Methodology for Prioritizing Sidewalk Maintenance with GIS Overlay Analysis

Executive Summary

The Public Works department implements the Five Year Sidewalk Maintenance and Gap Infill Program. Each year, Geographic Information Systems analysis assists with identification of priority locations for sidewalk repair or gap infill. This document details the GIS analysis and contains three sections which include "Incorporating Pedestrian Crash Data", "Pedestrian Traffic Generator Analysis" and "Determining Locations with Gaps on one or Both Sides". The overarching goal of the analysis is to provide a scientific approach to identifying the most important locations to improve for the maximum benefit of the community.

Methodology for Prioritizing Sidewalk Maintenance with GIS Overlay Analysis

The following document outlines the steps taken to identify locations for prioritization in the upcoming sidewalk maintenance plan produced by the Public Works department. This analysis is performed upon the sidewalk survey performed by City staff in 2020, and which was subsequently updated with improvements made in 2023. This document contains three main sections outlining the steps taken to achieve the results. The sections included here are "Pedestrian Traffic Generator Analysis", "Determining Locations with Gaps on one or Both Sides", and "Incorporating Pedestrian Crash Data". Results are then aggregated for a final product that is then vetted by City staff to remove locations that present significant engineering challenges.

## Pedestrian Traffic Generator Analysis

The following outlines an overlay analysis involving inputs from pedestrian generator buffers, the sidewalk survey layer, and the spatial relationship between them. The result is a copy of the sidewalk survey layer with an additional data value for the number of traffic generators each sidewalk feature intersects, indicating its significance for pedestrian travel.

GIS Inputs:

- **Pedestrian Traffic Generators (Point Features):**
    - Bus Stops
    - State Assisted Living Facilities
    - Housing Choice Voucher Program Locations
    - Schools
    - Registered Paratransit Homes
    - Parks
    - Major Destinations (Grocery stores, Shopping, Government, Library, etc.)

- **Sidewalk Survey GIS dataset (Line Features):**
    - In 2020 City staff assessed all sidewalks in the city limits for overall condition by looking at several criteria.
    - In 2023 the survey data was updated to reflect where sidewalk improvements had been made, to serve as the base layer.
    - GIS features (polylines) were created to represent the existing sidewalk and locations where sidewalk was missing or where there was a gap:
        - Missing sidewalk denotes locations where no sidewalk exists for two or more blocks, and was never a part of the original right of way construction.
        - Gaps in the sidewalk represent locations where two sidewalk segments are made non-continuous by a gap or significant obstacle in the approach of the pedestrian. This could be driveways with flared shoulders that create a step down or up in the sidewalk approach, for example.

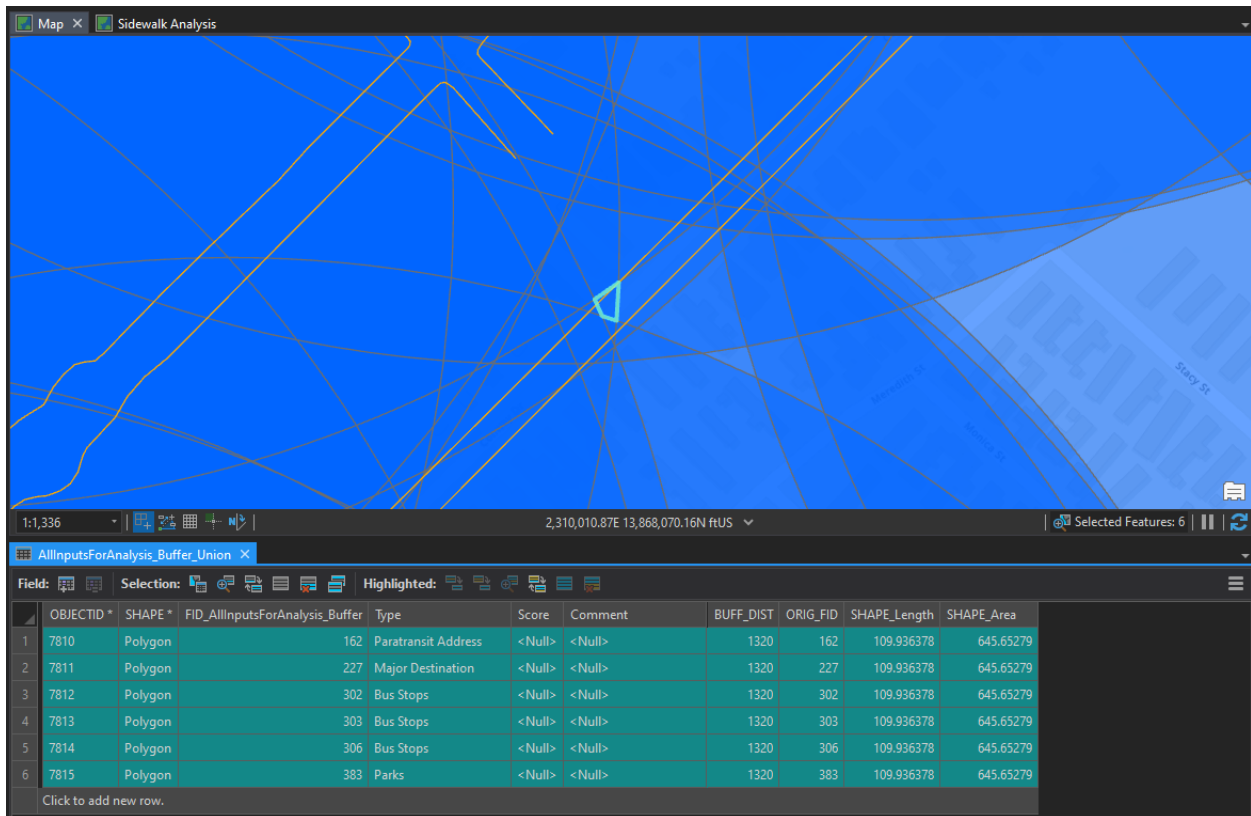1) Add the Pedestrian Traffic Generators point feature class to the map. There are a total of 436 points.
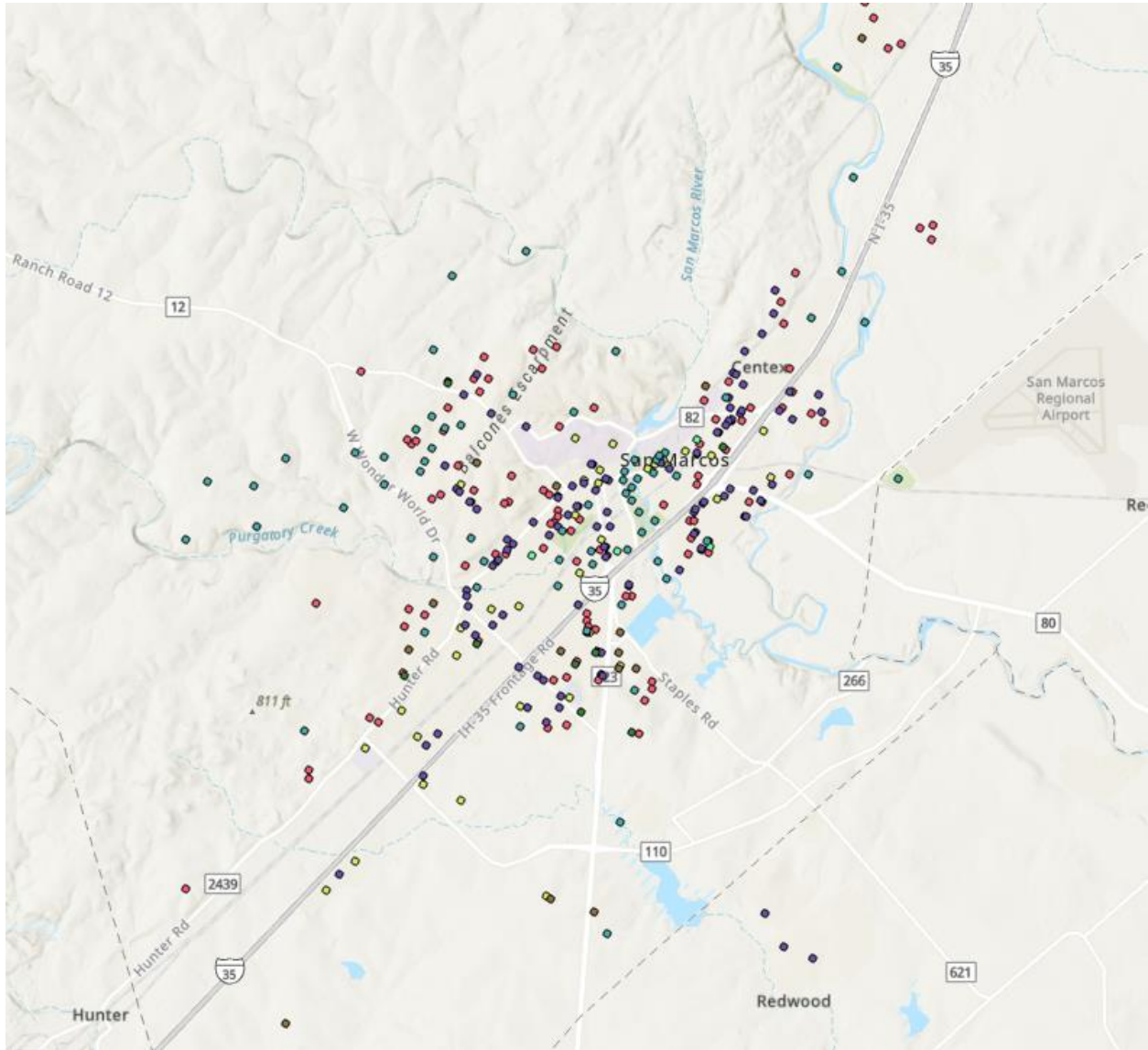
2) Next, buffer the points with ¼ mile radius, producing circular polygons. Quarter mile was chosen as this value is generally agreed upon by Transit experts to be the furthest distance most pedestrians choose to walk when traveling to bus stops and destinations. References to the ¼ mile distance can be found in this article (https://savethedinky.org/walking-distance/). Result below shows a ¼ mile buffer per pedestrian traffic generator, for a total of 436.
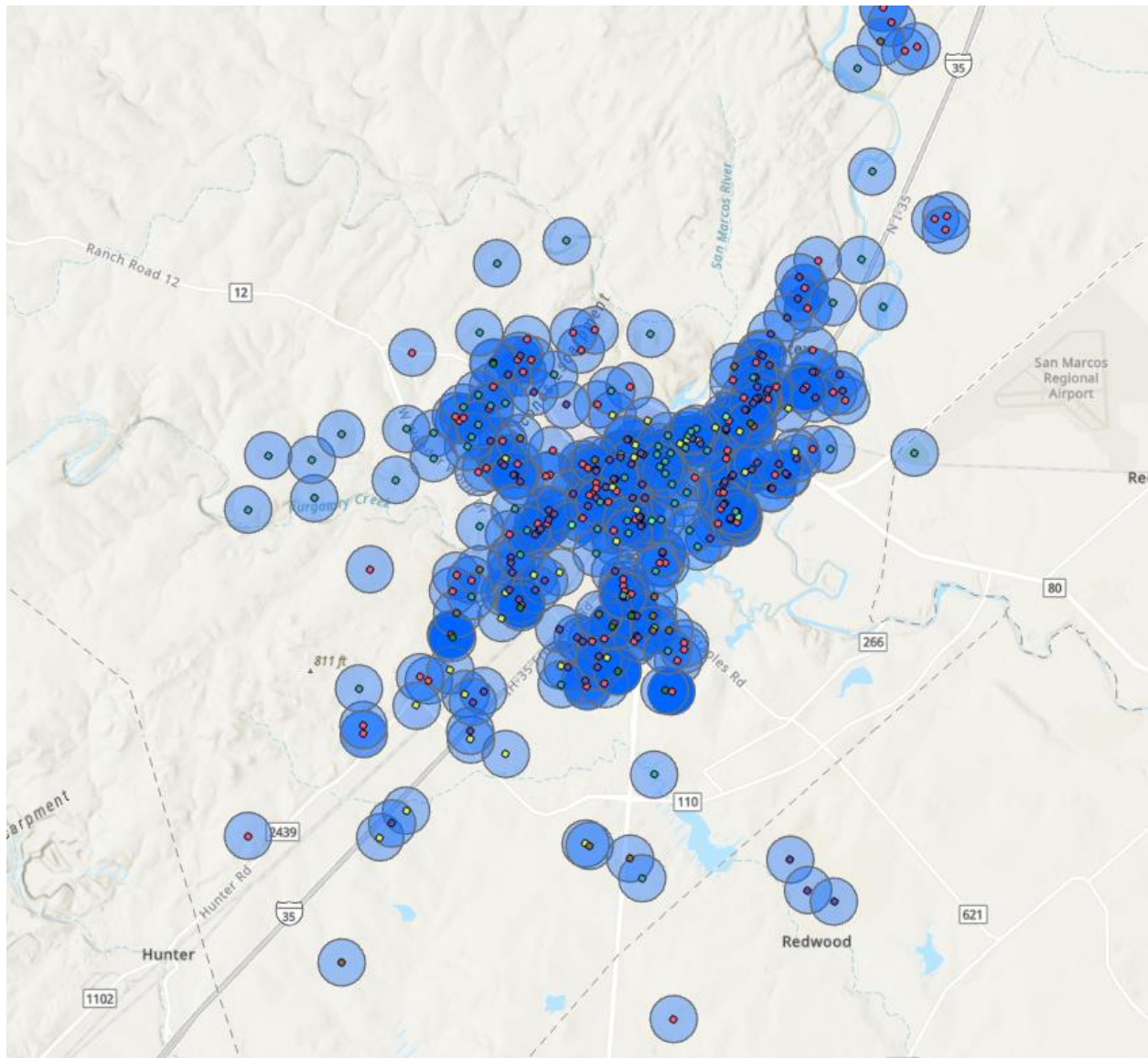
3) Add the updated sidewalk survey layer (Polyline). The sidewalk survey layer includes information such as whether the line represents existing sidewalk or gap, and the overall condition of the sidewalk.
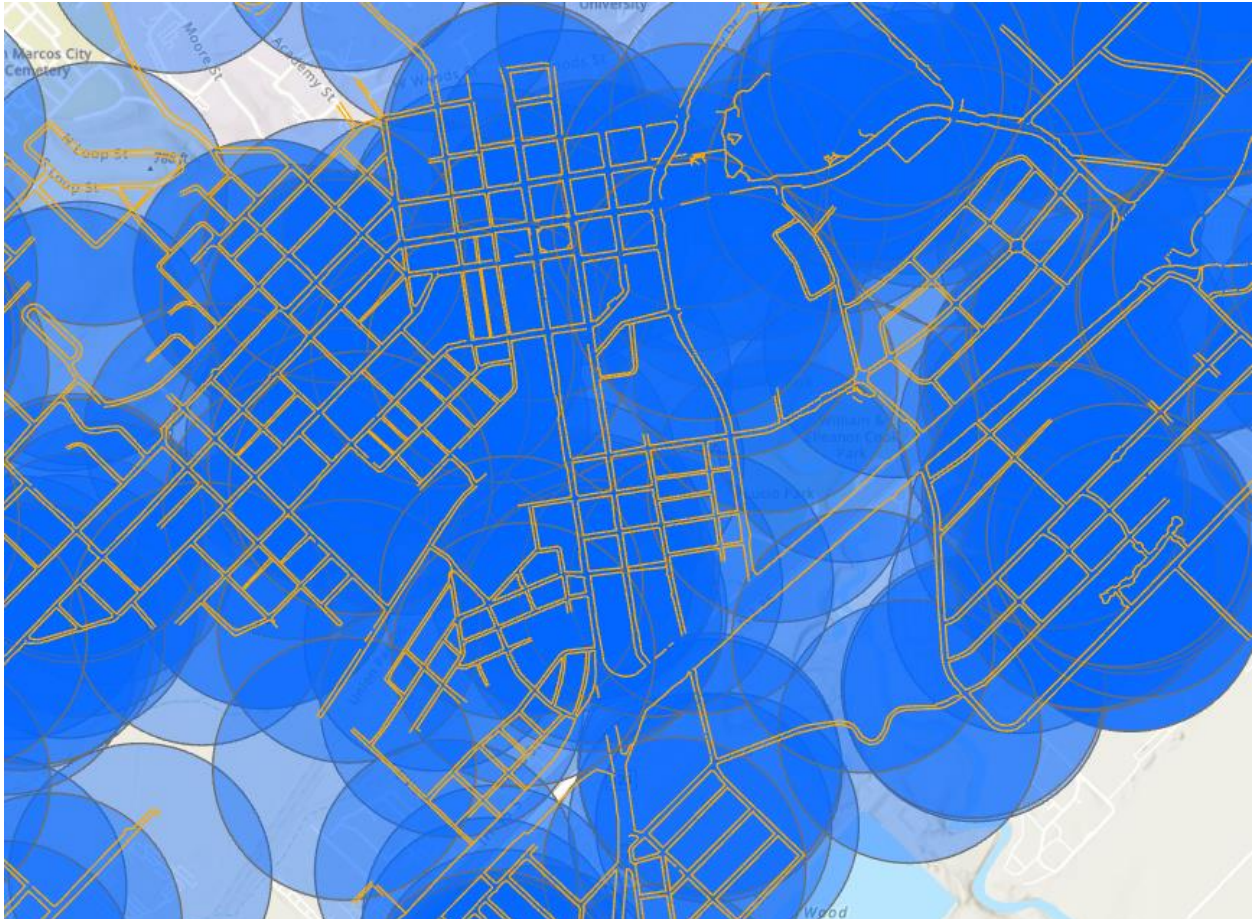
4) Execute the "Union" geo-processing tool on the previously created buffers. Essentially the Union tool creates a new polygon for each buffer type (bus stop, assisted living, schools, etc.) everywhere the buffers overlap. See example below where the small polygon selected from the Union tool output is 6 different polygons, representing the different pedestrian generator buffers that occur at that spot. There are only 436 pedestrian generator buffers, but after running the Union tool, the output contains over 48,000 polygons. Read more about the Union tool here. (https://desktop.arcgis.com/en/arcmap/10.6/tools/analysis-toolbox/union.htm)

|	OBJECTID *	SHAPE *	FID_AllInputsForAnalysis_Buffer	Type	Score	Comment	BUFF_DIST	ORIG_FID	SHAPE_Length	SHAPE_Area
1	7810	Polygon	162	Paratransit Address	<Null>	<Null>	1320	162	109.936378	645.65279
2	7811	Polygon	227	Major Destination	<Null>	<Null>	1320	227	109.936378	645.65279
3	7812	Polygon	302	Bus Stops	<Null>	<Null>	1320	302	109.936378	645.65279
4	7813	Polygon	303	Bus Stops	<Null>	<Null>	1320	303	109.936378	645.65279
5	7814	Polygon	306	Bus Stops	<Null>	<Null>	1320	306	109.936378	645.65279
6	7815	Polygon	383	Parks	<Null>	<Null>	1320	383	109.936378	645.65279

5) Next, perform a spatial join between the sidewalk survey layer (as the target features in the tool) and the Union polygons (join features) on a one to one basis. The result is a copy of the sidewalk survey layer with a [Join_Count] field. The value in the join count field represents the number of Union polygons created previously, that the sidewalk intersects.
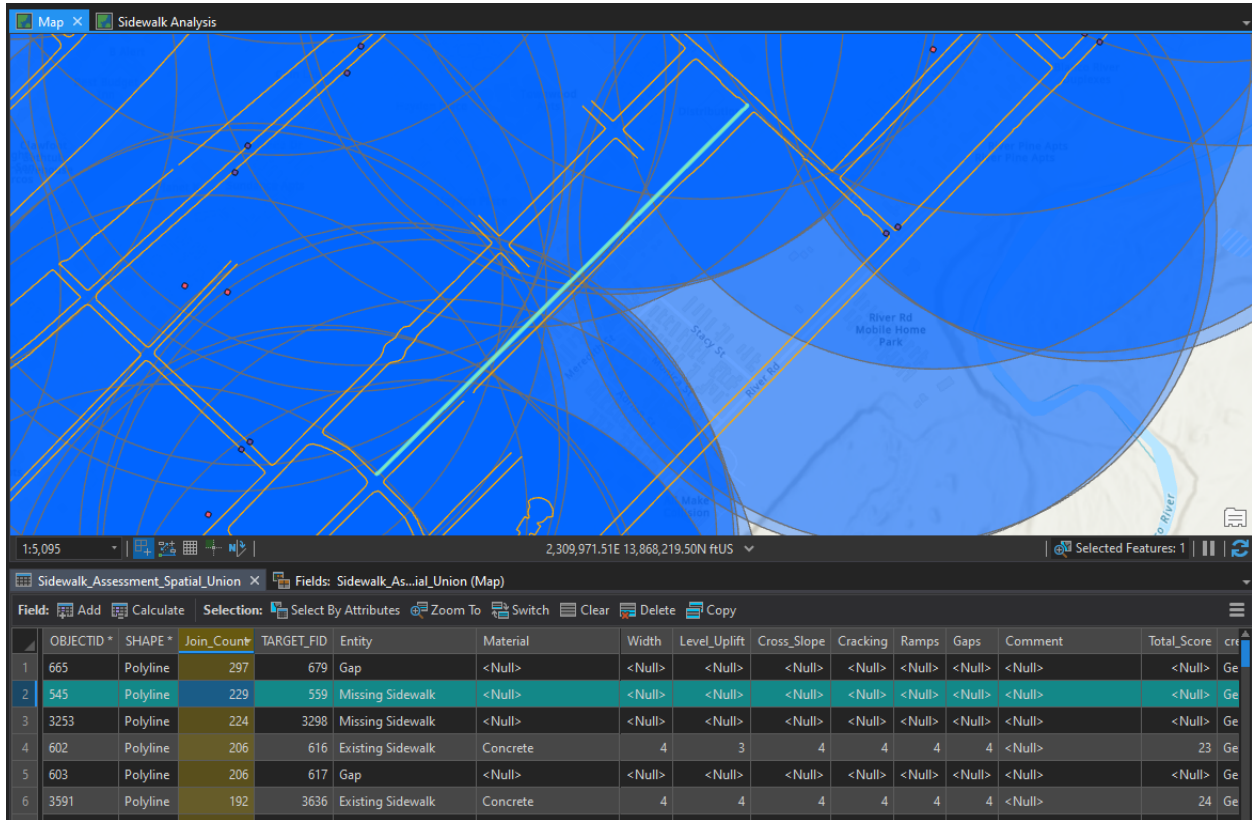

This is the same area as demonstrated previously in step 4. Above demonstrates the sidewalk survey layer output after the spatial join with the Union pedestrian generator buffers. Notice the [Join_Count] field for this segment of "missing sidewalk". It ranks 2nd when ordered from highest joint count to lowest, with a total of 229. There aren't 229 pedestrian generators at this location, but there are 229 instances of pedestrian generator buffer overlaps. This creates "zones of influence" that act as spatial-weighting mechanisms. See example image on next page demonstrating how join count values differ depending on whether the polygons are "unioned" or not.
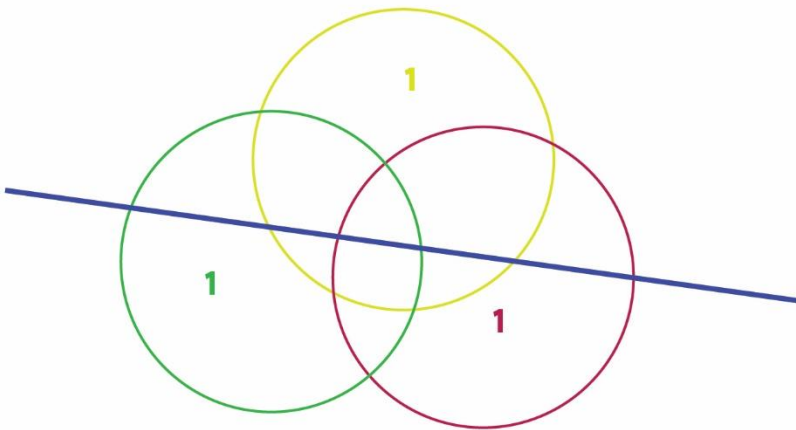
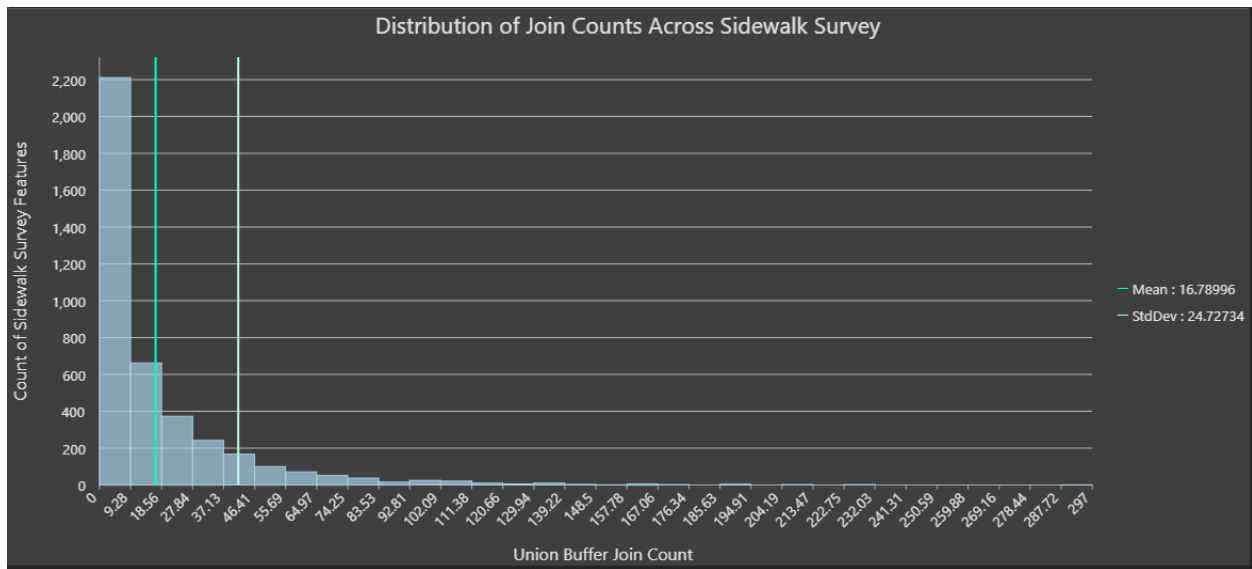## Spatial Joining Sidewalk to Unioned Polygons

1

2

2

3

1

2

1

Join Count = 9

0	1	2	3	2	1	0
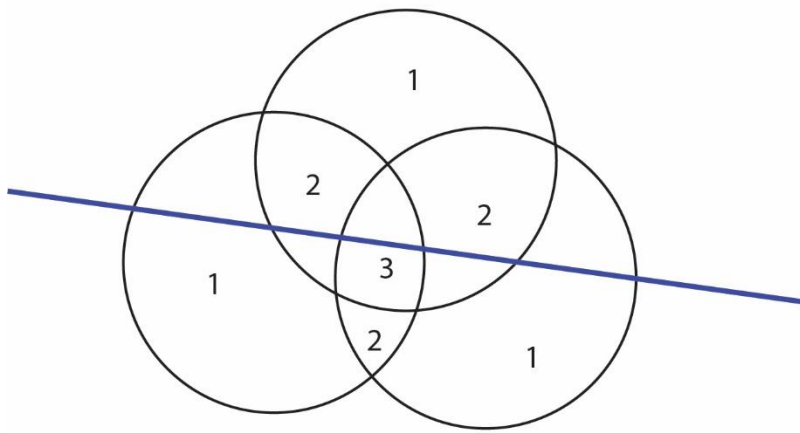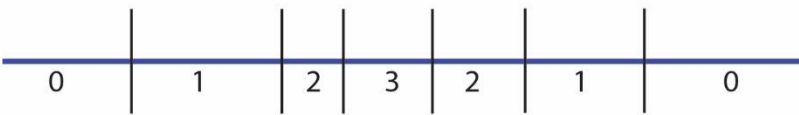
Spatial Joining Sidewalk to Polygons
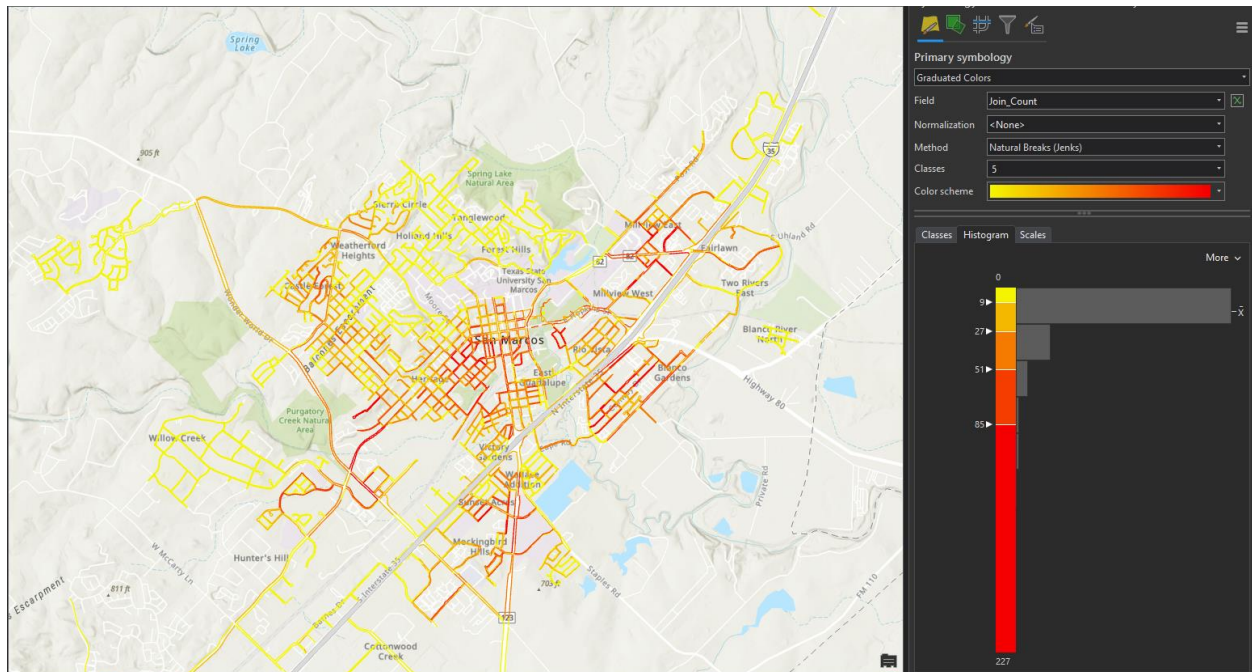
1

1

1

Join Count = 3

0	1	1	1	0

Graph demonstrating the distribution of join count values across the entire sidewalk survey layer.

Map showing the join count field symbolized using graduated colors with natural breaks classification. Red indicates higher join count.

Determining Locations with Gaps on One or Both Sides

The following methodology was used to programmatically determine where the sidewalk survey layer contained either of the following:

- Sidewalk on both sides of the roadway
- Sidewalk on one side and no sidewalk or significant gap on the other side of the road
- No sidewalk of major gaps on both sides of the road

The purpose of identifying these locations is to aid in prioritizing sidewalk repair and installation locations where no sidewalk exists on both sides of the roadway.

Using the line feature class from the sidewalk pedestrian generator analysis performed previously (going forward, referred to as "sidewalk analysis layer"), the following steps were applied.

Pictured: The sidewalk analysis layer symbolized to show existing sidewalk (Green) and gaps (yellow)/ missing(brown) sidewalk.

1) First, converted the sidewalk analysis layer to points at the line centroids using the Feature to Point geoprocessing tool (inside option checked).
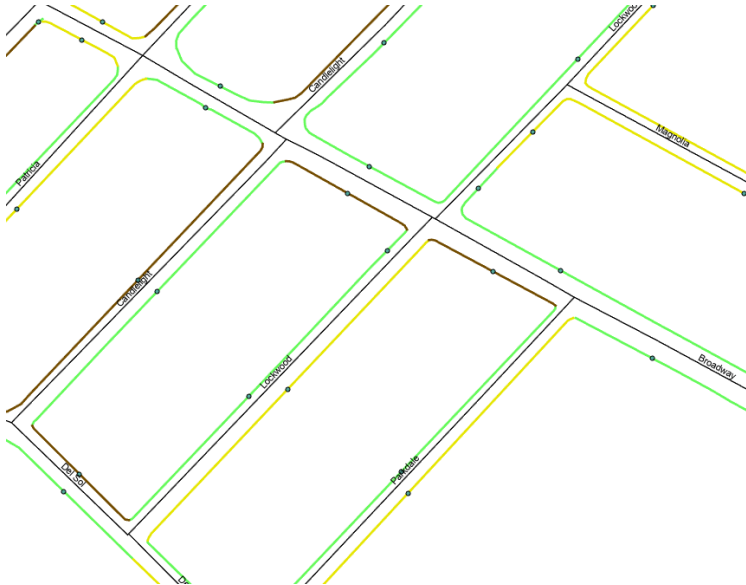
2) Buffered the newly created points 45 feet. If the value is too high you risk the buffers overlapping with neighboring buffers on different streets. If the value is too low, then you risk the buffers not overlapping at all. 45 was a good number to capture most locations.
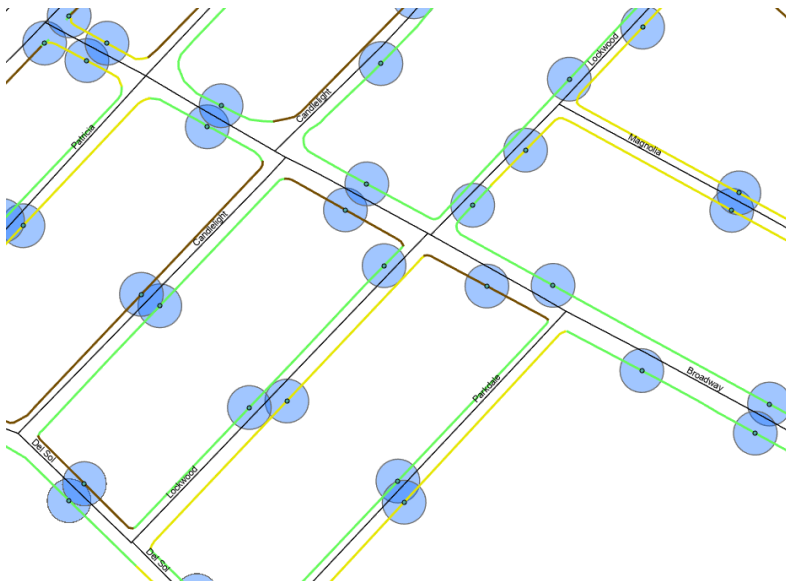
Notice when two buffers are directly across the street and overlap, it provides the ideal scenario for determining whether gap is on both or one side. Pictured below, brown polygon represents missing sidewalk, and the green polygon represents existing sidewalk.
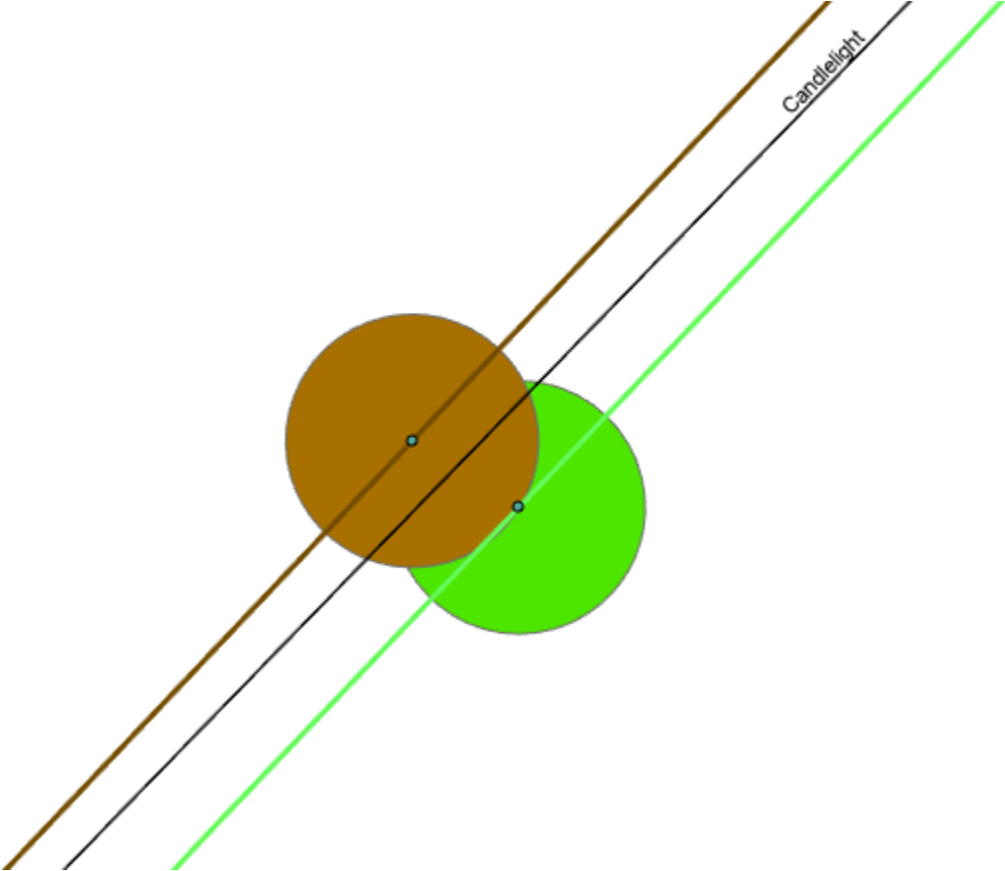
3) Within the new buffer feature class table, add a new field "GapPresence" to store either a 1 or 0 depending on whether the sidewalk is an existing sidewalk or a gap/missing sidewalk. If the sidewalk was an existing sidewalk it received a 0, and if the sidewalk was missing/gap it received a 1. The table below illustrates this.

Entity	Material	Total_Score	Overall_Condition	GapPresence
Existing Sidewalk	Concrete	24	Excellent	0
Existing Sidewalk	Concrete	24	Excellent	0
Existing Sidewalk	Concrete	24	Excellent	0
Existing Sidewalk	Concrete	24	Excellent	0
Gap	<Null>	0	Gap	1
Gap	<Null>	0	Gap	1
Gap	<Null>	0	Gap	1
Gap	<Null>	0	Gap	1
Gap	<Null>	0	Gap	1

4) Next, the buffer feature class needs to be split into two different feature classes. One feature class for existing sidewalk, and one feature class for gap and missing sidewalks. The purpose of doing this is for spatial joining them later.

Missing sidewalk buffers as a standalone feature class.
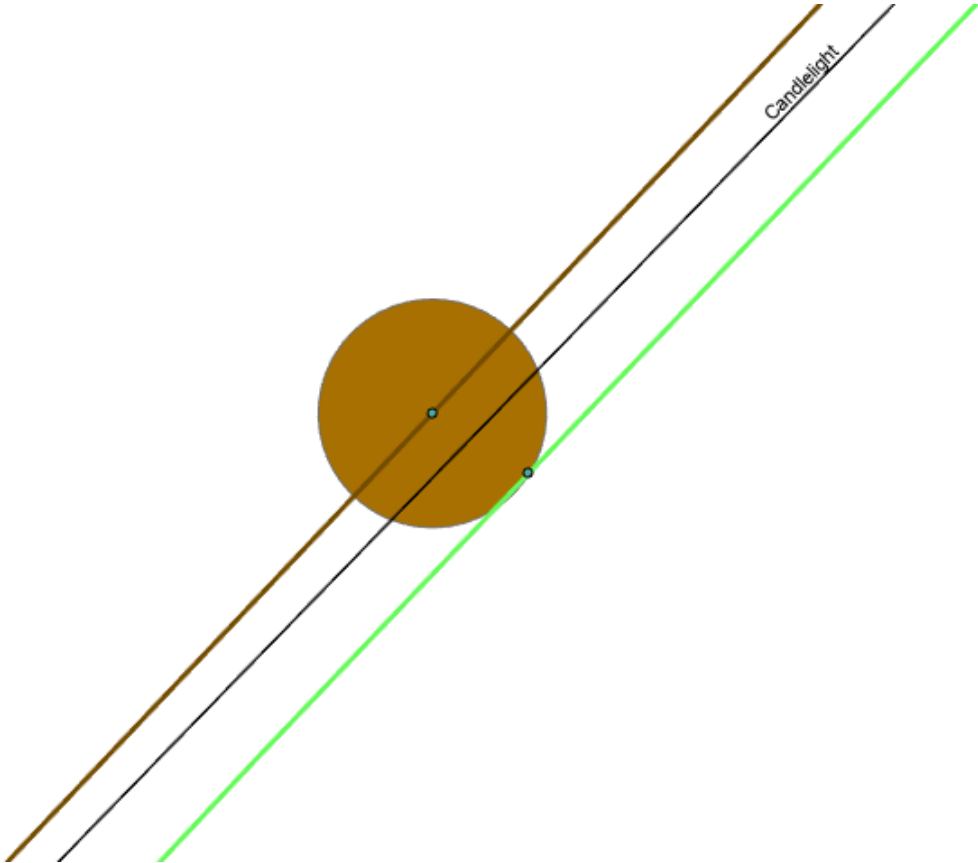
Existing Sidewalk as a standalone feature class.

Candlelight
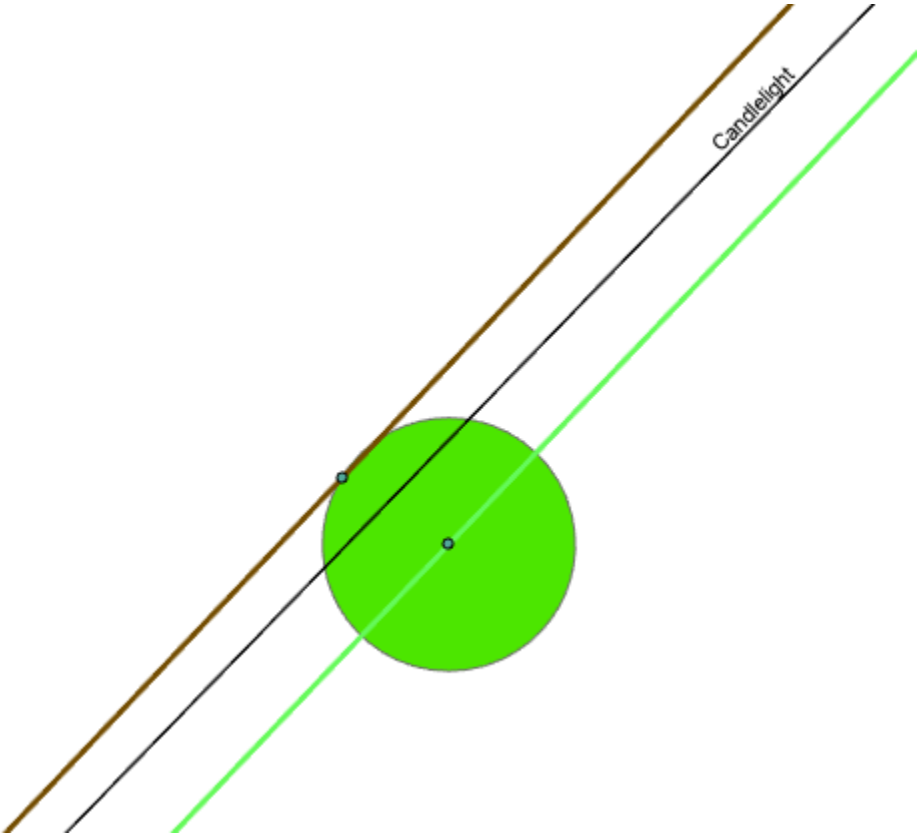
To perform a spatial join and sum the "GapPresence" fields between the two buffers, I next ran the Near GP tool, in order to discover the distribution of distances in feet between the buffers. This chart illustrates that a large majority of the features are within 5 ft. of one another. I will use this value in the spatial join GP tool.

Distance Distribution Between Buffers

— Mean : 34.91632
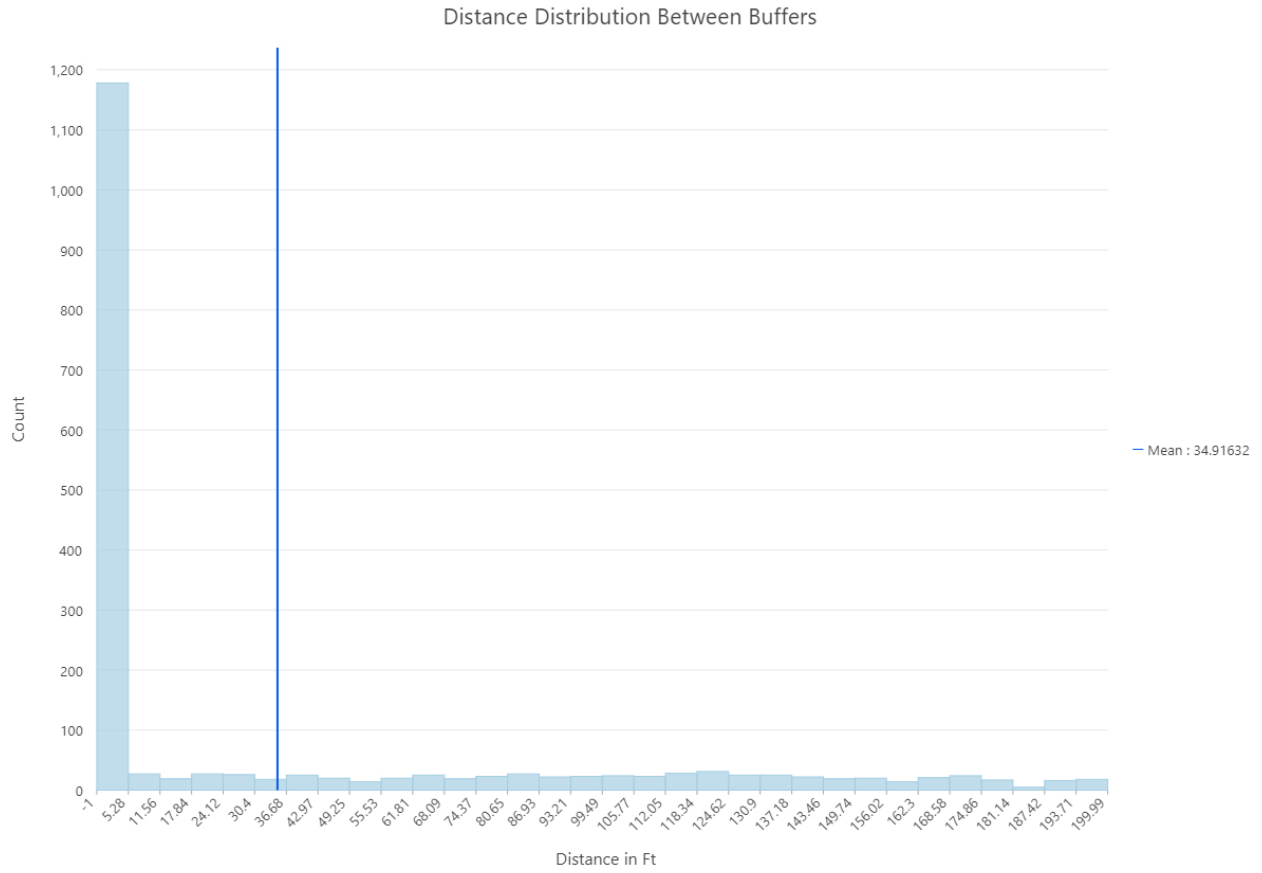
5) Spatial join the two separated buffer features classes and sum the "GapPresence" field from the two different buffers.
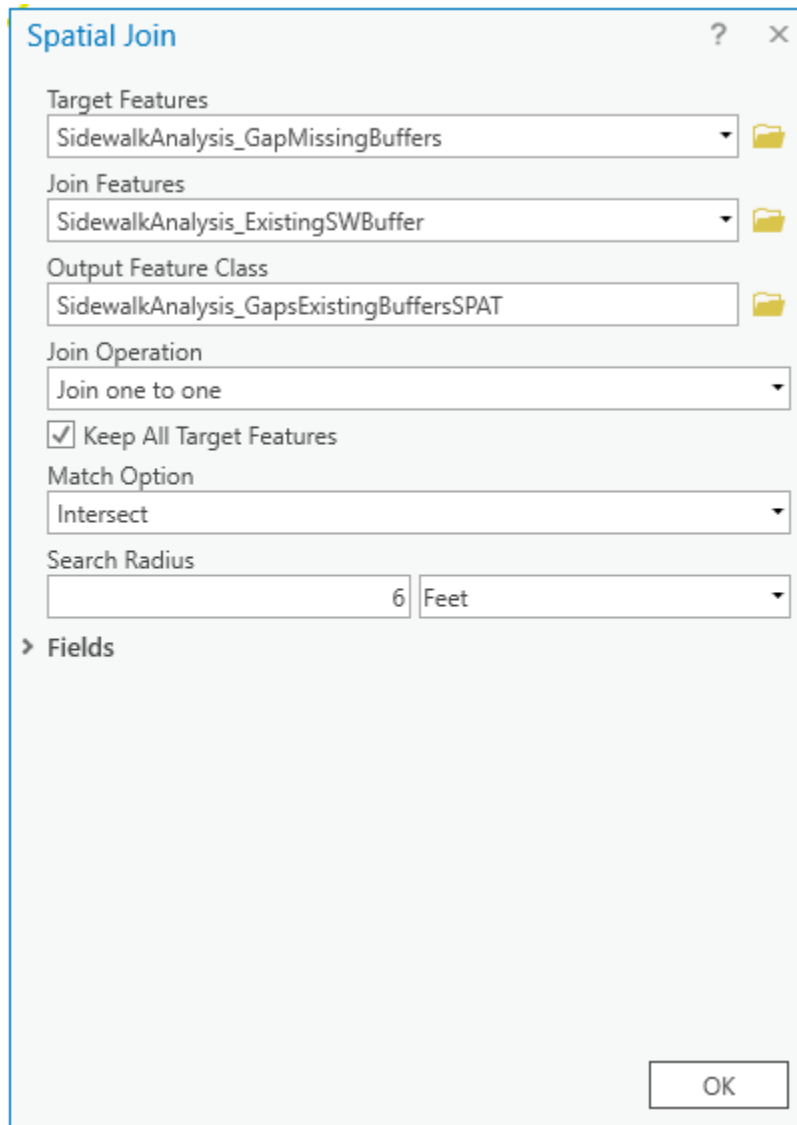
Below is the result of the spatial join. You can see that were there were two buffers, there is now only one. The green buffer (existing sidewalk) was joined to the yellow buffer (gap sidewalk) and the attributes transferred over. In the table you can see that the "GapPresence" field is there twice, once for the gap buffer, and once for the existing sidewalk buffer.

6) Add a new field to this output called "SumGapPresence", sum the two "GapPresence" fields. Then there are only two values in the result, either Null or 1. Null values indicate locations with two Gap/Missing sidewalk sections, while values equal to 1, indicate locations with Gap/Missing sidewalk on one side, and existing sidewalk on the other.

7) Select by Attributes from the "SumGapPresence" field where it equals 1, then select by location the sidewalk analysis layer using the selected buffers.
Sample of buffers that were selected based on a "SumGapPresence" value of 1 and then made into a layer.
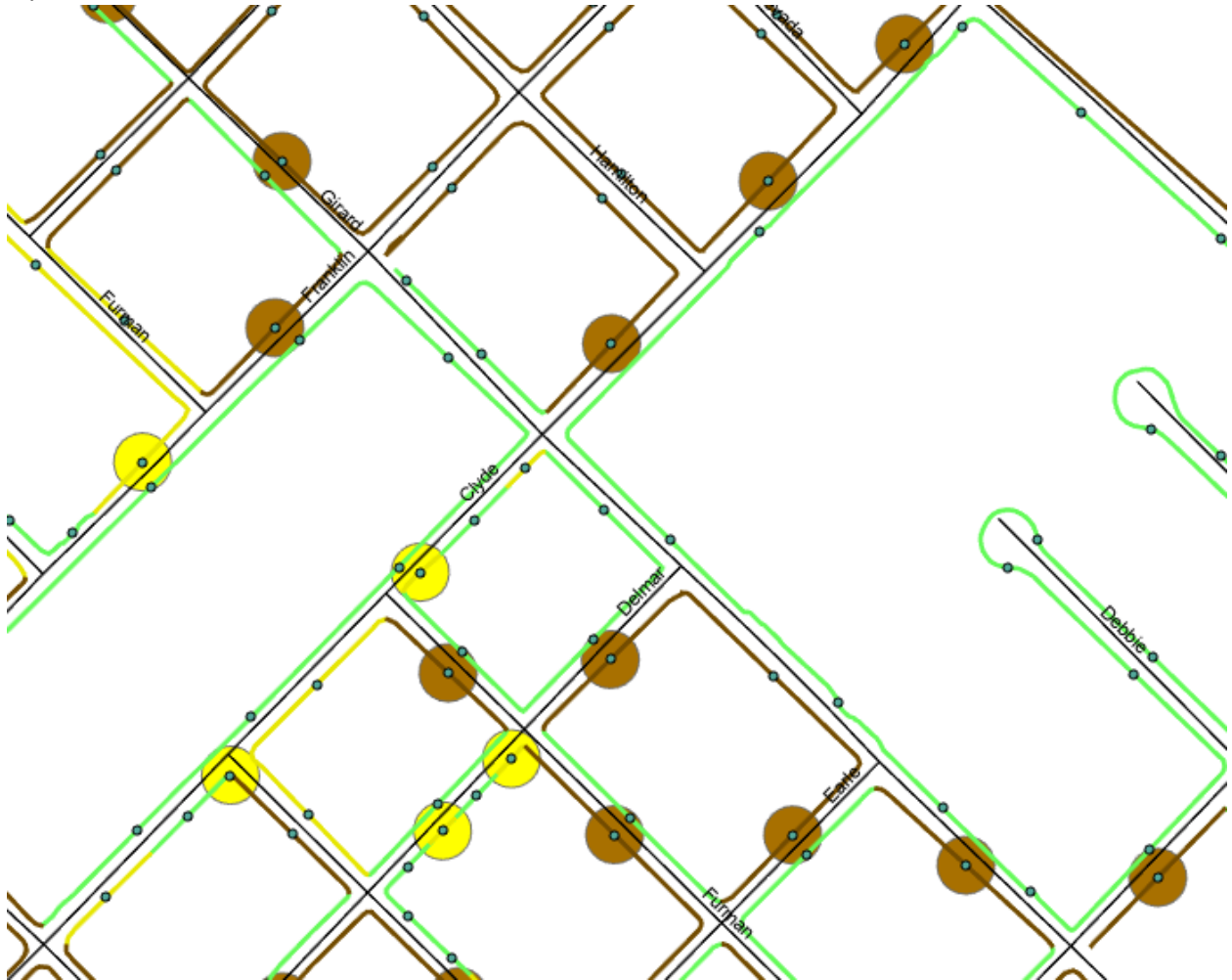
Then use the selected buffers to select the sidewalk analysis layer
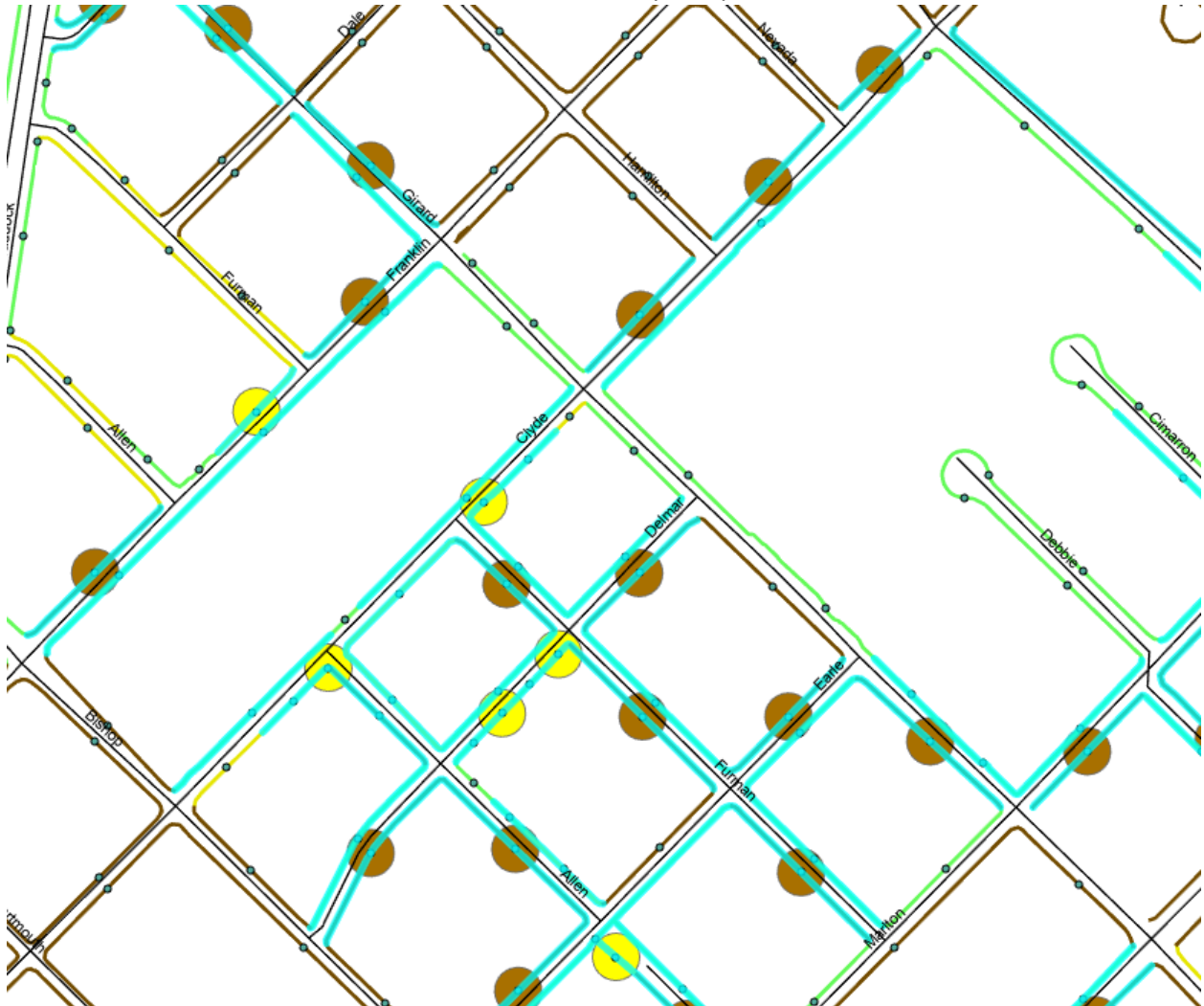
8) Once the Sidewalk Analysis Layer is selected according to its proximity to the buffers, then field calculate the "GapPresence" field to 1.

Do the same procedure, but instead select the spatial join buffer layer based on "SumGapPresence" = Null, select the sidewalk analysis layer accordingly, and field calculate the "GapPresence" field = 2 indicating gaps on both sides of the road.

9) Lastly, select the sidewalk analysis layer for "GapPresence" contains the values 1 and 2. This selects all of the segments that have gap on one or both sides, then reverse the selection. By reversing the selection, you are selecting all of the sidewalk analysis features that have sidewalk on both sides. Field calculate the "GapPresence" field to 0.

In the end you will have a "GapPresence" field on the sidewalk analysis layer with three values, 0(sidewalk on both sides), 1 (sidewalk on one side), and 2 (no sidewalk).

Incorporating Pedestrian Crash Data

The original sidewalk assessment data collected by staff during 2020 has been assessed for proximity to traffic generators and given a count value, and has been assessed for segments that have gaps on one or both sides of the road. The next step in the analysis is to utilize pedestrian crash data and identify sidewalks that are proximate to crash locations. Each crash is given a score based on the severity of the crash (see appendix for matrix). The pedestrian crash data used in this analysis was obtained from the Texas Department of Transportation's CRIS (Crash Records Information System) for San Marcos from January 2018 to June 2023.

 A total of 144 pedestrian crashes occurred over the 4 1/2 year query for San Marcos. The data schema includes fields for both address, and latitude and longitude value.

Step 1. Plot the crashes as points on a map, and buffer them 100 feet (radius = 100 ft., diameter = 200 ft.) A value of 200 was chosen to ensure that sidewalk on wide roads such as Wonder World Drive were influenced. Picture below are the buffers and the sidewalk analysis line layer.

Step 2. Within the buffered FC, add a new field called "CrashSeverityWeight" (type short integer). This field will contain a weight value depending on the crash severity. Each buffer was field calculated with the following schedule.

- Fatality Crash = 500
- Severe Injury Crash = 400

- Minor Injury Crash = 300
- Possible Injury Crash = 200

Step 3. Add a field to the sidewalk analysis feature class called "CrashSeverityScore". This field will house an aggregated crash score value for all crashes that influence that sidewalk segment.

Step 4.Spatial Join the pedestrian crash buffer features to the sidewalk analysis features, one to one. The crash severity values for each crash buffer are aggregated into the "CrashSeverityScore" field on the sidewalk analysis feature class. See result below.

a. In this sample are 15 pedestrian crashes that intersect the sidewalks on Hopkins. Each pedestrian crash "CrashSeverityScore" is aggregated into the sidewalk analysis layer's "CrashSeverityScore".

Spatial Join Tool Parameters
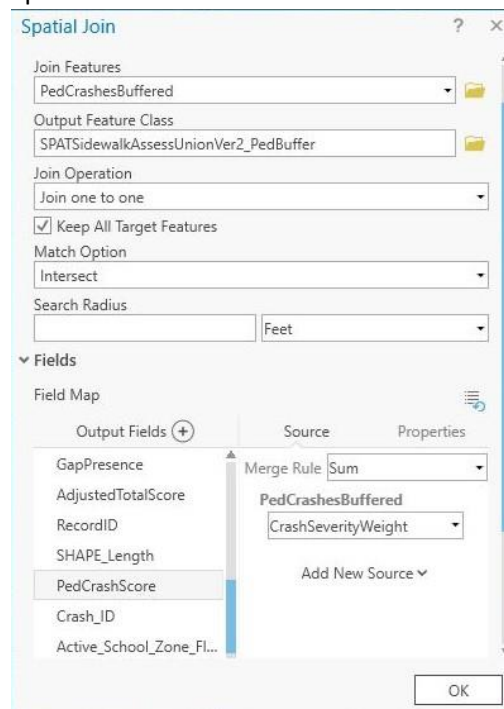
b.

Pop-up

⊿ SidewalkAssess_CrashScores (1)

SH0080

SidewalkAssess_CrashScores - SH0080

|	
Listed Address	N Guadalupe St
Column1	E Hopkins St
Notes	V was wondering when called in- Last call notes state the victim stated he was hit @ N Guadalupe/ Hopkins. Call location shows N LBJ Dr/E Hopkins St.
Adjusted Lat	29.883236
Adjusted Long	-97.941513
BUFF_DIST	200
ORIG_FID	5
Shape_Length	1256.637061
CrashSeverityScore	3900
Shape_Length	1889.675342

◀ 1 of 1 ▶   2,304,017.93E 13,869,986.08N ftUS

c. Overview of the City with sidewalk analysis layer symbolized on the total summed crash severity values.
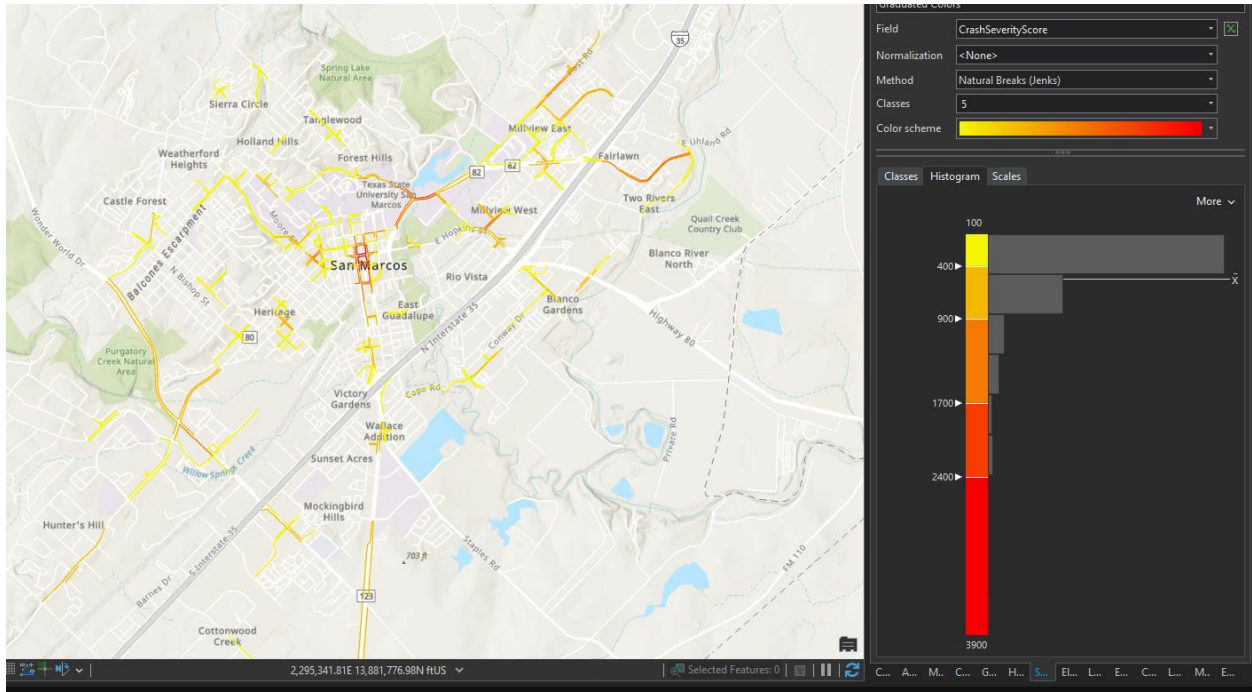
d. Distribution of aggregated crash severity scores.
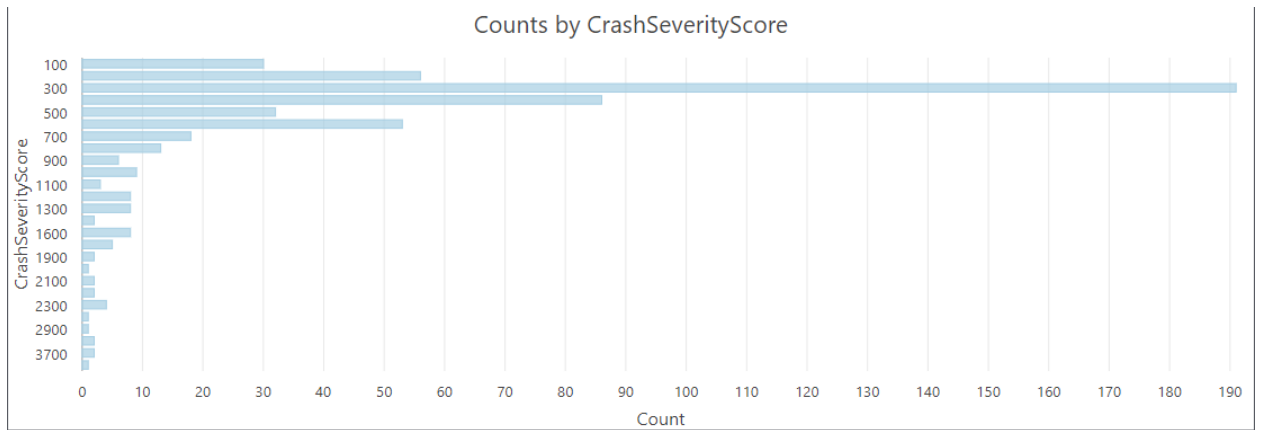
At this point the sidewalk analysis layer contains data on the following properties:

- Number of pedestrian generators intersected by the sidewalk stored in the [_Count] field
- Values of 0, 1, and 2 to determine if a gap exists on one (1) or both sides (2) of the road, or whether there is no gap (0), stored in [SumGapPresence] field
- An aggregated crash severity score calculated in step 4
- A relative condition score for each sidewalk (excellent, good, fair, poor)

The next steps include:

- Quantifying the qualitative values of excellent, good, fair, and poor for each sidewalk's condition to values set out by analysis criteria.
- Assigning scores to sidewalk gap presence, i.e. gaps on one or both sides as set out by the analysis criteria.

Step 5. Add three new fields to the sidewalk analysis layer, "SW_Condition_Score", "Gap_Presence_Score" and "Total_Final_Score":

- SW_Condition_Score: Converts the qualitative values of excellent, good, fair, and poor to the quantitative values:
    - Excellent/Good = 0
    - Fair = 25
    - Poor = 50
    - Gap/Missing = 100
- Gap_Presence_Score: Converts the coded value of 0, 1 , 2 stored in the GapPresence field to criteria values:
    - Gaps on both sides (2) = 50
    - Gap on one side (1) = 25
    - No gaps (0) = 0
- Total_Final_Score: Is used to sum the values and produce a total score aggregating all criteria used in the analysis. The fields aggregated include:
    - Count_: the total number of traffic generator intersections for the sidewalk
    - PedCrashScore: the total aggregated pedestrian crash severity scores
    - SW_Condition_Score: the value assigned to the sidewalk's over all condition
    - Gap_Presence_Score: the presence of gap on one or both sides of the road as a score
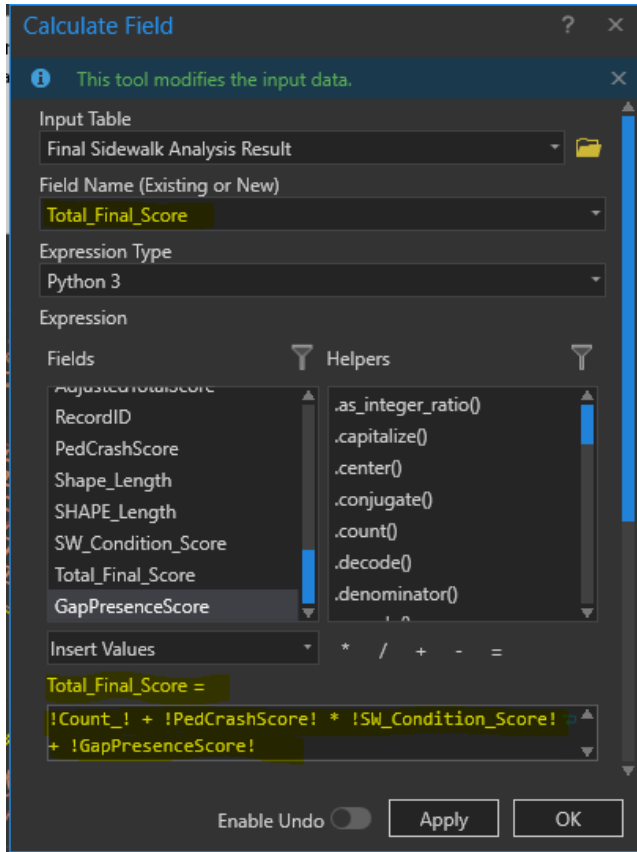
Sidewalk Analysis Layer symbolized on the total value aggregated across all criteria.
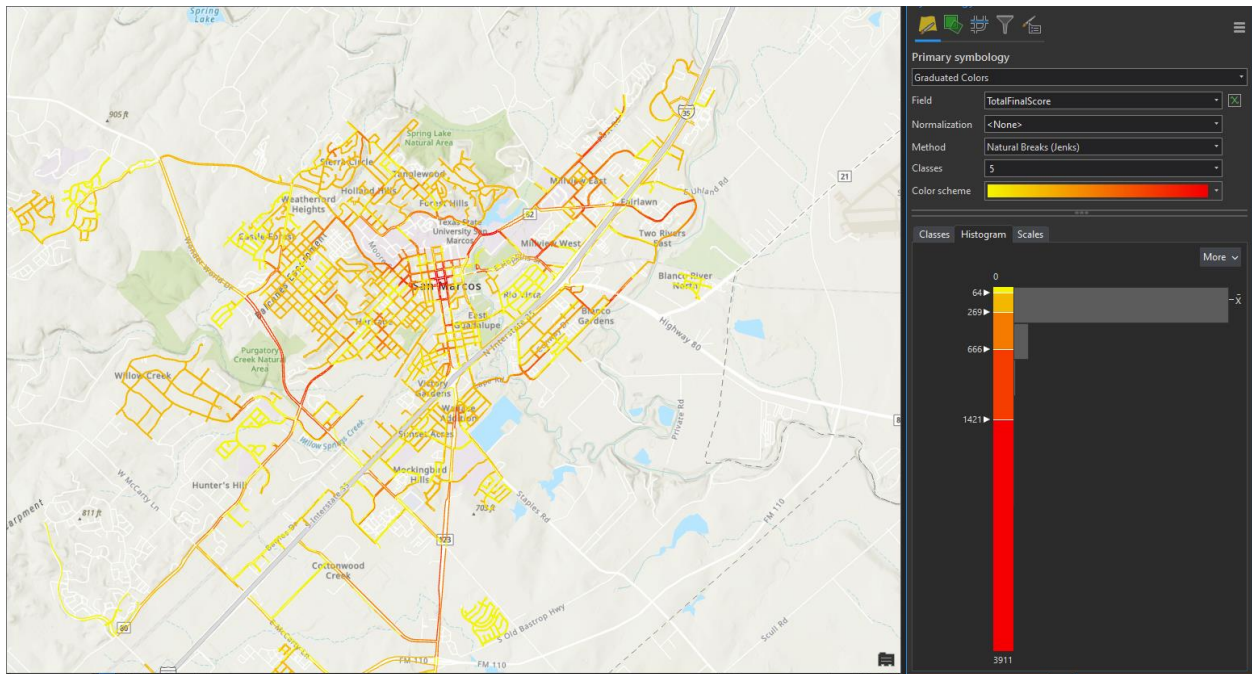
The resulting value aggregated into the "Total_Final_Score" field is used to rank the sidewalk segments from highest "Total_Final_Score" value to lowest. This ranking represents a theoretical priority list for inclusion into the 5 Year Sidewalk Plan for maintenance and installation of sidewalk, and will be handed off to the Sidewalk program manager for further analysis.

Appendix

Analysis Criteria Scores

Criteria	Criteria Values
Pedestrian Crash Severity	
Fatalities	500
Serious Injury	400
Minor Injury	300
Suspected Injury	200
No Injury	100
Pedestrian Generator Counts	0-Max Value (297)
Sidewalk Conditions	
Poor	50
Fair	25
Excellent/Good	0
Gap On Both Sides	50
Gap On One Side	25

Texas Department of Transportation C.R.I.S data for download

https://cris.dot.state.tx.us/public/Query/app/home