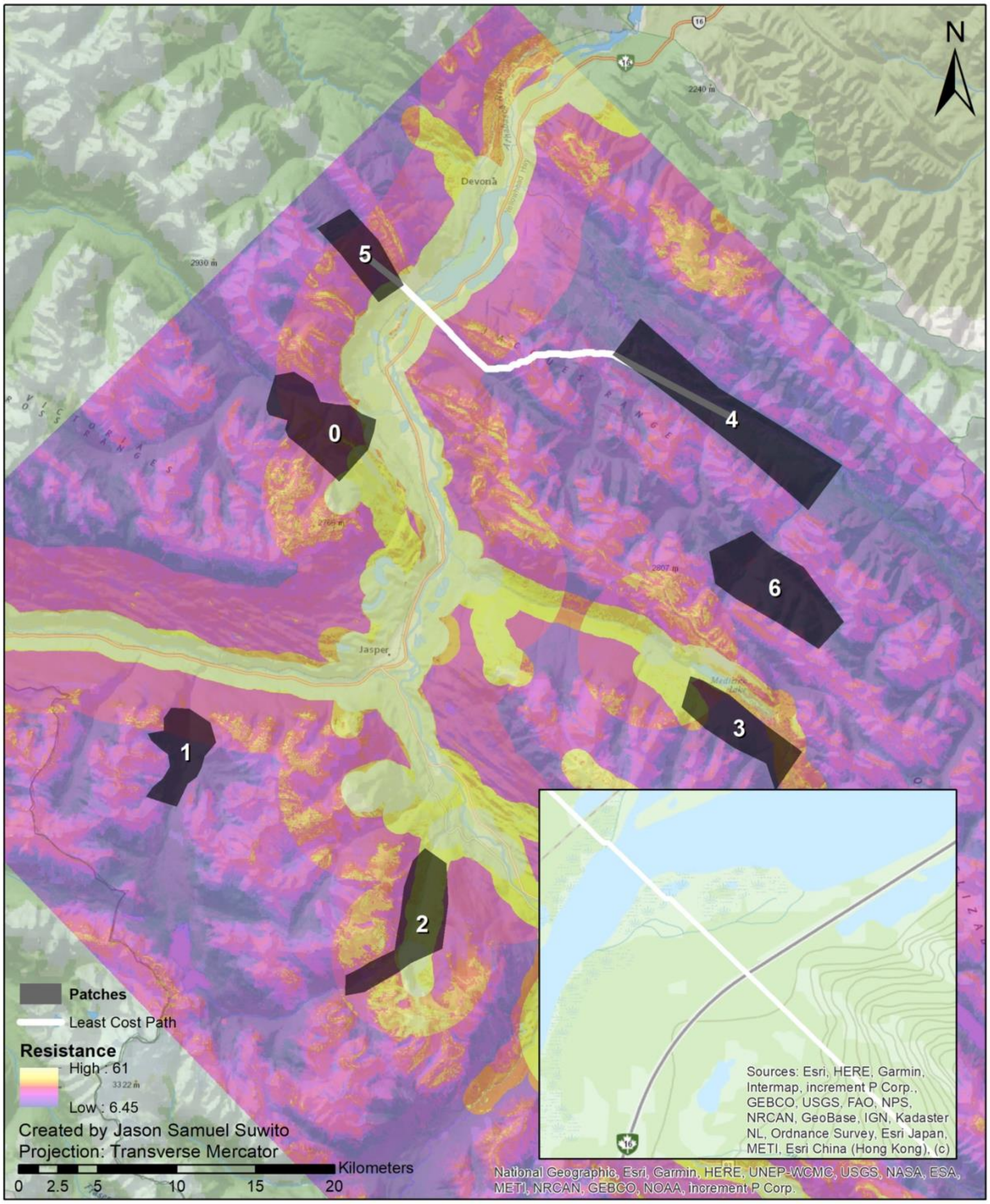

Figure 4. Map of proposed wildlife overpass over Highway 16.

References:

ESRI. (n.d.). *What is GIS?* ESRI. Retrieved February 7, 2023, from https://www.esri.com/en-us/what-is-gis/overview

Hood, G. A., & Parker, K. L. (2001). Impact of Human Activities on Grizzly Bear Habitat in Jasper National Park. *Wildlife Society Bulletin (1973-2006)*, *29*(2), 624–638. http://www.jstor.org/stable/3784189

Sawaya, M. A., Kalinowski, S. T., & Clevenger, A. P. (2014). Genetic connectivity for two bear species at wildlife crossing structures in Banff National Park. Proceedings of the Royal Society B: Biological Sciences, 281(1780), 20131705.