

Assignment 4: Network Analysis of Fire Response Coverage in the Region of Waterloo

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Introduction

The Region of Waterloo relies heavily on spatial analysis and GIS to support its police, fire, and first responder units, using these tools to plan routes, forecast demand, and locate new facilities. Despite strong coverage over the region, rural areas currently experience gaps in fire response times. To help address this, the Region is considering the addition of a new fire station and has identified two proposed locations: Elmira and New Hamburg. This report uses network analysis to evaluate both options against the existing station network and recommends which of the two proposed locations would most improve fire response coverage.

Methods

The analysis began with data for the road network, existing fire stations, historic fire calls, and the two proposed stations (Elmira and New Hamburg). A network dataset was then built from the road network. Travel time for each road segment was calculated from its length and posted speed limit, a one-way restriction was applied, and two travel modes were configured (distance and time). The full workflow is summarized in Figure 1.

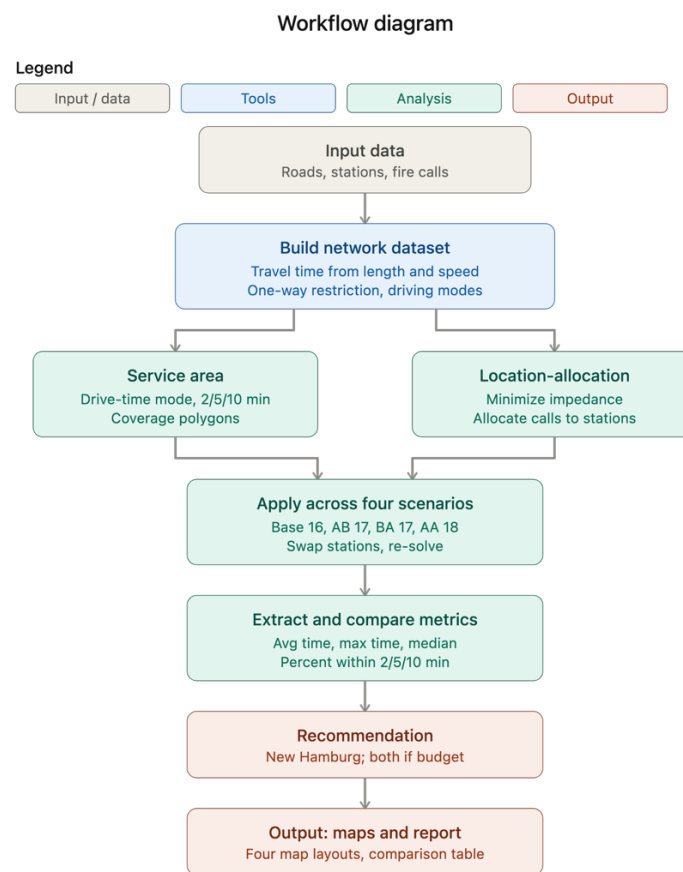


Figure 1. Workflow diagram of the network analysis process, from input data through to the recommended scenario.

Two analyses were run on this network dataset. First, a *Service Area analysis* was run using the drive-time mode to generate 2, 5, and 10-minute coverage polygons around the fire stations. Second, a *Location-Allocation analysis* was run to assign each historic fire call to its optimal station by minimizing impedance. This produced the response time per call and the number of calls allocated to each station, from which the average response time, longest trip, and percentage of calls within 2, 5, and 10 minutes were derived. Specifically, the *Total_Minutes* value for each allocated call was taken from the Location-Allocation Lines output and used to calculate the mean, median, and maximum response times, and to count the calls falling within and beyond the 2, 5, and 10-minute thresholds.

Both analyses were repeated across four scenarios: the base case (16 existing stations), Elmira added (17 stations), New Hamburg added (17 stations), and both proposed stations added (18 stations). A separate station shapefile was prepared for each scenario, and the analysis was re-run for each.

Because the Region intends to add only one new station, the core of this analysis is a comparison between the two proposed locations. Elmira and New Hamburg were evaluated against each other on their reduction in average response time, longest trip, and the number of calls brought within 10-minute coverage, in order to determine which single location most improves rural fire response.

Results

Coverage was assessed at the 2, 5, and 10-minute thresholds, but the 10-minute measure is the most meaningful for this analysis. Because the 2 and 5-minute zones are dominated by the dense urban core of Kitchener, Waterloo, and Cambridge, they remain almost unchanged across all four scenarios (roughly 34% of calls within 2 minutes and around 90% within 5 minutes in every case). The 10-minute threshold is where coverage actually varies between scenarios, since this is where the rural gaps appear, so it is the measure that best distinguishes the two proposed stations.

Table 1 compares the four scenarios across all three response measures. In the base case, the average response time is 3.01 minutes, and the longest trip is 21.44 minutes, with 203 calls (3.2%) falling outside 10-minute coverage. It is worth noting that the median response time (2.42 minutes) is well below the mean (3.01 minutes); this gap reflects a small number of very long rural trips that pull the average upward, which is precisely the problem the proposed stations aim to address.

Scenario	Stations	Avg time (min)	Longest trip (min)	Outside 2 min	Outside 5 min	Outside 10 min
Base (existing)	16	3.01	21.44	4,143 (66.2%)	675 (10.8%)	203 (3.2%)
AB: + Elmira	17	2.87	21.19	4,111 (65.7%)	559 (8.9%)	162 (2.6%)
BA: + New Hamburg	17	2.83	21.44	4,126 (66.0%)	601 (9.6%)	98 (1.6%)
AA: + Both	18	2.70	19.23	4,094 (65.5%)	485 (7.8%)	57 (0.9%)

Table 1. Comparison of the four station scenarios across response-time and coverage measures, relative to the base case. New Hamburg (highlighted) is the recommended single-station option.

Figure 2 shows the base case geographically. The majority of the fire calls is covered within 10 minutes (purple), but a scatter of uncovered calls (red) remains, concentrated in the rural townships of Woolwich (near Elmira), Wilmot (near New Hamburg), and Wellesley. These clusters confirm the coverage gap and explain why these two locations were proposed.

Existing Fire Response Coverage in Region of Waterloo

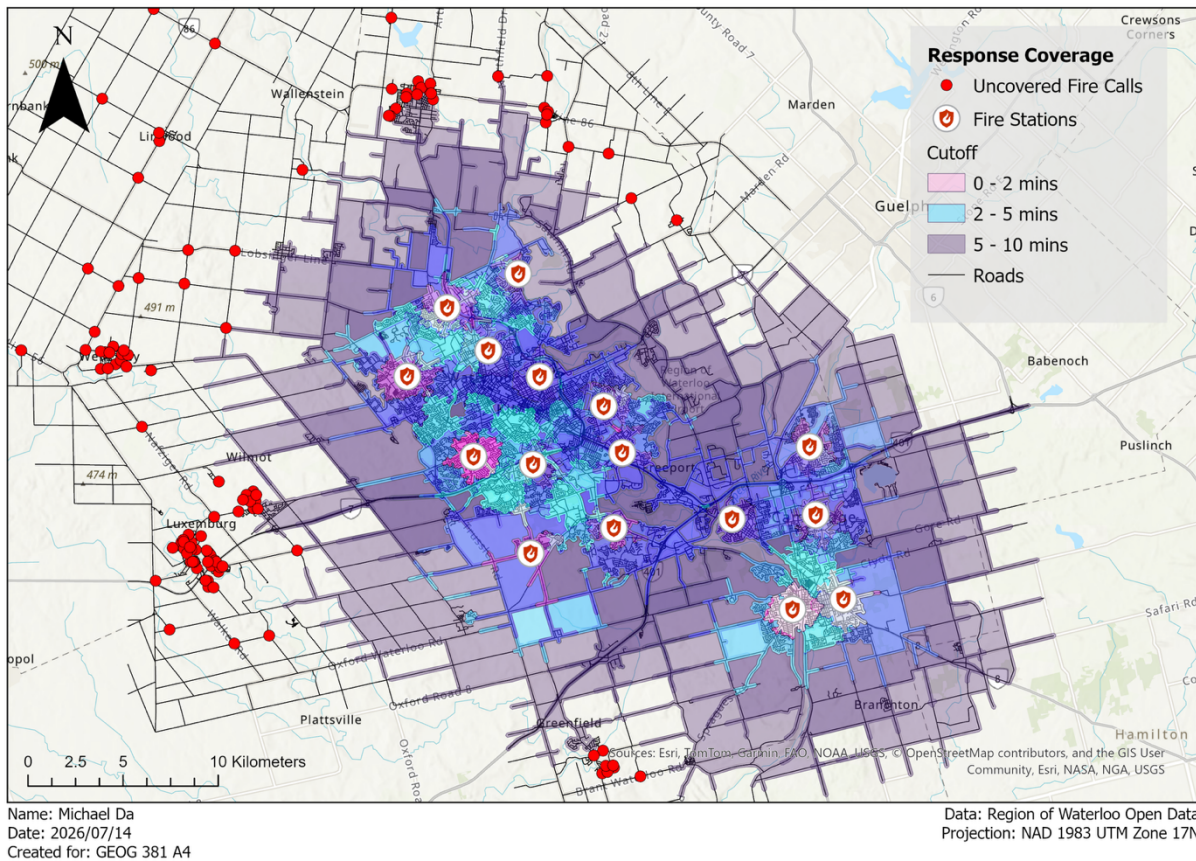


Figure 2. Base case scenario with 16 existing fire stations and their 2, 5, and 10-minute drive-time service areas.

Each proposed station was then assessed. Adding Elmira (AB) reduces calls outside 10 minutes from 203 to 162, with an average response time of 2.87 minutes. Adding New Hamburg (BA) reduces calls outside 10 minutes to 98, with an average of 2.83 minutes. Adding both stations (AA) reduces calls outside 10 minutes to 57, lowers the average response time to 2.70 minutes, and drops the longest trip to 19.23 minutes.

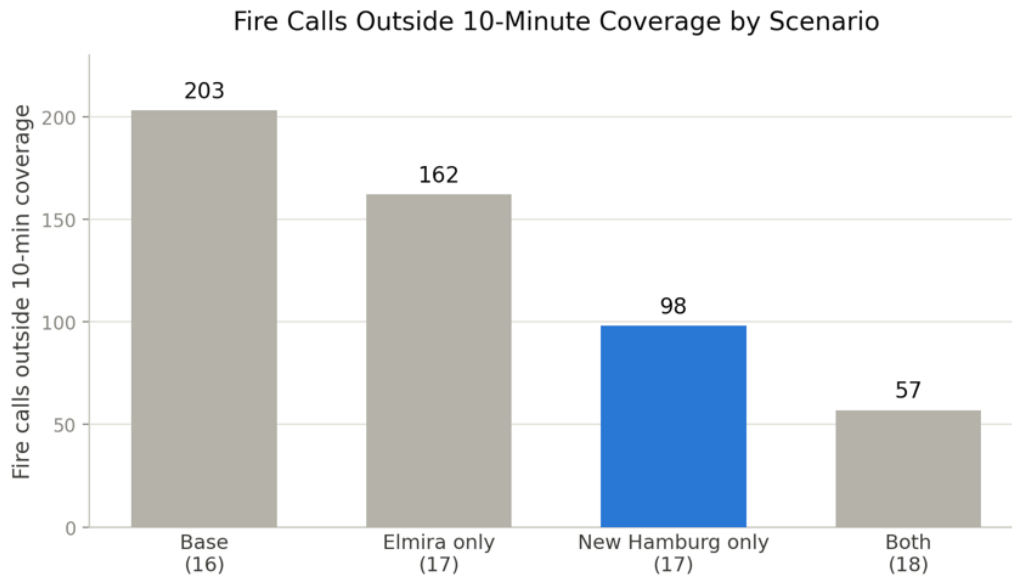


Figure 3. Number of fire calls outside 10-minute coverage for each of the four scenarios.

Between the two single-station options, New Hamburg is clearly the stronger choice. It removes 105 calls from the over-10-minute group compared to Elmira's 41, more than double the improvement, while also producing a slightly lower average response time.

The one measure where Elmira performs better is the longest trip. Elmira lowers the maximum from 21.44 to 21.19 minutes, while New Hamburg leaves it unchanged, suggesting that the single worst-served call is located closer to Elmira's proposed service area. However, this affects only one extreme case, whereas New Hamburg improves coverage for a far larger number of calls. This also shows that no single station fully resolves the rural coverage gap on its own, and that adding both stations would be the most complete solution if budget allows.

Discussion

The comparison between the two proposed stations points clearly to New Hamburg. Although both improve rural coverage, New Hamburg addresses more than twice as many underserved calls as Elmira, making it the stronger single-station investment. This difference is not just a matter of totals but of where each station sits relative to the rural coverage gap.

Fire Response Coverage with Elmira Stations

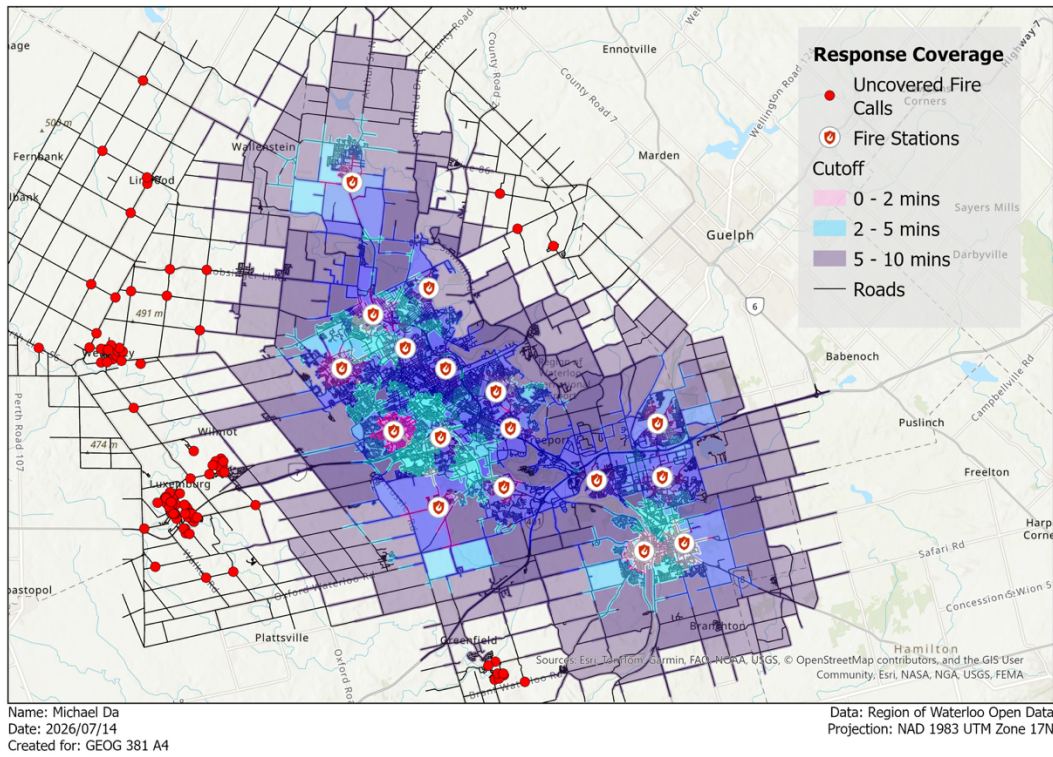


Figure 4. Elmira scenario (AB) with 17 stations and their 2, 5, and 10-minute service areas.

Fire Response Coverage with New Hamburg Stations

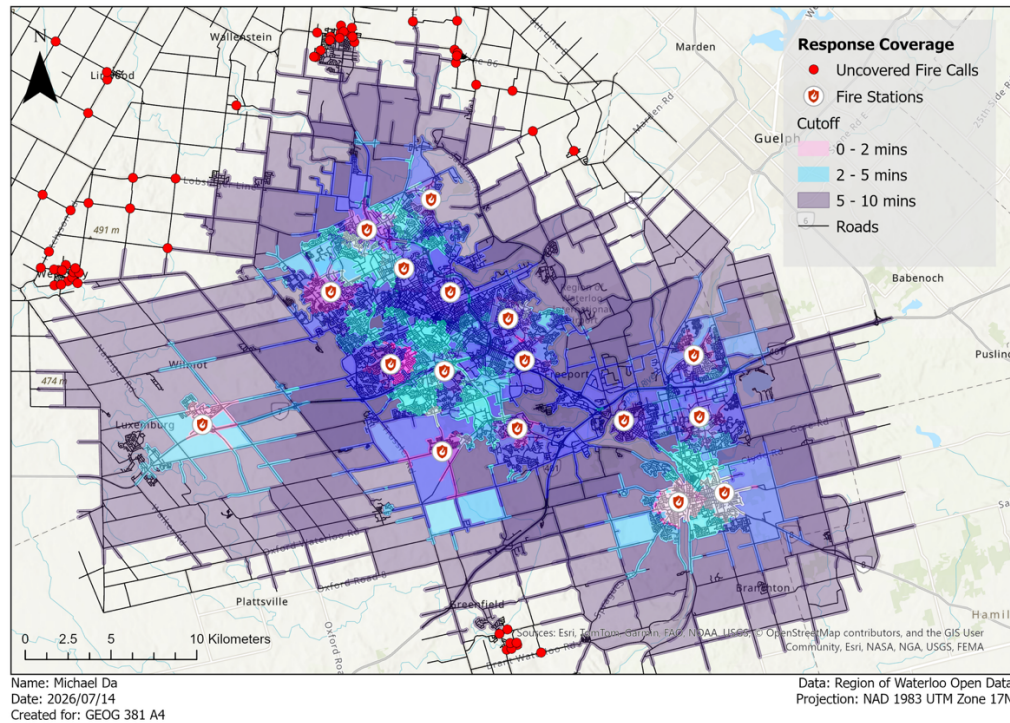


Figure 5. New Hamburg scenario (BA) with 17 stations and their 2, 5, and 10-minute service areas.

The maps make this difference visible. New Hamburg's service area closes a larger and denser cluster of previously uncovered rural calls than Elmira's, which is why it clears more than double the calls from the underserved group despite both being single-station additions.

However, if budget allows, adding both stations (AA) produces the best outcome overall, reducing calls outside 10 minutes to 57 and lowering the longest trip to 19.23 minutes. This confirms that Elmira and New Hamburg address different parts of the rural coverage gap: New Hamburg serves a larger volume of underserved calls, while Elmira reaches the single most remote one. No single station fully resolves the gap on its own.

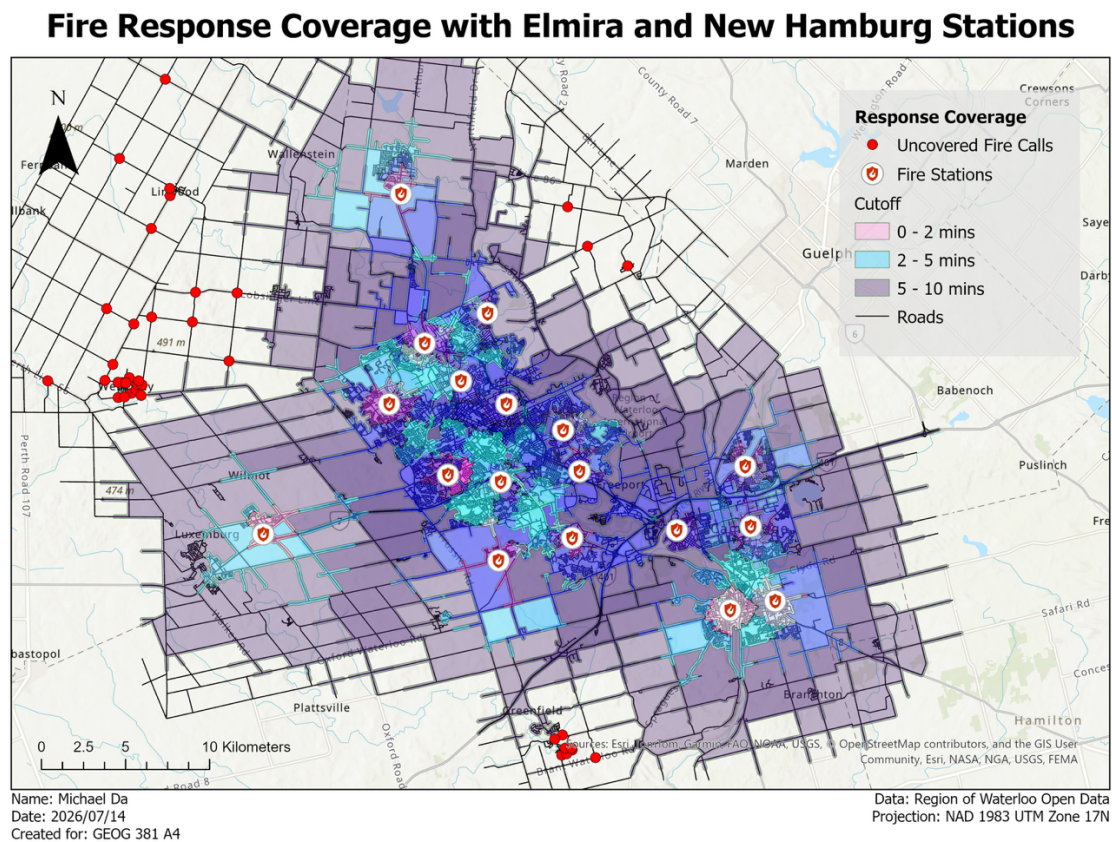


Figure 6. Combined scenario (AA) with 18 stations and their 2, 5, and 10-minute service areas.

Conclusion

The Region of Waterloo should add New Hamburg as its next fire station. It delivers the greatest improvement in rural fire response for a single-station investment, more than halving the number of calls outside 10-minute coverage and lowering the average response time. While the ideal solution would be to build both proposed stations, New Hamburg is the clear priority if only one can be built, and is recommended as the Region's next fire station.

References

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Region of Waterloo. (n.d.). Fire calls, proposed fire stations, and road network [Data set].
Provided in course materials, University of Waterloo.