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GEOG 381 – Lab 103 – Assignment 4

# Assignment 4: Comparison Analysis of Proposed Rural Fire Stations in Waterloo Region

## Introduction/Background

This report analyzes the effectiveness of current fire stations in Waterloo Region, and compares the addition of two new fire stations in the towns of Elmira and New Hamburg. Through investigating statistics from network analysis, the Region can determine the more suitable location for a new fire station to better support rural response times.

## Study Site & Data

This analysis is being done in Waterloo Region, Ontario, Canada. All data is sourced from the assignment. This includes:

- **Waterloo Region Roads** – shapefile data from Waterloo Region
- **Waterloo Region Fire Stations** – shapefile data from Waterloo Region
- **Waterloo Region New Fire Stations** – shapefile data from Waterloo Region
- **Waterloo Region Fire Calls** – shapefile data from the WRPS

All datasets have a projection of UTM NAD83 17N, which is used throughout the assignment

## Methods/Process

The flowchart for creating the Network Dataset, Service Area (SA) layers, and Location-Allocation (LA) layers can be found as **FIGURE 1a** in the appendices. Please see the assignment description for a detailed explanation of these steps.

The flowchart for analysis on the SA and LA layers can be found as **FIGURE 1b** in the appendices.

To find the average response time of each system, I used the **Summary Statistics** tool. The input table was the Lines from each LA layer and the calculated field was Total_Minutes with a statistic type of Mean. The Lines layer represents the allocation of each call to its closest station, so the mean of these times is the average response time over all stations and calls.

To find the longest trip time, I opened the Lines table for each LA layer and filtered Total_Minutes in Descending order. Again, this follows directly from the purpose of the Lines layer.

To find the calls allocated to each station, I opened the Facilities table for each LA layer and viewed the Demand_Count field. The Facilities layer is used to store each fire station and information about its allocated resources, including how many calls it services.

Finally, to find the proportion of calls in each SA cutoff, I first used the **Select Layer by Attribute** tool to select the SA polygons representing the current cutoff. The input rows were the Polygons from each SA layer, and the condition was `WHERE FromBreak IS LESS THAN OR EQUAL TO n`, where n was the current cutoff. I then used the **Select Layer by Location** tool to find the fire calls within each of the selected areas. The input features were FireCalls, the relationship was Completely Within, and the selecting features were the currently selected SA layer Polygons (toggle on the “use selected records”). Then, the number of calls in the current cutoff is clearly the number of selected items minus the number of SA polygons (since these are still selected). The proportion is finally this value divided by 6255 (the total number of calls in our network dataset).

## Results or Analyst Summary

First, we’ll explore the results from the LA analysis (**FIGURES 9-12**).

For average response time, refer to the first row of **FIGURE 2**. Originally, this value was 3.01 mins. The Elmira station (E) reduces this by 9 seconds, and the New Hamburg station (N) reduces this by 11 seconds. Having both stations (B) would reduce this by 19 seconds to an average of 21 mins 42 secs.

For the number of calls allocated to each station, refer to the second row of **FIGURE 2** and

**FIGURES 3a-d**. For the original stations and N, the minimum demand is 134 calls, and for E and B it's 124. For all systems, the max demand is 714 calls. The three most in demand stations are Locations 3, 9, and 1, and the three least in demand stations are Locations 16, 11, and 6. E and B reduce the demand of Location 1 and Location 16 significantly, while N doesn't reduce demand from any of the most and least in demand stations. E is allocated 135 calls and N is allocated 162.

For the longest trip, refer to the third row of **FIGURE 2**. The original longest trip is 21 mins 26 seconds, and occurs in the northwest (**FIGURE 4a**). E is close to the call from this trip, so it reduces this length and the next longest trip is 21 mins 11 secs in the west (**FIGURE 4b**). N has the same longest trip as the original, since it's far from this call (**FIGURE 4c**). The longest trip for B is over 2 mins shorter than the original at just 19 mins 14 secs (**FIGURE 4d**).

Now, we'll explore the results from the SA analysis (**FIGURES 5-8**).

For the proportion of calls outside each service area cutoff, refer to the fourth row of **FIGURE 2**. Originally, there were 3.1% calls outside 10 mins, 10.5% outside 5 mins, and 63.2% outside 2 mins. For all of E, N, and B, the proportion outside 2 mins was very similar to the original. E improved mostly on proportion outside 5, having 8.8%. N improved mostly on proportion outside 10, having 1.5%. B improved greatly on both, with 0.9% outside 10 and 7.6% outside 5.

## Discussion & Conclusion

For average response time, N is very slightly better than E but they are practically the same.

For the number of calls, having any new station will improve the distribution across stations, so this is good for both E and N. Based on the results, E reduces demand from stations that are currently high in demand, which is good, but also reduces demand unnecessarily from low-demand stations. N doesn't reduce from highly or lowly in demand stations, implying that it only reduces demand from moderately overrun stations. N is also allocated more calls than E, meaning it has a greater reduction to other stations overall.

For the longest trip, E was close to the call in the original longest trip and N wasn't, which causes E to reduce the longest trip by a significant amount and N to not reduce it at all. However, this is fairly specific to this dataset and is down to chance where in the rural areas there happens to be a fire. It's also important to note that the next longest trip in the original dataset (as shown by the longest trip in E) is to the west and thus it would be close to N.

For the proportion of calls, neither E nor N greatly affect close calls since their proportion of calls outside 2 mins are very similar This is because both stations are rural, so settlements and calls are less dense. E reduces calls outside 5 more than N, but outside 10 less than N. Additionally, from **FIGURES 9-11**, we can see that there are more long trips extending west (where N is) than north (where E is). These facts indicate that E mostly reduces mid-length journeys and N mostly reduces long journeys.

Overall, E provides a better distribution of resources (closer to more in demand stations), while N provides more coverage for long calls (further from the original system). If the Region wants to prioritize a more even Location-Allocation structure to reduce stress on high-demand stations, E would be a good choice. If the Region wants to prioritize accommodating those who are currently furthest from a fire station, then N would be better.

I believe that speed is the most important factor in fighting fires, and would thus choose to build the new station in New Hamburg. Saving just a couple minutes can mean the difference between a house being salvageable or not, especially in new homes which use more highly flammable materials and burn much faster. Also, New Hamburg has a higher population than Elmira, so a fire is more likely to occur there and more people would be able to be served. Finally, New Hamburg still provides good coverage for other stations, since it takes on more allocations than Elmira overall.

## Appendices

**FIGURE 1a – Creation Flowchart**

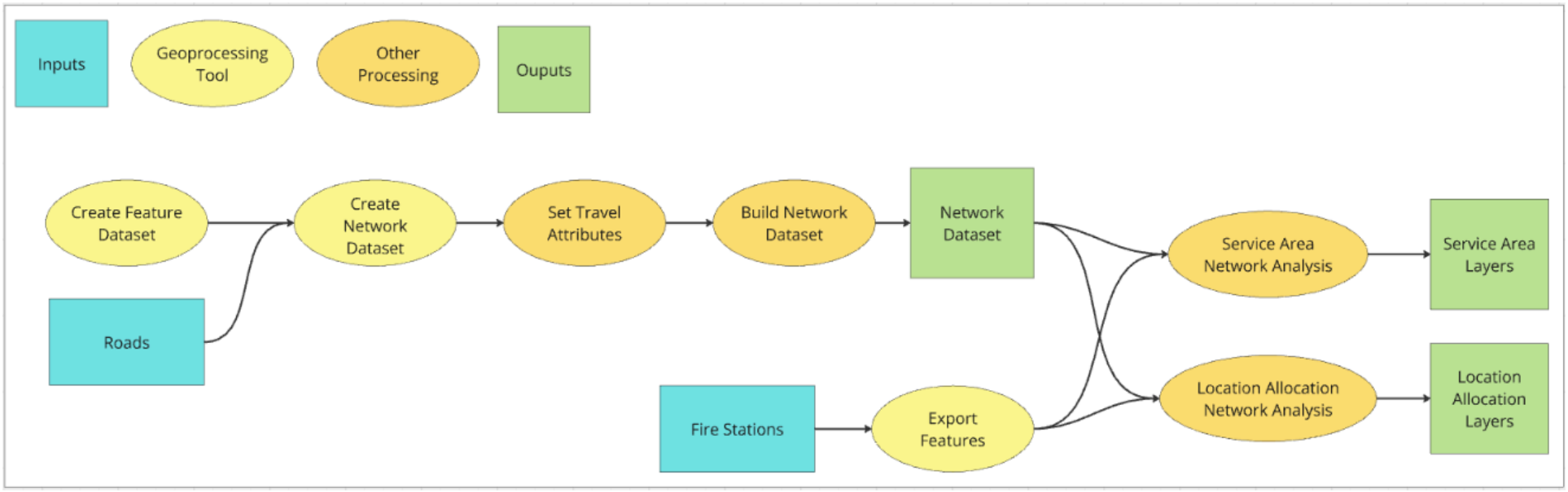

**FIGURE 1b – Analysis Flowchart**

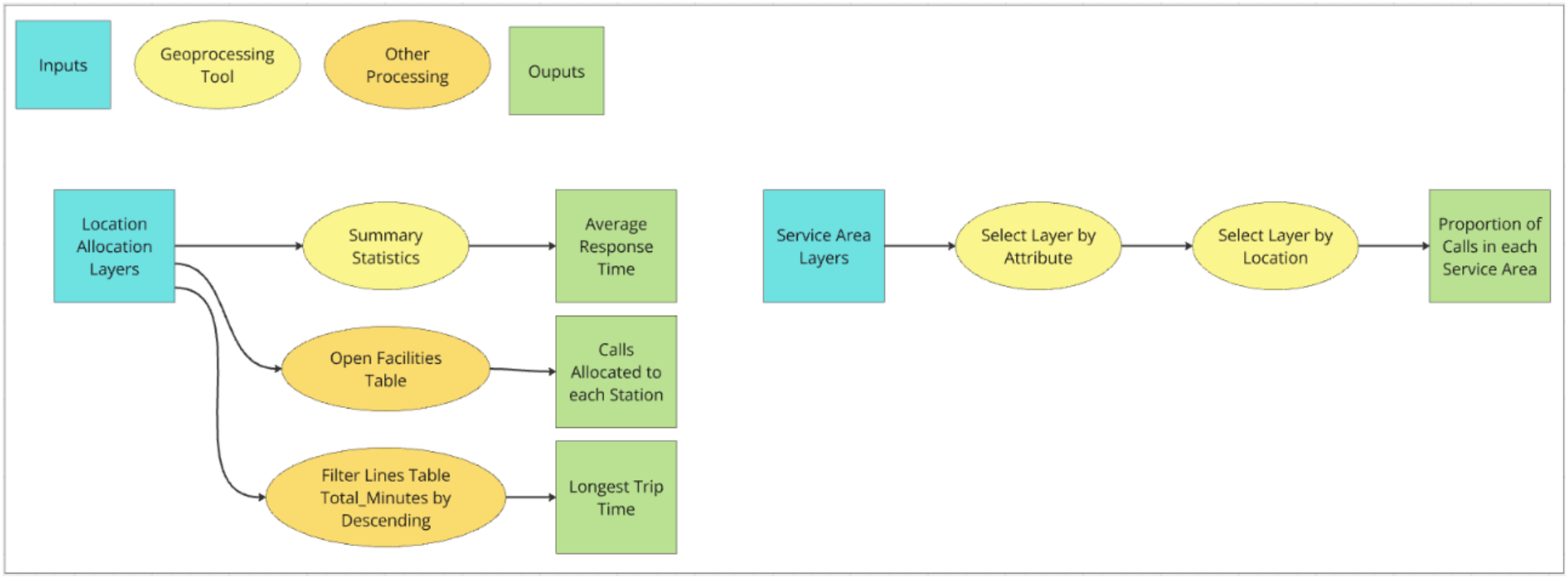

**FIGURE 2 – Comparison Statistics Table**

| | Original Stations | Original Stations + Elmira Station | Original Stations + New Hamburg Station | Original Stations + Both New Stations |
|---|---|---|---|---|
| **Average Response Time for the Entire System** | 3.01 mins (3 mins 1 sec) | 2.87 mins (2 mins 52 secs) | 2.83 mins (2 mins 50 secs) | 2.70 mins (2 mins 42 secs) |
| **Number of Calls Allocated to Each Station** | See **FIGURE 3a** | See **FIGURE 3b** | See **FIGURE 3c** | See **FIGURE 3d** |
| **Longest Trip in the System** | 21.44 mins (21 mins 26 secs) | 21.19 mins (21 mins, 11 secs) | 21.44 mins (21 mins 26 secs) | 19.23 mins (19 mins 14 secs) |
| **Proportion of Calls Outside 10, 5, and 2 Minute Service Areas** | 10 – 3.1% (194 of 6255)<br>5 – 10.5% (655 of 6255)<br>2 – 63.2% (3953 of 6255) | 10 – 2.6% (161 of 6255)<br>5 –8.8% (550 of 6255)<br>2 – 62.7% (3919 of 6255) | 10 – 1.5% (92 of 6255)<br>5 – 9.2% (578 of 6255)<br>2 – 62.8% (3931 of 6255) | 10 – 0.9% (56 of 6255)<br>5 – 7.6% (473 of 6255)<br>2 – 62.3% (3897 of 6255) |

## FIGURE 3a – Original Allocated Calls

| Name | FacilityType | Weight | Capacity | DemandCount |
|---|---|---|---|---|
| Location 1 | Chosen | 1 | <Null> | 498 |
| Location 2 | Chosen | 1 | <Null> | 398 |
| Location 3 | Chosen | 1 | <Null> | 714 |
| Location 4 | Chosen | 1 | <Null> | 357 |
| Location 5 | Chosen | 1 | <Null> | 339 |
| Location 6 | Chosen | 1 | <Null> | 220 |
| Location 7 | Chosen | 1 | <Null> | 350 |
| Location 8 | Chosen | 1 | <Null> | 441 |
| Location 9 | Chosen | 1 | <Null> | 545 |
| Location 10 | Chosen | 1 | <Null> | 428 |
| Location 11 | Chosen | 1 | <Null> | 218 |
| Location 12 | Chosen | 1 | <Null> | 482 |
| Location 13 | Chosen | 1 | <Null> | 483 |
| Location 14 | Chosen | 1 | <Null> | 337 |
| Location 15 | Chosen | 1 | <Null> | 311 |
| Location 16 | Chosen | 1 | <Null> | 134 |

## FIGURE 3b – Elmira Allocated Calls

| Name | FacilityType | Weight | Capacity | DemandCount |
|---|---|---|---|---|
| Location 1 | Chosen | 1 | <Null> | 373 |
| Location 2 | Chosen | 1 | <Null> | 398 |
| Location 3 | Chosen | 1 | <Null> | 714 |
| Location 4 | Chosen | 1 | <Null> | 357 |
| Location 5 | Chosen | 1 | <Null> | 339 |
| Location 6 | Chosen | 1 | <Null> | 220 |
| Location 7 | Chosen | 1 | <Null> | 350 |
| Location 8 | Chosen | 1 | <Null> | 441 |
| Location 9 | Chosen | 1 | <Null> | 545 |
| Location 10 | Chosen | 1 | <Null> | 428 |
| Location 11 | Chosen | 1 | <Null> | 218 |
| Location 12 | Chosen | 1 | <Null> | 482 |
| Location 13 | Chosen | 1 | <Null> | 483 |
| Location 14 | Chosen | 1 | <Null> | 337 |
| Location 15 | Chosen | 1 | <Null> | 311 |
| Location 16 | Chosen | 1 | <Null> | 124 |
| Location 17 | Chosen | 1 | <Null> | 135 |

## FIGURE 3c – New Hamburg Allocated Calls

| Name | FacilityType | Weight | Capacity | DemandCount |
|---|---|---|---|---|
| Location 1 | Chosen | 1 | <Null> | 497 |
| Location 2 | Chosen | 1 | <Null> | 398 |
| Location 3 | Chosen | 1 | <Null> | 714 |
| Location 4 | Chosen | 1 | <Null> | 357 |
| Location 5 | Chosen | 1 | <Null> | 339 |
| Location 6 | Chosen | 1 | <Null> | 220 |
| Location 7 | Chosen | 1 | <Null> | 308 |
| Location 8 | Chosen | 1 | <Null> | 441 |
| Location 9 | Chosen | 1 | <Null> | 545 |
| Location 10 | Chosen | 1 | <Null> | 428 |
| Location 11 | Chosen | 1 | <Null> | 218 |
| Location 12 | Chosen | 1 | <Null> | 482 |
| Location 13 | Chosen | 1 | <Null> | 373 |
| Location 14 | Chosen | 1 | <Null> | 337 |
| Location 15 | Chosen | 1 | <Null> | 302 |
| Location 16 | Chosen | 1 | <Null> | 134 |
| Location 17 | Chosen | 1 | <Null> | 162 |

## FIGURE 3d – Both Allocated Calls

| Name | FacilityType | Weight | Capacity | DemandCount |
|---|---|---|---|---|
| Location 1 | Chosen | 1 | <Null> | 372 |
| Location 2 | Chosen | 1 | <Null> | 398 |
| Location 3 | Chosen | 1 | <Null> | 714 |
| Location 4 | Chosen | 1 | <Null> | 357 |
| Location 5 | Chosen | 1 | <Null> | 339 |
| Location 6 | Chosen | 1 | <Null> | 220 |
| Location 7 | Chosen | 1 | <Null> | 308 |
| Location 8 | Chosen | 1 | <Null> | 441 |
| Location 9 | Chosen | 1 | <Null> | 545 |
| Location 10 | Chosen | 1 | <Null> | 428 |
| Location 11 | Chosen | 1 | <Null> | 218 |
| Location 12 | Chosen | 1 | <Null> | 482 |
| Location 13 | Chosen | 1 | <Null> | 373 |
| Location 14 | Chosen | 1 | <Null> | 337 |
| Location 15 | Chosen | 1 | <Null> | 302 |
| Location 16 | Chosen | 1 | <Null> | 124 |
| Location 17 | Chosen | 1 | <Null> | 135 |
| Location 18 | Chosen | 1 | <Null> | 162 |

**FIGURE 4a – Original Longest Trip**

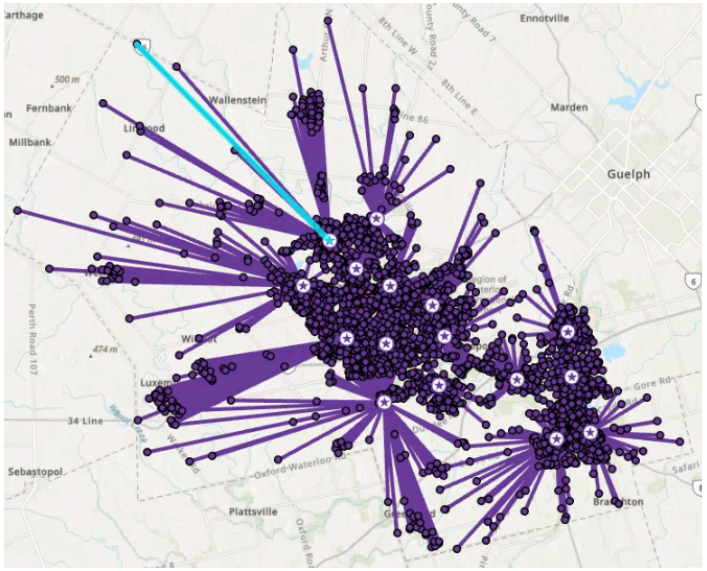


**FIGURE 4b – Elmira Longest Trip**

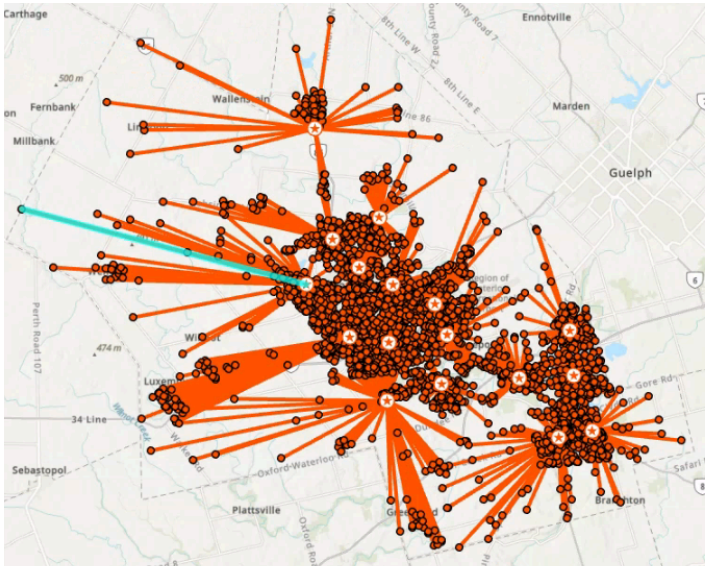


**FIGURE 4c – New Hamburg Longest Trip**

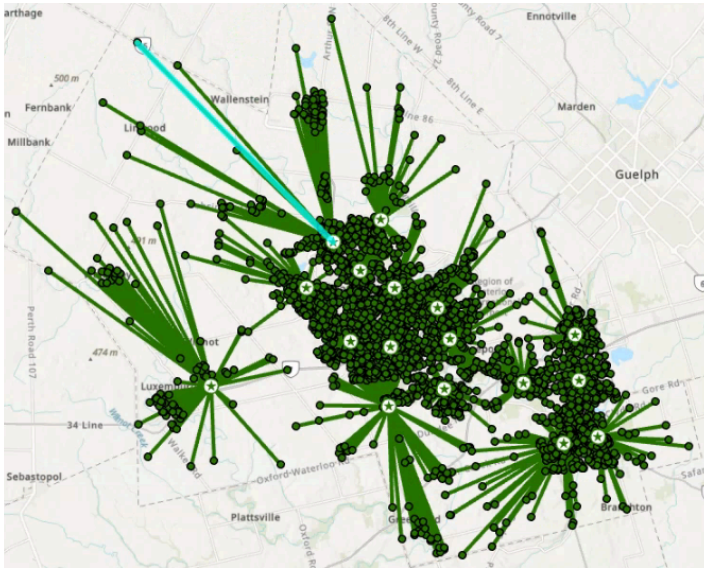


**FIGURE 4d – Both Longest Trip**

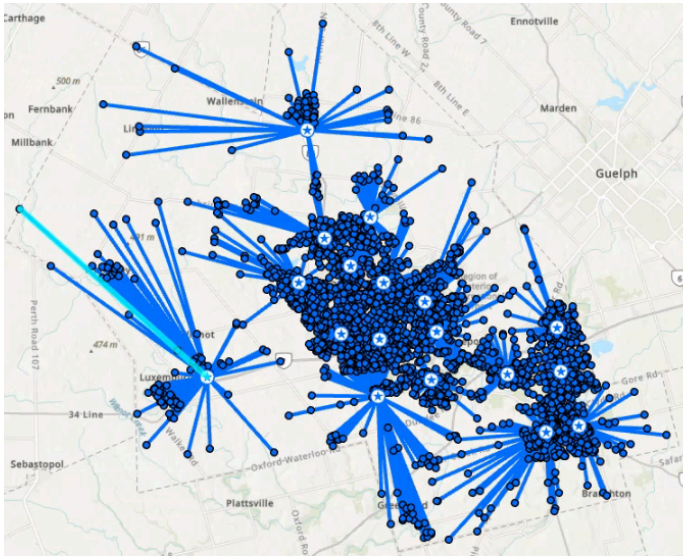

**FIGURE 5 – Original SA**

# Service Areas For Existing Fire Stations in Waterloo Region

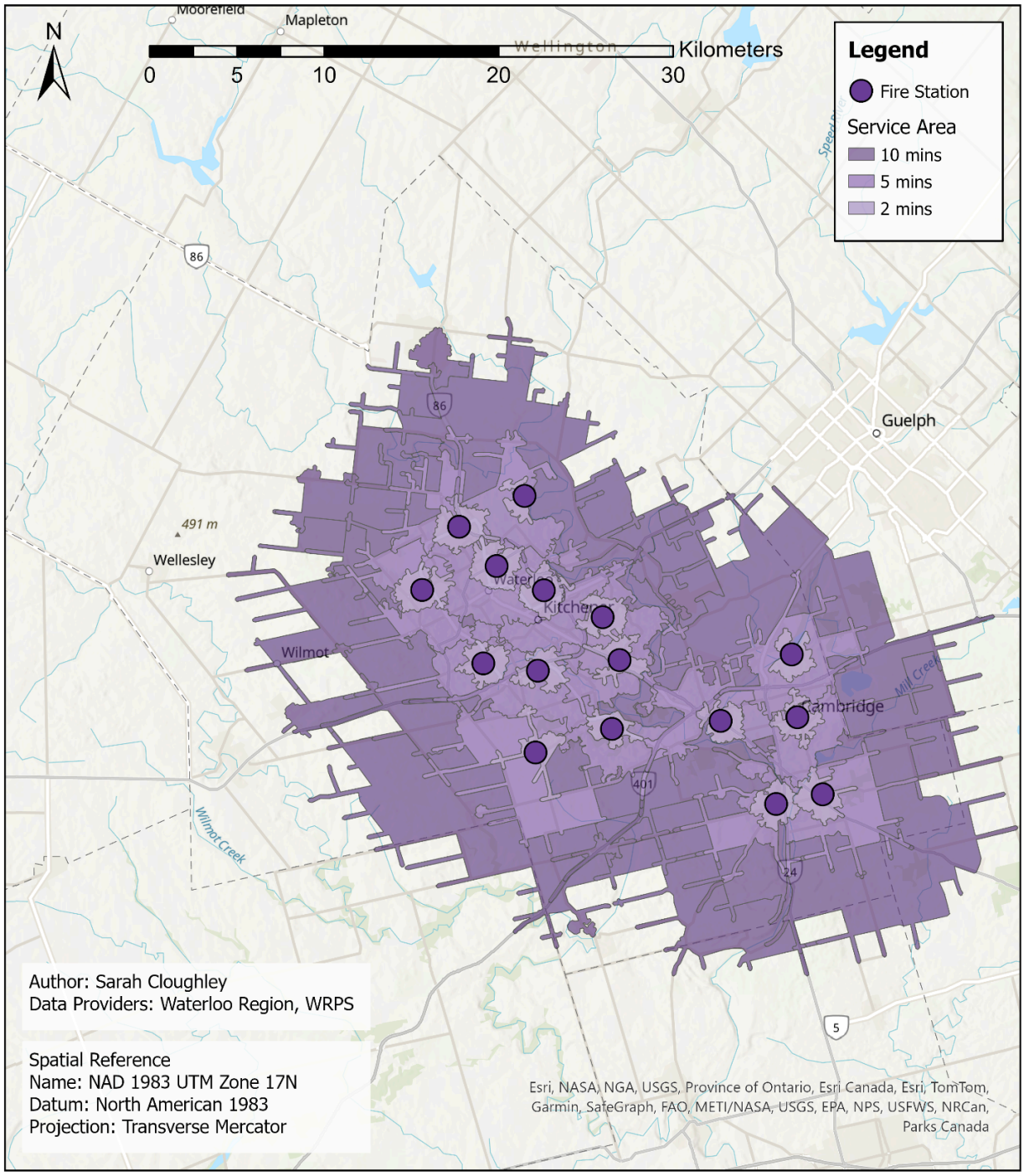

**FIGURE 6 – Elmira SA**

# Service Areas For Existing Fire Stations and Proposed Elmira Station in Waterloo Region

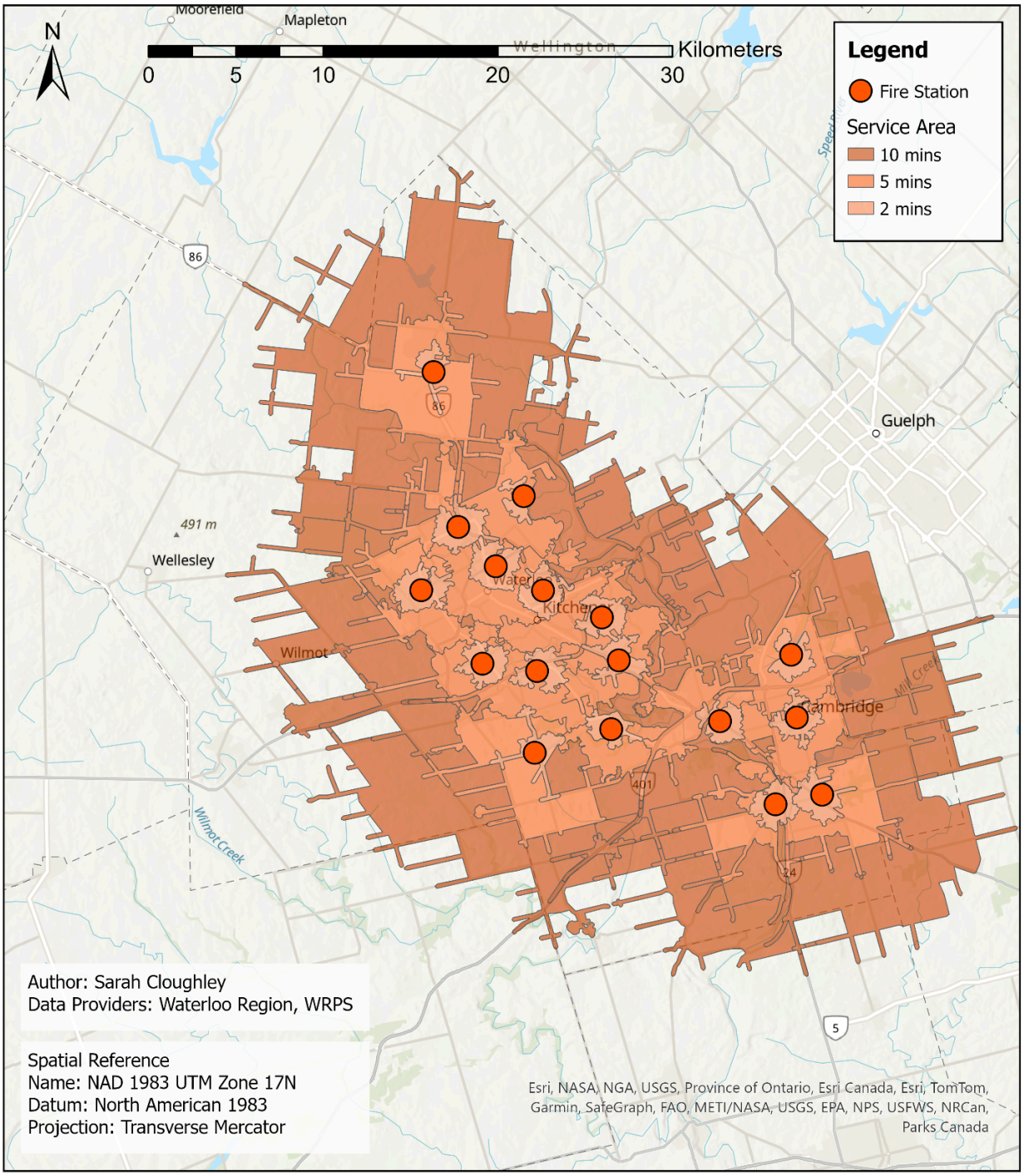

**FIGURE 7 – New Hamburg SA**

# Service Areas For Existing Fire Stations and Proposed New Hamburg Station in Waterloo Region

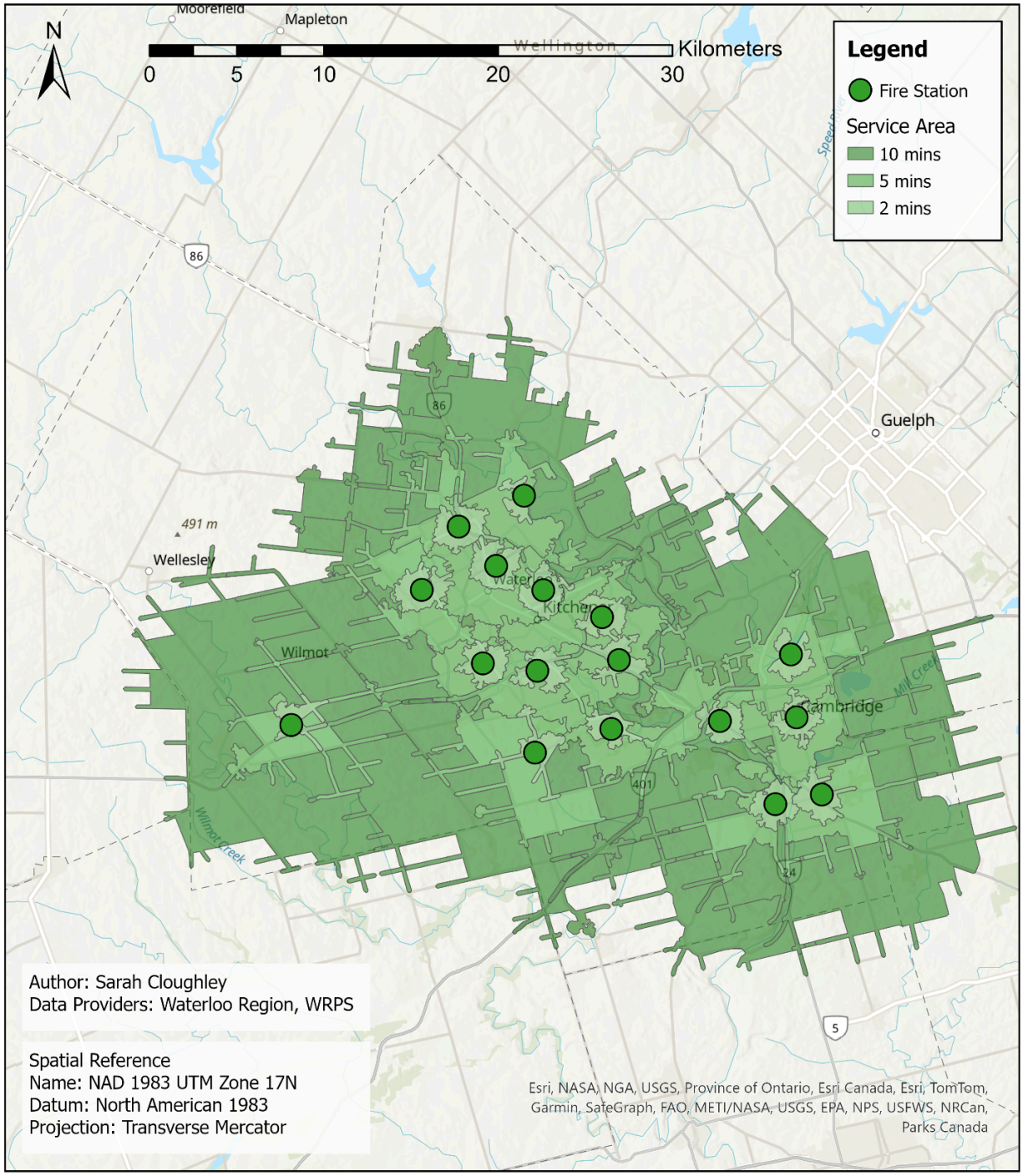

**FIGURE 8 – Both SA**

# Service Areas For Existing Fire Stations and Proposed Elmira and New Hamburg Stations in Waterloo Region

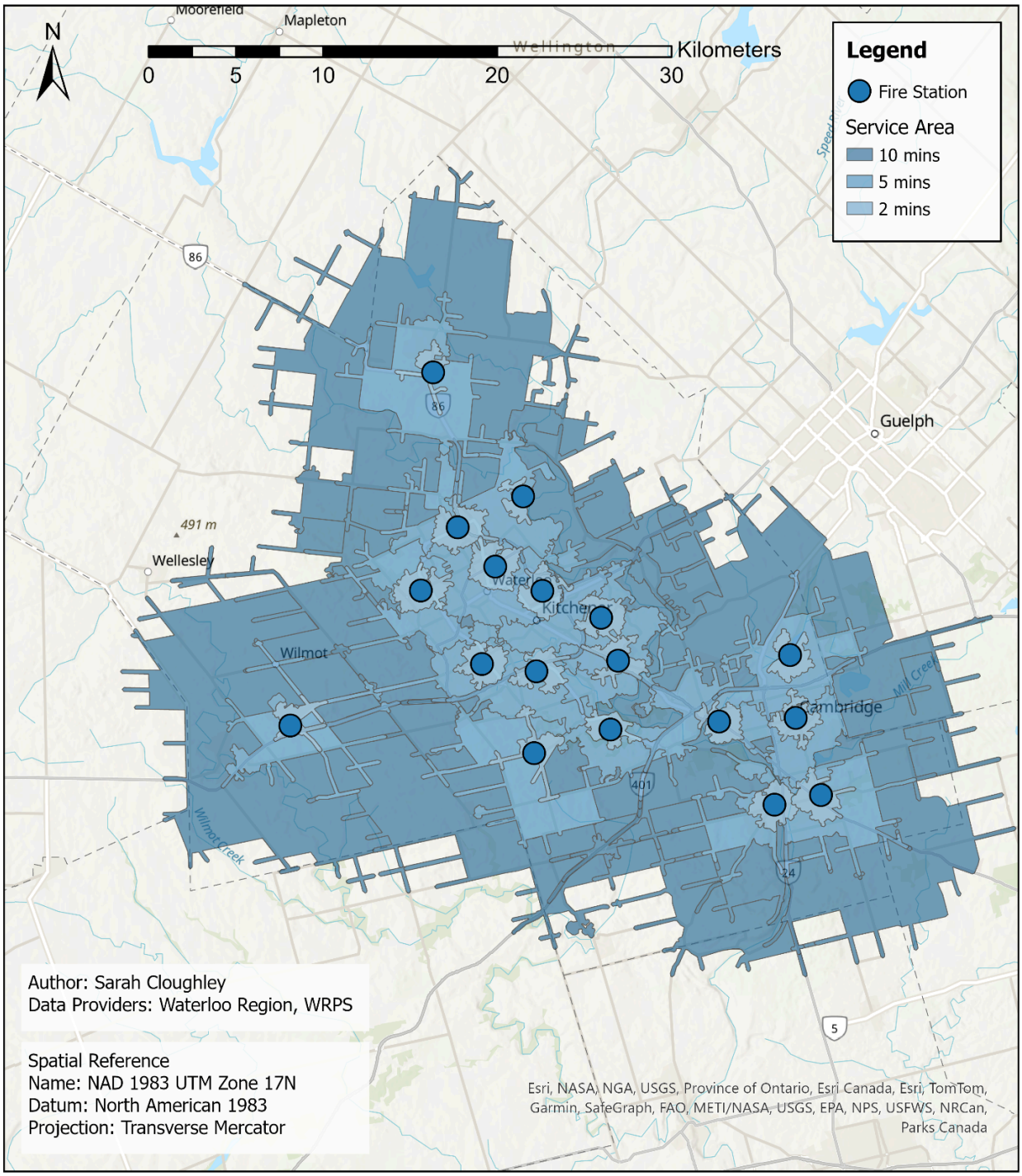

**FIGURE 9 – Original LA**

# Location-Allocation For Existing Fire Stations in Waterloo Region

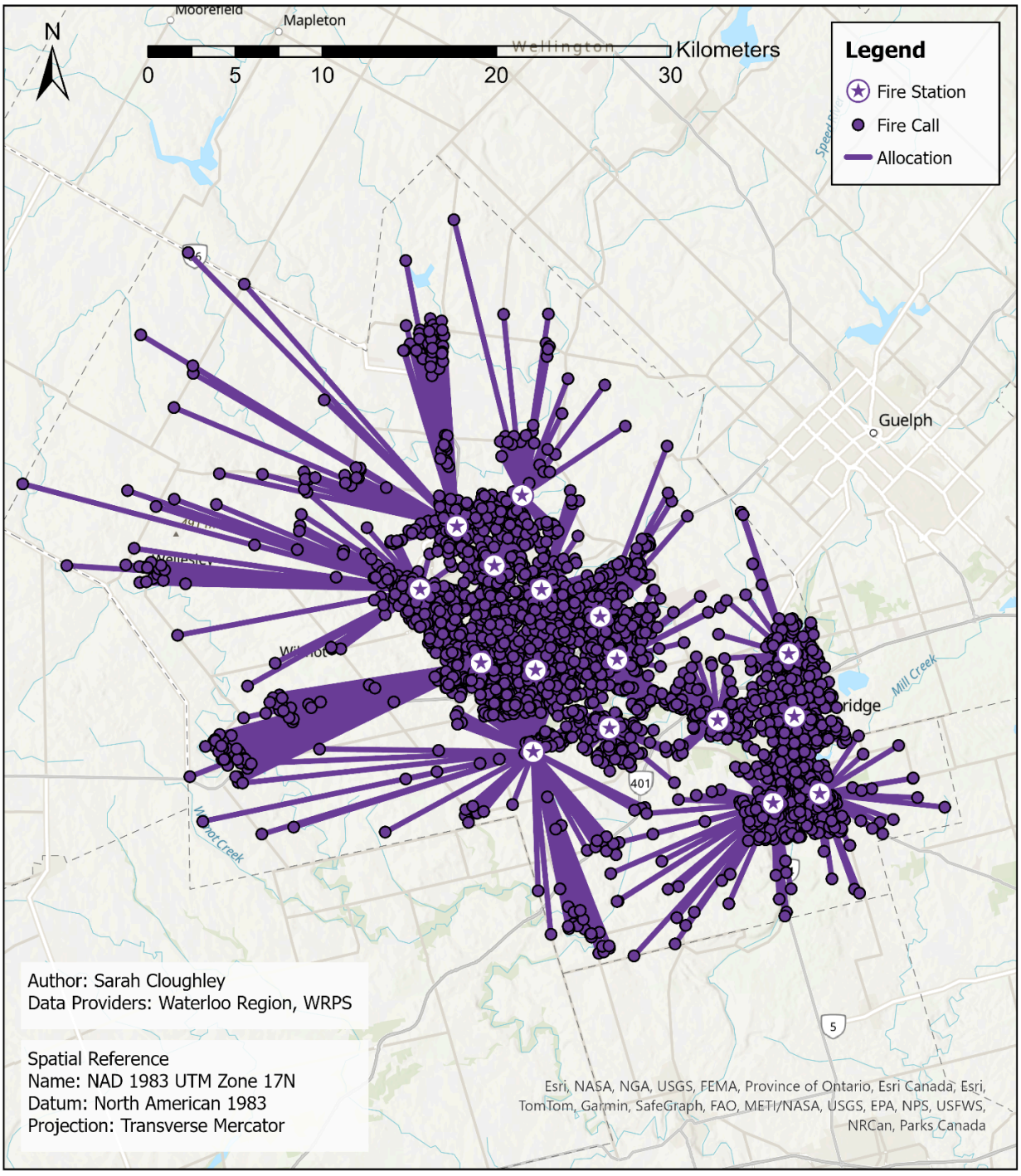

**FIGURE 10 – Elmira LA**

# Location-Allocation For Existing Fire Stations and Proposed Elmira Station in Waterloo Region

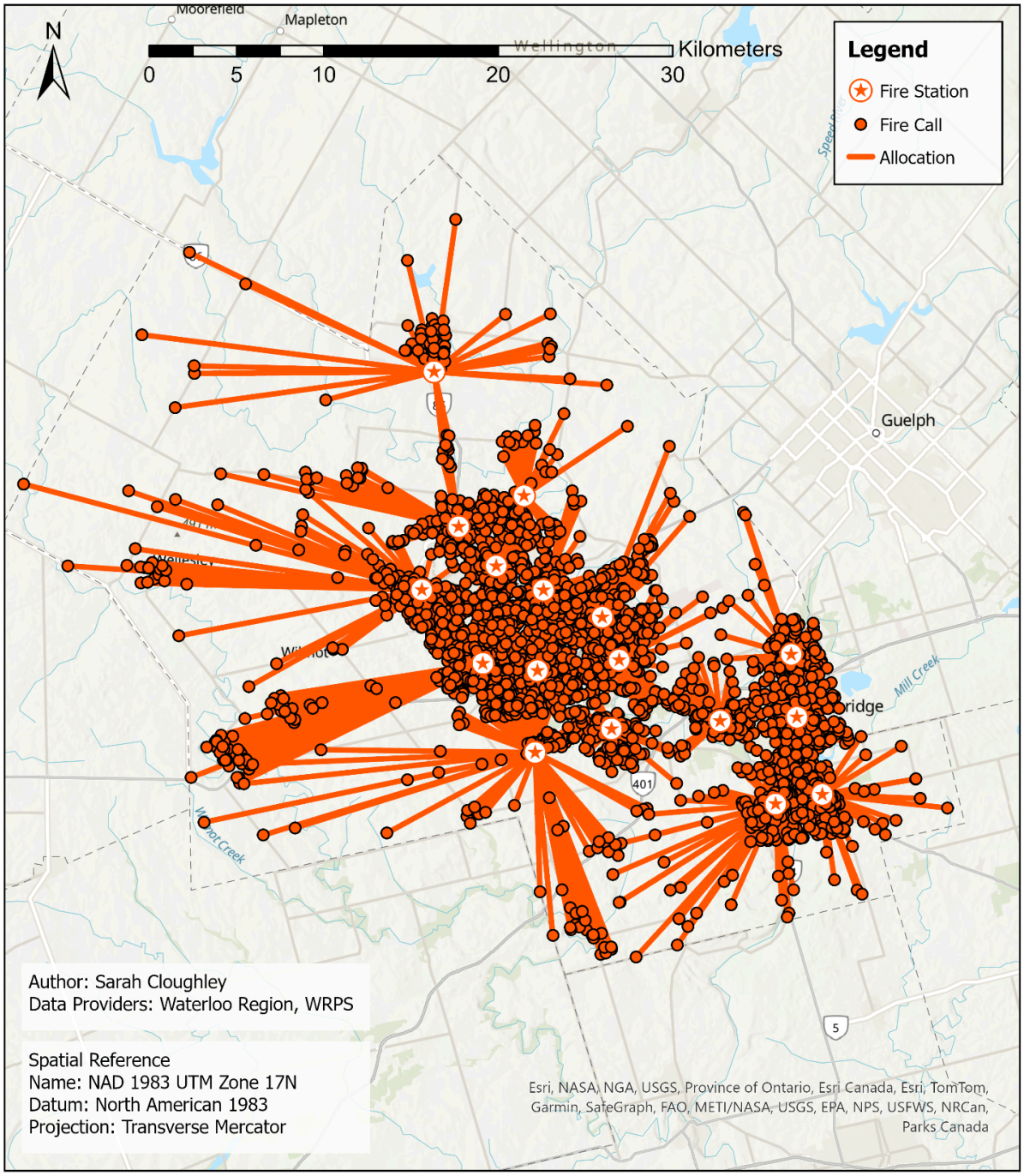

**FIGURE 11 – New Hamburg LA**

# Location-Allocation For Existing Fire Stations and Proposed New Hamburg Station in Waterloo Region

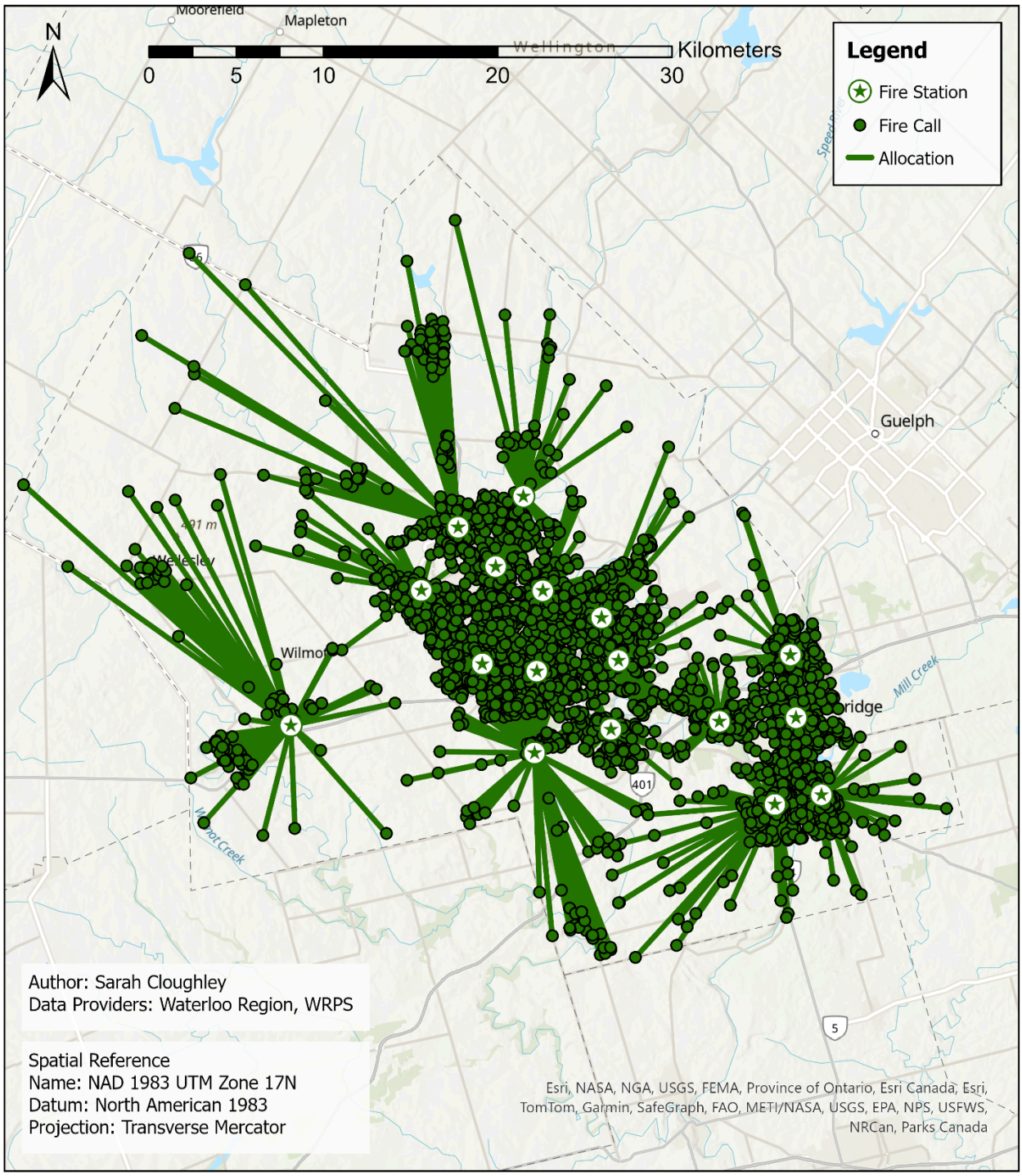

**FIGURE 12 – Both LA**

# Location-Allocation For Existing Fire Stations and Proposed Elmira and New Hamburg Stations in Waterloo Region