Accident Findings Report

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11/24/2021

Report of Grand Rapids Accident Analysis

Load necessary packages and set max numerical digits displayed in tibble to 8 (necessary for long/lat coordinates):

```
library(tidyverse)
library(sf)
library(osmdata)
library(ggpubr)
library(ggforce)
options(digits = 8)
```

Specify size of all graphs in Knitted Documents:

```
knitr::opts_chunk$set(echo = TRUE, fig.width = 16, fig.height = 8)
```

Upload Grand Rapids Crash Dataset (2008 - 2017):

```
crash_data <- read_csv(here::here("data", "CGR_Crash_Data.csv"))
head(crash_data[1:6])
```

```
## # A tibble: 6 x 6
##       X     Y OBJECTID ROADSOFTID BIKE  CITY
##   <dbl> <dbl>    <dbl>      <dbl> <chr> <chr>
## 1 -85.7  42.9        1    2589528 No    Grand Rapids
## 2 -85.6  42.9        2    2593183 No    Grand Rapids
## 3 -85.7  43.0        3    2582102 No    Grand Rapids
## 4 -85.6  42.9        4    2579820 No    Grand Rapids
## 5 -85.7  43.0        5    2594624 No    Grand Rapids
## 6 -85.7  43.0        6    2599372 No    Grand Rapids
```

Configure features necessary for Grand Rapids map (using openstreetmap api)

```
location_gr <- getbb("Grand Rapids") %>%
    opq()

major_roads_gr <- location_gr %>%
    add_osm_feature(key = "highway", value = c("motorway", "trunk", "primary", "secondary", "tertiary")) %>%
    osmdata_sf()

#minor_roads_gr <- location_gr %>%
    #add_osm_feature(key = "highway", value = c("unclassified", "residential")) %>%
    #osmdata_sf()

water_gr <- location_gr %>%
```

```
    add_osm_feature(key = "waterway", value = c("river")) %>%
    osmdata_sf()

boundary_gr <- location_gr %>%
    add_osm_feature(key = "boundary", value = "administrative") %>%
    add_osm_feature(key = "name", value = "Grand Rapids") %>%
    osmdata_sf()
```

Grand Rapids accidents associated with trains:

I am interested in studying the impact gates at a railroad crossing have on the number of accidents associated with trains.

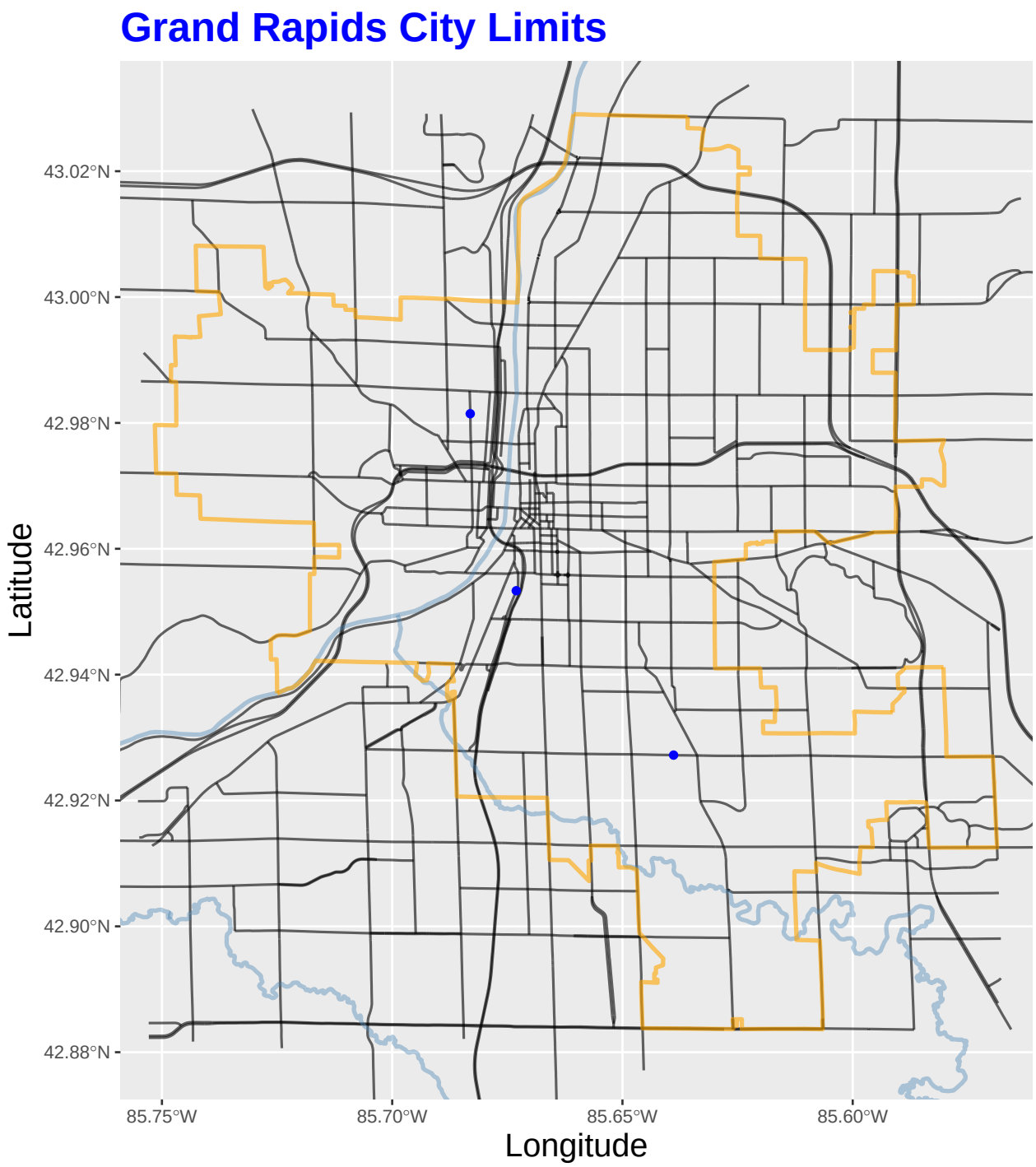
Let's start by visualizing the number of Grand Rapids crashes associated with a train from 2008 - 2017.

```
crash_data_train <- crash_data %>%
  filter(TRAIN == "Yes")

crash_data_train %>%
  select(`Longitude` = X, `Latitude` = Y, CRASHDATE, TRAIN, `Principal Road` = PRNAME)
```

```
## # A tibble: 3 x 5
##   Longitude Latitude CRASHDATE  TRAIN `Principal Road`
##       <dbl>    <dbl> <date>     <chr> <chr>
## 1     -85.6     42.9 2008-02-19 Yes   BURTON
## 2     -85.7     43.0 2014-05-03 Yes   11TH
## 3     -85.7     43.0 2017-12-27 Yes   CENTURY
```

```
  ggplot()+
            geom_sf(data = major_roads_gr$osm_lines, size = .6, alpha = .6, color = 'black') +
            #geom_sf(data = minor_roads_gr$osm_lines, size = .3, alpha = .3, color = 'black') +
            geom_sf(data = water_gr$osm_lines, size = 1, alpha = .4, color = 'steelblue') +
            geom_sf(data = boundary_gr$osm_lines, size = 1, alpha = .6, color = "orange") +
            geom_point(data = crash_data_train, mapping = aes(x = X, y = Y), color = "blue") +
            coord_sf(xlim = c(-85.57, -85.75), ylim = c(42.88, 43.03)) +
            labs(title = "Grand Rapids City Limits", x = "Longitude", y = "Latitude") +
            font("title", size = 20, color = "blue", face = "bold") +
            font("x", size = 16) +
            font("y", size = 16)
```



As you can see, from 2008 to 2017 there were only three accidents that occurred in Grand Rapids involving a train (In 2017, 2014, and 2008).

Although we have a very limited number of accidents directly involving a train, this is not a dead-end for our analysis.

Next let's upload a a dataset from Transportation.gov (https://data.transportation.gov/Railroads/Crossing-Inventory-Data-Current/m2f8-22s6) that provides information about every railroad crossing in the USA:

```
rr_crossing_data <- read_csv(here::here("data", "Crossing_Inventory_Data_-_Current.csv"))
```

```
head(rr_crossing_data[1:6])
```

```
## # A tibble: 6 x 6
##   `Revision Date` `Reporting Agency Type I~ `Reporting Agency Typ~ `Reason Code`
##   <date>                              <dbl> <chr>                            <dbl>
## 1 1970-01-01                              1 Railroad                            15
## 2 1970-01-01                              1 Railroad                            15
## 3 1970-01-01                              1 Railroad                            15
## 4 1970-01-01                              1 Railroad                            15
## 5 1970-01-01                              1 Railroad                            15
## 6 1970-01-01                              1 Railroad                            15
## # ... with 2 more variables: Reason Description <chr>, Crossing ID <chr>
```

Now we filter this data for only railroad crossing within the Grand Rapids city limits (Note that there are three crossing located in the city center where Latitude = 42.96336 that I removed as it seems like the long/lang for these were placeholders):

```
rr_crossing_data_gr <- rr_crossing_data %>%
  filter(`State Name` == "MICHIGAN", `City Name` == "GRAND RAPIDS", `Intersecting Roadway` == "Yes", La

head(rr_crossing_data_gr[1:6])
```

```
## # A tibble: 6 x 6
##   `Revision Date` `Reporting Agency Type I~ `Reporting Agency Typ~ `Reason Code`
##   <date>                              <dbl> <chr>                            <dbl>
## 1 1991-04-03                              1 Railroad                            16
## 2 1997-12-31                              1 Railroad                            16
## 3 2001-08-31                              1 Railroad                            16
## 4 2010-01-01                              2 State                               16
## 5 2010-01-01                              2 State                               16
## 6 2010-09-01                              1 Railroad                            16
## # ... with 2 more variables: Reason Description <chr>, Crossing ID <chr>
```

Let's Make Sure that there are no duplicates in the data:

```
nrow(distinct(rr_crossing_data_gr, Latitude))
```

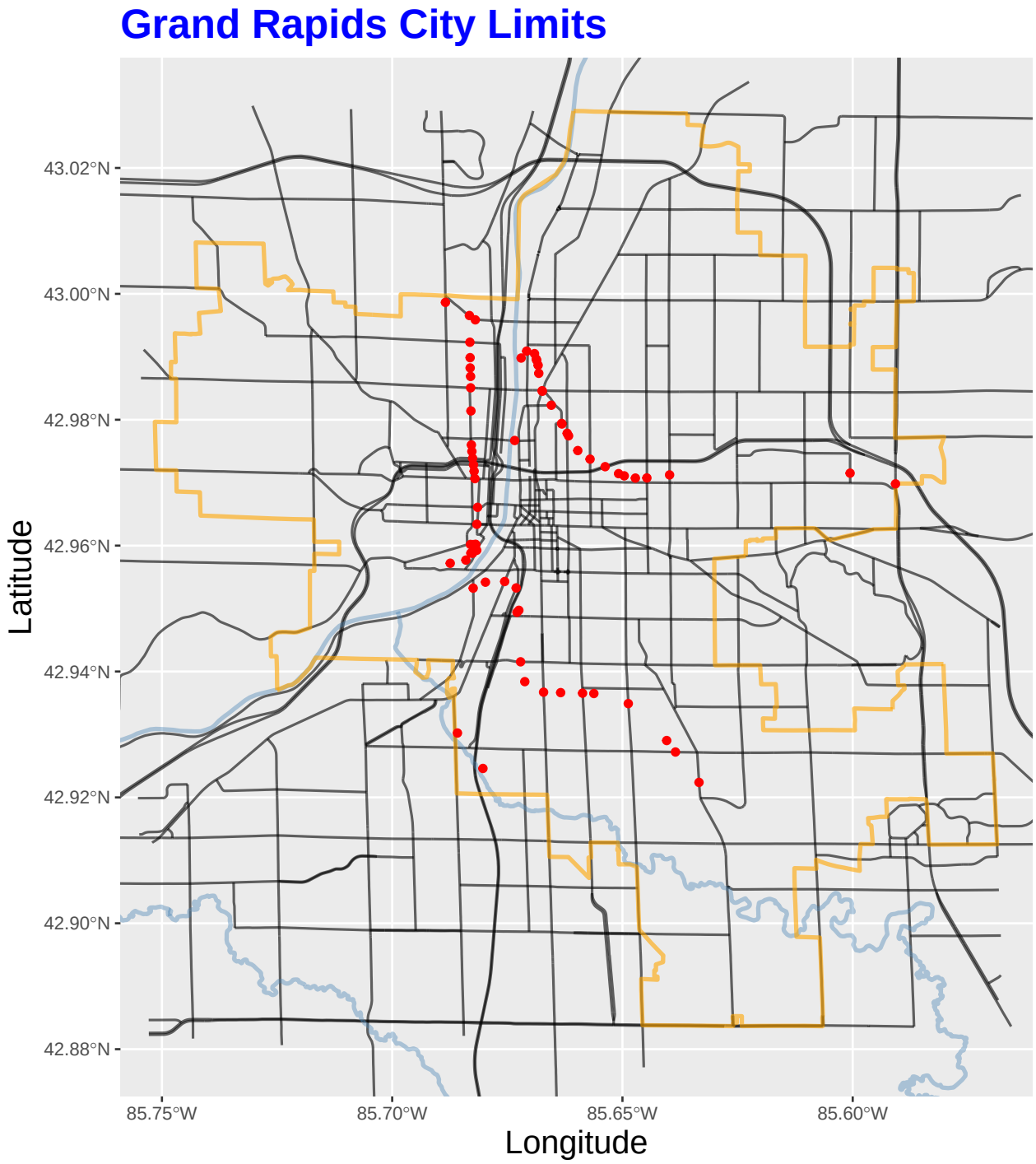
```
## [1] 74
```

```
nrow(rr_crossing_data_gr)
```

```
## [1] 74
```

We can visualize this data in red on our Grand Rapid's Map:

```
  ggplot()+
            geom_sf(data = major_roads_gr$osm_lines, size = .6, alpha = .6, color = 'black') +
            #geom_sf(data = minor_roads_gr$osm_lines, size = .3, alpha = .3, color = 'black') +
            geom_sf(data = water_gr$osm_lines, size = 1, alpha = .4, color = 'steelblue') +
            geom_sf(data = boundary_gr$osm_lines, size = 1, alpha = .6, color = "orange") +
            geom_point(data = rr_crossing_data_gr, mapping = aes(x = Longitude, y = Latitude), color =
            coord_sf(xlim = c(-85.57, -85.75), ylim = c(42.88, 43.03)) +
            labs(title = "Grand Rapids City Limits", x = "Longitude", y = "Latitude") +
            font("title", size = 20, color = "blue", face = "bold") +
            font("x", size = 16) +
            font("y", size = 16)
```



We now would like to know how many crashes fall within a .0005 (longitudinal units) radius of each railroad crossing.

To do so, we first write a function called in_radius() that detects if a longitude/latitude coordinate is located within a .0005 radius of all railroad crossings:

```
in_radius <- function(x1, y1, x2, y2) {
  if_else(((x1 - x2) ^ 2 + (y1 - y2) ^ 2) <= .0005 ^ 2, 1, 0)
}
```

Next we create a new accident subset named near_rr_crash that only contains crashes that occurred within

a .0005 radius of a railroad crossing:

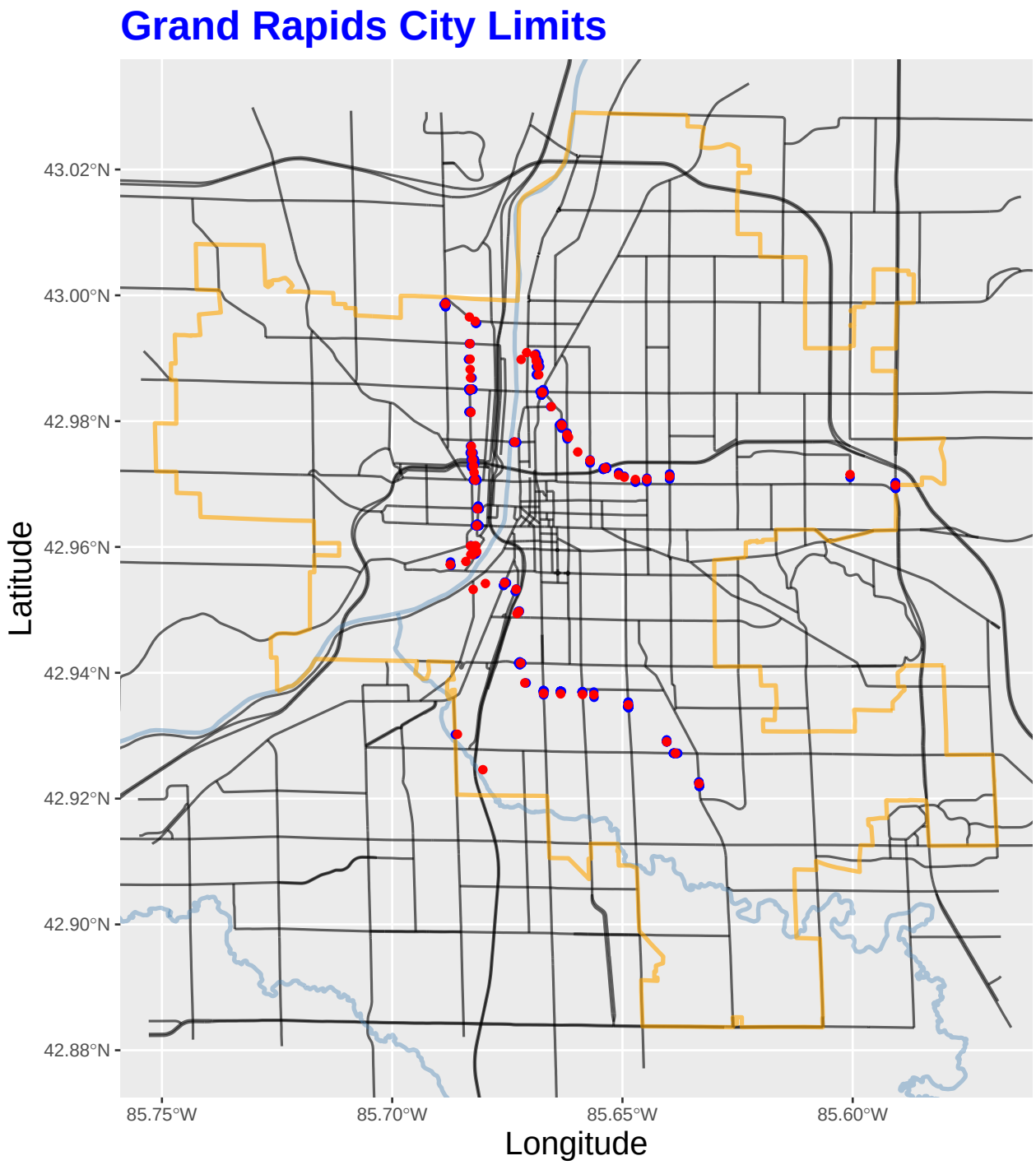
```
near_rr_crash <- crash_data %>%
  rowwise() %>%
  filter(1 %in% in_radius(X, Y, rr_crossing_data_gr$Longitude, rr_crossing_data_gr$Latitude))

head(near_rr_crash[1:6])
```

```
## # A tibble: 6 x 6
## # Rowwise:
##       X     Y OBJECTID ROADSOFTID BIKE  CITY
##   <dbl> <dbl>    <dbl>      <dbl> <chr> <chr>
## 1 -85.6  42.9      120    2587376 No    Grand Rapids
## 2 -85.7  43.0      343    2579633 No    Grand Rapids
## 3 -85.6  42.9      663    2591863 No    Grand Rapids
## 4 -85.6  42.9      664    2597546 No    Grand Rapids
## 5 -85.6  42.9      665    2583626 No    Grand Rapids
## 6 -85.6  42.9      666    2579464 No    Grand Rapids
```

We plot this data on our grand rapids map to visualize the result:

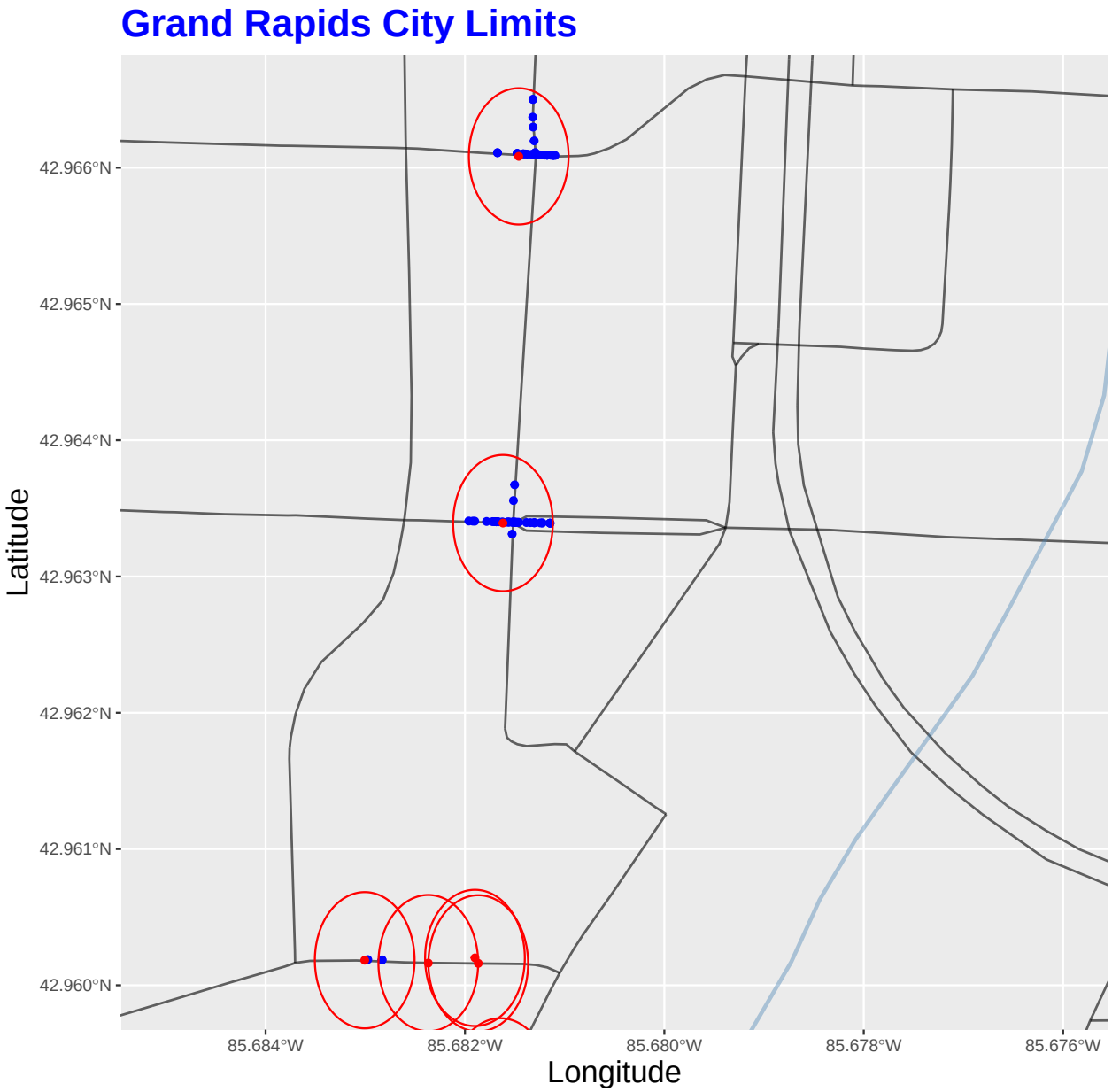
```
  ggplot()+
            geom_sf(data = major_roads_gr$osm_lines, size = .6, alpha = .6, color = 'black') +
            #geom_sf(data = minor_roads_gr$osm_lines, size = .3, alpha = .3, color = 'black') +
            geom_sf(data = water_gr$osm_lines, size = 1, alpha = .4, color = 'steelblue') +
            geom_sf(data = boundary_gr$osm_lines, size = 1, alpha = .6, color = "orange") +
            geom_point(data = near_rr_crash, mapping = aes(x = X, y = Y), color = "blue") +
            geom_point(data = rr_crossing_data_gr, mapping = aes(x = Longitude, y = Latitude), color =
            geom_circle(data = rr_crossing_data_gr, mapping = aes(x0 = Longitude, y0 = Latitude, r = .0
            coord_sf(xlim = c(-85.57, -85.75), ylim = c(42.88, 43.03)) +
            labs(title = "Grand Rapids City Limits", x = "Longitude", y = "Latitude") +
            font("title", size = 20, color = "blue", face = "bold") +
            font("x", size = 16) +
            font("y", size = 16)
```



Below is a zoomed-in portion of the map for better detail (located around the GVSU Pew Campus):

```
ggplot()+
          geom_sf(data = major_roads_gr$osm_lines, size = .6, alpha = .6, color = 'black') +
          #geom_sf(data = minor_roads_gr$osm_lines, size = .3, alpha = .3, color = 'black') +
          geom_sf(data = water_gr$osm_lines, size = 1, alpha = .4, color = 'steelblue') +
          geom_sf(data = boundary_gr$osm_lines, size = 1, alpha = .6, color = "orange") +
          geom_point(data = near_rr_crash, mapping = aes(x = X, y = Y), color = "blue") +
          geom_point(data = rr_crossing_data_gr, mapping = aes(x = Longitude, y = Latitude), color =
          geom_circle(data = rr_crossing_data_gr, mapping = aes(x0 = Longitude, y0 = Latitude, r = .0
```

```
  coord_sf(xlim = c(-85.676, -85.685), ylim = c(42.96, 42.9665)) +
  labs(title = "Grand Rapids City Limits", x = "Longitude", y = "Latitude") +
  font("title", size = 20, color = "blue", face = "bold") +
  font("x", size = 16) +
  font("y", size = 16)
```



Now we create a tibble that sums the number of crashes that fall within a .0005 radius of each crossing along with the number of Gate arms at that crossing and the total number of trains that pass through during the day and night:

```
exposure <- rr_crossing_data_gr %>%
  rowwise() %>%
  mutate(Radius_Count = sum(in_radius(Longitude, Latitude, near_rr_crash$X, near_rr_crash$Y))) %>%
  select(Longitude, Latitude, Street, "Gate_Arm_N" = `Count Roadway Gate Arms`, Radius_Count, `Total Da
  arrange(desc(Radius_Count)) %>%
```

```
  ungroup()

head(exposure,10)
```

```
## # A tibble: 10 x 7
##    Longitude Latitude Street         Gate_Arm_N Radius_Count `Total Daylight Th~
##        <dbl>    <dbl> <chr>               <dbl>        <dbl>                <dbl>
##  1     -85.7     43.0 PLAINFIELD AV~          0          111                    0
##  2     -85.7     43.0 LEONARD ST              0          108                    0
##  3     -85.7     43.0 W LEONARD ST            0           84                    0
##  4     -85.7     42.9 HALL ST                 2           79                    2
##  5     -85.6     43.0 E BELTLINE AV~          0           74                    1
##  6     -85.7     43.0 FULTON STREET           0           45                    1
##  7     -85.7     43.0 ALPINE AVENUE           0           41                    1
##  8     -85.7     43.0 LAKE MICHIGAN~          2           40                    1
##  9     -85.7     43.0 11TH STREET             0           38                    0
## 10     -85.7     42.9 JEFFERSON AVE           2           32                    2
## # ... with 1 more variable: Total Nighttime Thru Trains <dbl>
```

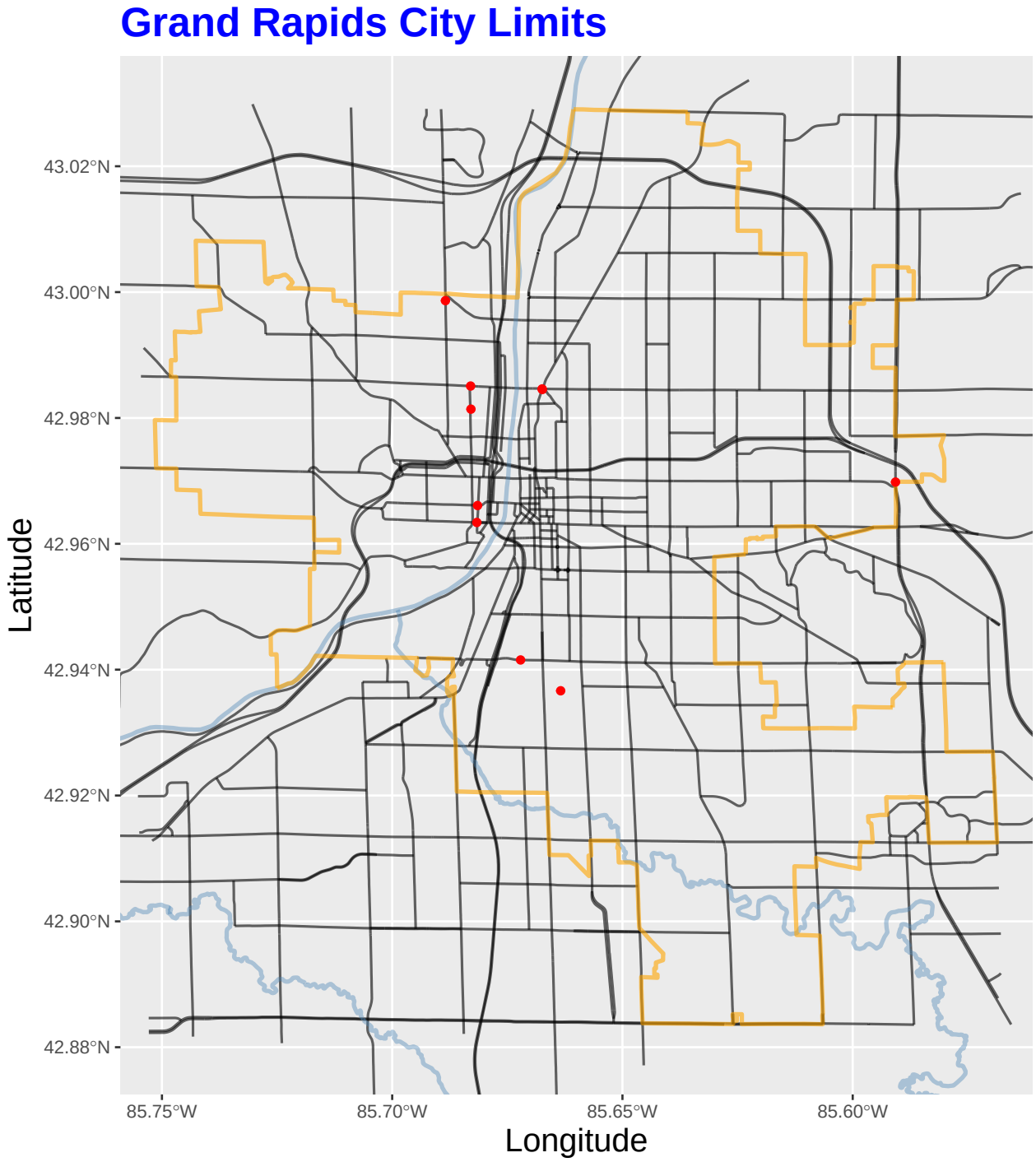
We can use the number of accidents that occur within .0005 longitudinal units from a crossing (Radius_Count) to represent/correspond to traffic exposure. We are deriving latent information from this variable to determine if additional safety protocols should be put in place at any particular train crossing.

The tibble shows us the crossings with the highest number of crashes that occurred near-by (Radius_Count). We see that out of the top 10 crossings with the highest traffic exposure, only 3 have gate arms.

Let's take a look at these top 10 traffic exposure crossings on the Grand Rapids Map:

```
exposure_top_10 <- exposure %>%
  slice_head(n = 10)
```

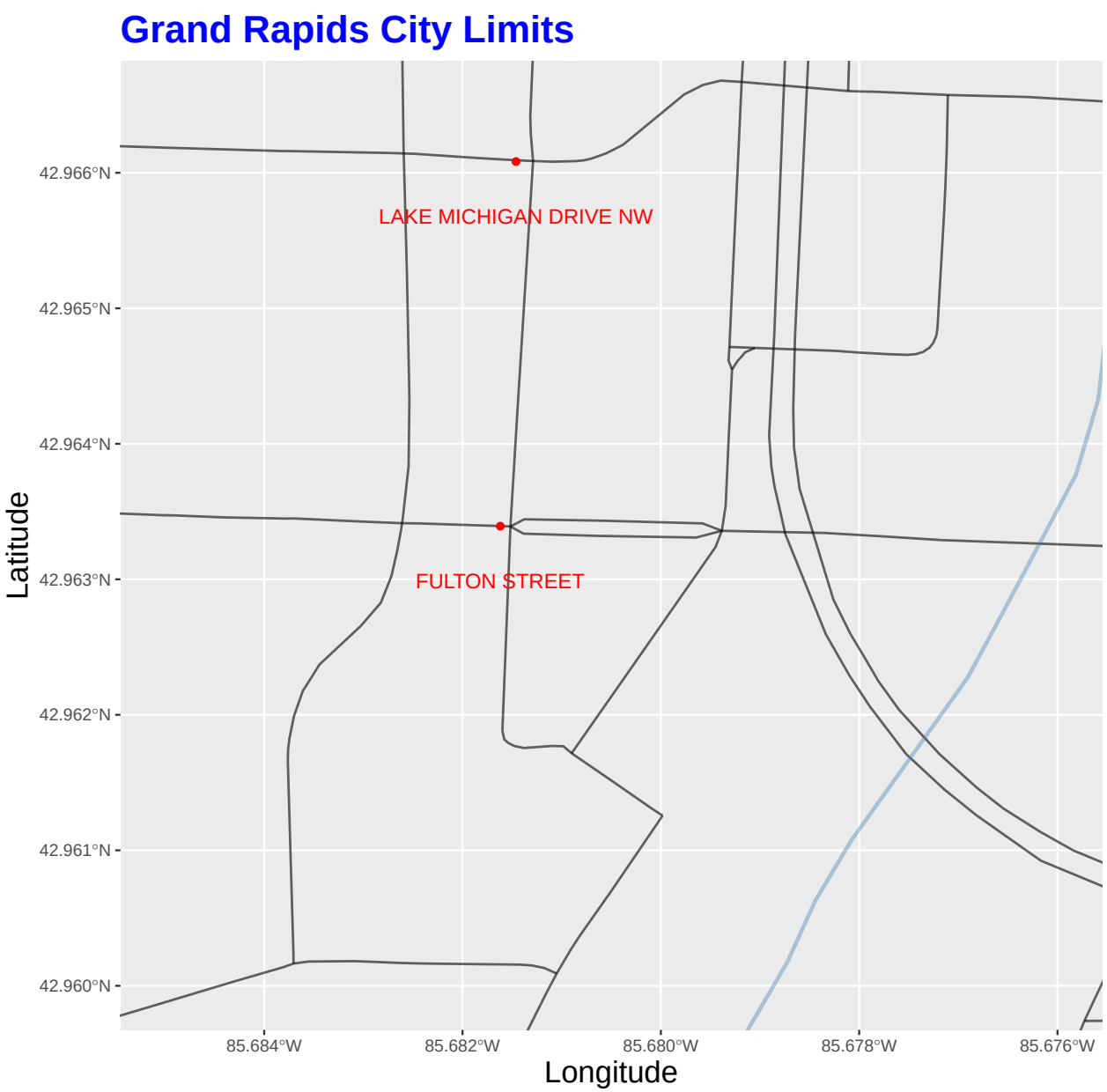
```
  ggplot()+
            geom_sf(data = major_roads_gr$osm_lines, size = .6, alpha = .6, color = 'black') +
            #geom_sf(data = minor_roads_gr$osm_lines, size = .3, alpha = .3, color = 'black') +
            geom_sf(data = water_gr$osm_lines, size = 1, alpha = .4, color = 'steelblue') +
            geom_sf(data = boundary_gr$osm_lines, size = 1, alpha = .6, color = "orange") +
            geom_point(data = exposure_top_10, mapping = aes(x = Longitude, y = Latitude), color = "red
            coord_sf(xlim = c(-85.57, -85.75), ylim = c(42.88, 43.03)) +
            labs(title = "Grand Rapids City Limits", x = "Longitude", y = "Latitude") +
            font("title", size = 20, color = "blue", face = "bold") +
            font("x", size = 16) +
            font("y", size = 16)
```



We can see these crossings are scattered around the city. Notice that two of these crossings are located on the GVSU Pew Campus:

```
ggplot()+
          geom_sf(data = major_roads_gr$osm_lines, size = .6, alpha = .6, color = 'black') +
          #geom_sf(data = minor_roads_gr$osm_lines, size = .3, alpha = .3, color = 'black') +
          geom_sf(data = water_gr$osm_lines, size = 1, alpha = .4, color = 'steelblue') +
          geom_sf(data = boundary_gr$osm_lines, size = 1, alpha = .6, color = "orange") +
          geom_point(data = exposure_top_10, mapping = aes(x = Longitude, y = Latitude), color = "red
          #geom_circle(data = exposure_top_10, mapping = aes(x0 = Longitude, y0 = Latitude, r = .0005
```

```
  coord_sf(xlim = c(-85.676, -85.685), ylim = c(42.96, 42.9665)) +
  labs(title = "Grand Rapids City Limits", x = "Longitude", y = "Latitude") +
  geom_text(data = exposure_top_10, mapping = aes(Longitude, Latitude, label = Street), nudge_
  font("title", size = 20, color = "blue", face = "bold") +
  font("x", size = 16) +
  font("y", size = 16)
```



We can see that the crossing at "LAKE MICHIGAN DRIVE NW" (-85.681461,42966083) does have gate arms while the crossing at "FULTON STREET" (-85.681619,42.963392) does not have gate arms. Also note that the total Daylight (1) and Nighttime (2) trains for these crossings are the same while the Radius_Count for the "FULTON STREET" crossing (45) is greater than the "LAKE MICHIGAN DRIVE NW" crossing (40):

```
exposure_top_10 %>%
  filter(Street %in% c("LAKE MICHIGAN DRIVE NW", "FULTON STREET"))
```

```
## # A tibble: 2 x 7
##   Longitude Latitude Street        Gate_Arm_N Radius_Count `Total Daylight Thru~
##       <dbl>    <dbl> <chr>              <dbl>        <dbl>                  <dbl>
## 1     -85.7     43.0 FULTON STREET          0           45                      1
## 2     -85.7     43.0 LAKE MICHIGA~          2           40                      1
## # ... with 1 more variable: Total Nighttime Thru Trains <dbl>
```

I am not sure what metrics are used by the city of Grand Rapids to determine if a railroad crossing arm is necessary, but there appears to be a degree of inconsistency.

Note that among all 74 railroad crossings in Grand Rapids, 26 have at least one gate arm.

```
exposure %>%
  filter(Gate_Arm_N > 0) %>%
  nrow()
```

```
## [1] 26
```

Of these 26 crossings, 22 have at least one Daylight Train OR one Nighttime train pass through. This is about 85% (22/26):

```
exposure %>%
  filter(Gate_Arm_N > 0, (`Total Daylight Thru Trains` > 0 | `Total Nighttime Thru Trains` > 0)) %>%
  nrow()
```

```
## [1] 22
```

With this in mind, let us take a second look at the top 10 traffic exposure crossings:

```
exposure_top_10
```

```
## # A tibble: 10 x 7
##    Longitude Latitude Street         Gate_Arm_N Radius_Count `Total Daylight Th~
##        <dbl>    <dbl> <chr>              <dbl>        <dbl>                <dbl>
##  1     -85.7     43.0 PLAINFIELD AV~          0          111                    0
##  2     -85.7     43.0 LEONARD ST              0          108                    0
##  3     -85.7     43.0 W LEONARD ST            0           84                    0
##  4     -85.7     42.9 HALL ST                 2           79                    2
##  5     -85.6     43.0 E BELTLINE AV~          0           74                    1
##  6     -85.7     43.0 FULTON STREET           0           45                    1
##  7     -85.7     43.0 ALPINE AVENUE           0           41                    1
##  8     -85.7     43.0 LAKE MICHIGAN~          2           40                    1
##  9     -85.7     43.0 11TH STREET             0           38                    0
## 10     -85.7     42.9 JEFFERSON AVE           2           32                    2
## # ... with 1 more variable: Total Nighttime Thru Trains <dbl>
```

As we noted earlier, 7 of these crossings do not have gate arms:

```
exposure_top_10 %>%
  filter(Gate_Arm_N == 0)
```

```
## # A tibble: 7 x 7
##   Longitude Latitude Street          Gate_Arm_N Radius_Count `Total Daylight Th~
##       <dbl>    <dbl> <chr>               <dbl>        <dbl>                <dbl>
## 1     -85.7     43.0 PLAINFIELD AVE~          0          111                    0
## 2     -85.7     43.0 LEONARD ST               0          108                    0
## 3     -85.7     43.0 W LEONARD ST             0           84                    0
## 4     -85.6     43.0 E BELTLINE AVE~          0           74                    1
## 5     -85.7     43.0 FULTON STREET            0           45                    1
## 6     -85.7     43.0 ALPINE AVENUE            0           41                    1
```

```
## 7     -85.7     43.0 11TH STREET              0           38                    0
## # ... with 1 more variable: Total Nighttime Thru Trains <dbl>
```

Of these 7, 5 have at least one daylight OR nighttime train go through each day:

```
exposure_top_10 %>%
  filter(Gate_Arm_N == 0, (`Total Daylight Thru Trains` > 0 | `Total Nighttime Thru Trains` > 0))
```

```
## # A tibble: 5 x 7
##   Longitude Latitude Street       Gate_Arm_N Radius_Count `Total Daylight Thru ~
##       <dbl>    <dbl> <chr>             <dbl>        <dbl>                  <dbl>
## 1     -85.7     43.0 W LEONARD ST          0           84                      0
## 2     -85.6     43.0 E BELTLINE ~          0           74                      1
## 3     -85.7     43.0 FULTON STRE~          0           45                      1
## 4     -85.7     43.0 ALPINE AVEN~          0           41                      1
## 5     -85.7     43.0 11TH STREET           0           38                      0
## # ... with 1 more variable: Total Nighttime Thru Trains <dbl>
```

I would recommend that the city of Grand Rapids takes a second look at these crossings to determine if a gate arm or additional traffic precautions are necessary.

Exploratory Application

To supplement this analysis, I have put together a Shiny Application for the city of Grand Rapids to explore the crash dataset on their own. This application can be accessed using the address below:

https://lcadagin.shinyapps.io/interactive_crash_plotting/