Edina Morningside Neighborhood Flood Risk Reduction Concepts

This report will summarize analysis conducted by Annetta Wilson, Jessica Wilson and Ross Bintner to define and describe flood risk and consequence for the Morningside Neighborhood in Edina and create a conceptual framework that could be used to create a scope of work that would compare or judge flood risk reduction options. The report is conceptual only and should not be relied on for actual improvement decisions.

Context and Scope

The Morningside neighborhood has a valley and several low or landlocked areas that are prone to flooding. The neighborhood is fully developed with primarily single family homes built between 1910 and 1960, with some infill happening later and redevelopment currently replacing some structures (Appendix A.) Stormwater characteristics for the neighborhood are described in greater detail in chapter 12 of the Comprehensive Water Resources Management Plan (2018 Draft, Barr Engineering). This document is the Local Water Plan (LWP) for the city.

For this report, flood risk will be described in terms of both the probability and possible consequence of high water on structures. Two rainfall probabilities modeled in development of the LWP are used in this analysis, the 1% and 10% probability rainfalls. Assuming normal soil moisture conditions (AEP neutral conditions), flood probabilities are assumed to be the same as the storm event probabilities creating the flooding. The possible consequences of flooding are categorized and costs are estimated assuming homeowners have taken no special effort to limit the consequence of flooding. Annualized potential costs to homeowners are then estimated to test economic return on possible flood mitigating infrastructure improvements to this area. Infrastructure improvement options were part of a separate effort by Barr Engineering. These options are preliminary, non-exhaustive, and not optimized.

A variety of data and analysis was conducted to inform the analysis of flood risk. The following subsections describe the original data sources (assembled data) and methods used to calculate criteria relating to flood risk (derived data).

Assembled and Derived Data

Geographical data was assembled from City of Edina sources and new data was derived from the relationships in the data to inform the flood risk analysis. The following is a summary of data and methods. The development of methodology to derive adjacent ground elevations based on LIDAR and home shape has applicability outside this study and is described in greater detail in Appendix B.

Assembled Data:

- Digital Elevation Map (DEM) from 2011-2012 Minnesota DNR LIDAR data with 5cm accuracy
- Subwatershed and Sewershed data (City of Edina)
- Building Footprints originally from 2002 Markhurd, Updated by City of Edina with 2012 and 2015 based on Hennepin County joint aerial photograph project
- Lot surveys from City of Edina Building Department records

- Property ID (PID), building year built, livable total and basement square footage, finished basement %, building sales data, and building market values data from the City Assessor
- City of Edina Datalink Map, Google Streetview, Google search for Real Estate sale pictures and descriptions of homes, Site visits
- 10% and 1% probability inundation polygon and elevation data from 2018 Comprehensive Water Resources Management Plan.
- 2017 Flood Loss Estimations Table (Source: National Food Services, FloodTools.com, based on national FEMA flood loss tables)
- Potential flood risk mitigation options from Barr Engineering

Derived Data:

- The following general data was derived from the assembled data to inform the analysis. Minimum, maximum, and average adjacent grade elevations. Adjacent grades were calculated by comparing DEM and building footprint clips using the method described in Appendix B.

The following building elevations data were derived

- Basement type was determined by looking at the elevation profile and StreetView. If it wasn't easy to see in StreetView or determine from the profile, the address was Google searched to find Real Estate information and additional pictures of the house. If those were unavailable, the site was visited to see in person, while remaining on city property. See the appendix for more information on how the basement type was used in the elevation calculations.
- Building elevations; Elevations were overwritten if a survey was found in Building Department survey data. Data source was recorded in a note field. Detailed information about building elevation calculations can be found in Appendix B.

The following attributes were calculated using the derived adjacent grades:

- Low floor elevation was calculated by subtracting 8 feet from the maximum adjacent elevation
- Low opening elevation was equated to the minimum adjacent ground elevation.
- Garage floor elevation was equated to the maximum adjacent ground elevation.
- First floor elevation was calculated by adding 1 foot to the maximum adjacent ground elevation.
- The Elevation Difference was calculated by subtracting the minimum adjacent ground elevation from the maximum adjacent ground elevation.

Property characteristics and property value were calculated to inform the analysis of consequence of flood risk:

- Number of Sales was calculated from Excel Pivot Table using data from Assessor's Office (see appendix)
- Value per Square Foot was calculated (Building MV/Square Footage)
- Subwatersheds names of subwatersheds that intersect with building footprint

Analysis of Structural Flood Probability

For this analysis flood probability is categorized based on various ways water can intrude into residential dwelling structures based on the following scheme. The thresholds defined in this scheme allow an in/not in trigger to describe flood risk at varying probability storms and are not based on a literature review of studies on flood effects on varying structures. A cursory review for similar work turned up many interesting concepts, but no direct examples or industry standards that detail flood risk at this granular a scale. The thresholds defined here are based on professional judgement and are obviously not definitive. The categories are used to define probability of damage to each vector of flood risk.

Direct flood risk is from waters that overtop the foundation block and saturate and infiltrate through wood framed portions of a home, overtop and flood window wells and collapse windows, or saturate and infiltrate through low opening elevations such as windows and doors. Direct flood risk will be categorized as follows:

- Moderate: Peak 1%/10% probability flood elevation is above minimum adjacent grade, but below or equal to average ground elevation.
- Major: Peak 1%/10% probability is above average adjacent grade, but below or equal to maximum adjacent grade.
- Severe: Peak 1%/10% probability is above maximum adjacent grade.

See Appendix B for GIS Methodology.

Indirect flood risk is from nearby standing flood waters saturating the ground and causing hydrostatic pressure on foundations that typically result in water leaking from cracks and joints in foundation block or concrete slab floors. In severe cases this hydrostatic pressure is known to collapse block foundations. While these issues can also be attributed to raised groundwater with a variety of causes such as temporary rises due to rainfall or flow paths, anywhere in the watershed, this category focuses only on those areas with nearby standing flood waters. Indirect flood risk will be categorized as follows:

- Minor: Peak 1%/10% probability flood elevation in same subwatershed is </= 4' above basement elevation but > 2' above basement elevation
- Moderate: Peak 1%/10% probability flood elevation in same subwatershed is >4' above basement elevation

Sanitary flood risk is from flood water in nearby homes subject to direct flooding flowing into the sanitary sewer system through flooded floor drains and fixtures making its way into the public sanitary line and overwhelming its capacity causing backup into other homes. Sanitary flood risk will be categorized as follows:

- Moderate: Home is within the same sanitary sewershed where between 1 and 3 neighboring homes are subject to Major or Severe Direct Flood Risk and the home is within 250' of one of the neighboring Direct Risk homes, and has a basement elevation lower than the flooded basement plus 1 foot.
- Major: Home is within the same sanitary sewershed where between greater than 3 neighboring homes are subject to Major or Severe Direct Flood Risk and the home is within 250' of one of the Direct Risk homes, and has a basement elevation lower than the flooded basement plus 5 feet.

The flood risk scheme above was compared to derived building low floor elevations to create effective differential flood elevations for each affected single family dwelling. These differential elevations, along with property characteristics were used to estimate the consequence of flooding, described in the next section.

Overall, direct flood risk is the highest risk type followed by sanitary flood risk, with indirect flood risk being the lowest risk. Since homes often fit into multiple risk types, they were assigned to the highest risk of their designated risk types.

Figure 1: Morningside 10% Annual Probability Flood Risk

Figure 2: Morningside 1% Annual Probability Flood Risk

Analysis of Flood Consequence

This analysis attempts to create a decision framework to generalize costs of flood risk at the neighborhood scale by assigning individual probability that any given home will experience damage by any of the three risk categories described above, using best available data. The cost of flooding is then annualized based on this probability. Using the same method, the base case condition is then compared to neighborhood wide potential flood mitigation options.

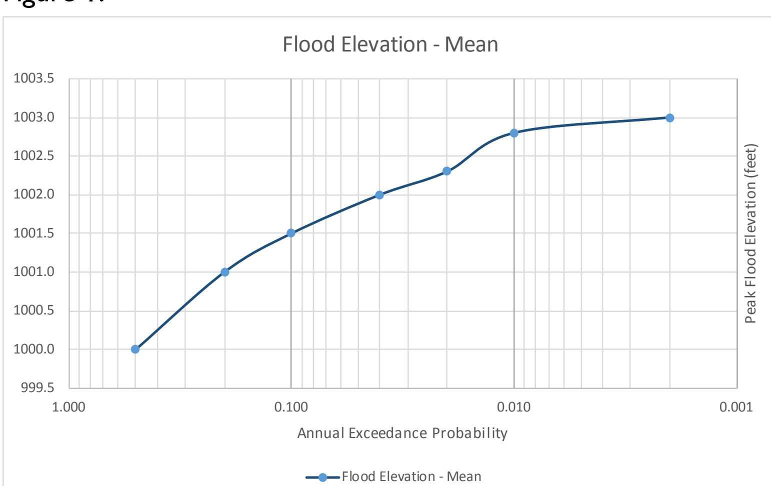
Methodology

The following steps were used to develop flood consequence on a home by home basis for the base case and each potential mitigation option. Only primary structures are considered.

1. Generate flood elevations. For this analysis, flood elevations were generated for 50, 20, 10, 4, 2 and 1% probability events by Barr Engineering for the existing conditions, and seven potential flood mitigation options.

2. Apply elevations to structures. To simplify conditions where a structure was subject to risk from more than one subwatershed (i.e. located on a subwatershed divide), each structure was assigned to a single subwatershed, whichever was judged to be highest risk or most significant.

Figure 1:



3. Determine possible damages. A square footage estimate of $40 per square foot was used. This estimate was informed by the referenced FEMA damage tables. The square foot estimate of damage was then factored for each risk category and a probability of damage was assigned to factor the square foot rate consistent with the scheme described above, and depicted in the table below. The probability of damage was based on the trigger elevations set in the section above, and the probability factor was a guess based on experience.

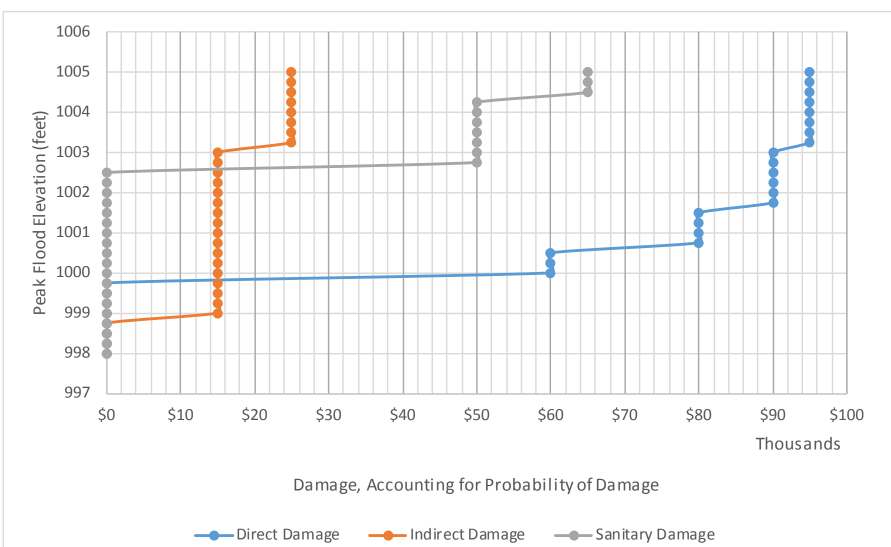
Table 1:

Probabilities of Damage Occurring, given a mode and a "chance of damage" factored with percent of maximum damage by mode				
	Direct Mode	Direct Mode2nd Level	Indirect Mode	Sanitary Mode
Minor	0.0	0.0	0.1	0.0
Moderate	0.5	0.0	0.2	0.5
Major	0.9	0.0	0.2	0.8
Severe	1.0	0.5	0.2	0.8

The results are very sensitive to these factors, particularly the indirect mode since it can trigger at lower elevations with correspondingly more probable events than the other damage types. The factors are based on feel, and a non-exhaustive review of similar work.

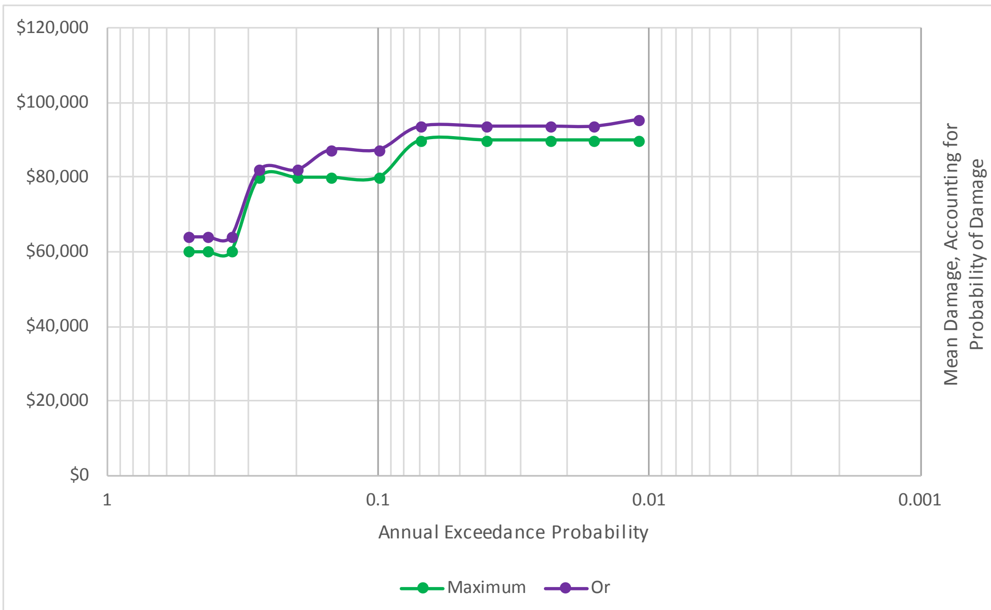
4. Determine elevation damage curves. Basement floor, minimum adjacent grade, average adjacent grade, and maximum adjacent grade were compared to subwatershed elevation data using the trigger elevations on the subject home to develop damage curves for each structure for direct and indirect risk.

Figure 2:



5. Relate damages to annual exceedance probability (AEP). Damages in dollars were related to AEP using the specified flood level elevations for the assigned subwatershed. Values for intermediate probabilities were interpolated to create a cost versus probability damage curve for calculating annualized damages. Two methods for combining risk types were tested, a maximum, and a combined probability 'or' method. The 'or' method was used in the analysis.

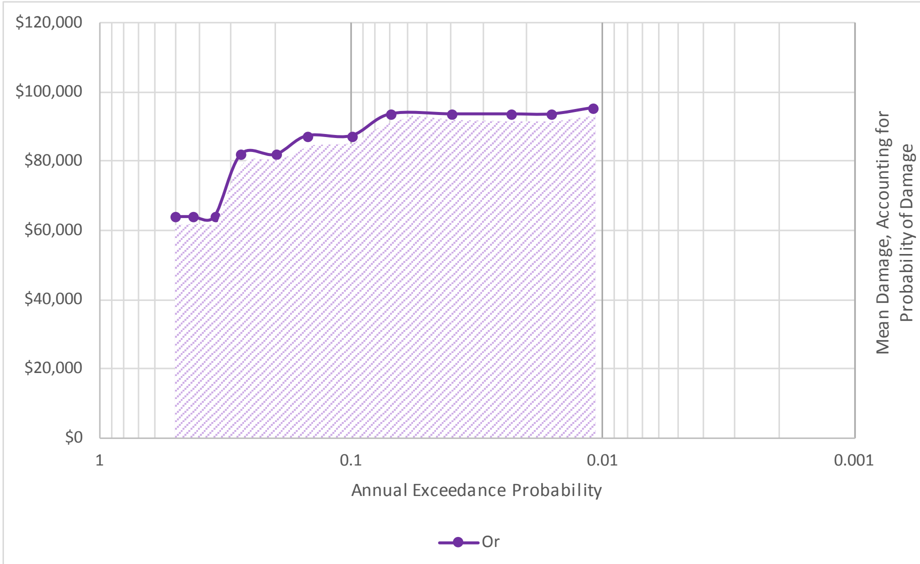
Figure 3:



6. Calculate total annualized flood risk. The annualized damages were calculated by integrating the potential damages by the AEP. The annualized expected damages take into account AEP for a wide range of precipitation events, probability of damages from an event, and potential damage cost to a home.

$$Risk\_\$ = \int_{AEP1}^{AEP2} (Damage\_\$)(dAEP)$$

Figure 4:



7. Calculate total neighborhood risk. The annualized damage cost for each home was then summarized for existing conditions to determine the annualized cost impact to the neighborhood under existing conditions.

8. Repeat steps 1 through 7 for Barr's proposed flood risk mitigation options. Calculate the total annualized neighborhood damage for each option, because none of the proposed options will eliminate all risk of damage.

9. Compare to option cost. The annual benefit for each improvement was calculated by subtracting the option annualized risk from the existing conditions annualized risk. A 60 year infrastructure lifecycle was assumed, which is a typical conservative lifecycle estimate for stormwater infrastructure. The option implementation cost was then annualized by the improvement lifecycle.. The annualized Benefit Cost Ratio for each solution was calculated dividing the solution cost avoidance by the annualized solution implementation cost. This simple, straight line depreciation approach ignores the cost of money. A future refinement could include a present value analysis.

Results

Potential Flood Mitigation Options

<u>Alt 2b:</u> Increase Storm Sewer Size (up to 60") and add flood wall at Weber Pond.

<u>Alt 3a:</u> Excavate Weber Field Park, area North of Weber Pond, Open Space 5, area West of Monterey Ave, and backyard between 44th St and Branson St. Add flood walls at Weber Pond and along Monterey Ave. Add culvert to Weber Pond to drain north.

Alt 4a: Excavate Open Space 5 and do predictive pumping from Open Space 5 and Weber Pond to park north of Calvin School

Alt 5a: Add Underground Storage to Weber Park and park west of Monterey Ave

Alt 7b: Combination of 3a and 4a

Alt 8: Excavate areas North and West of Weber Pond and add flood wall.

Alt 9: Alt 8 and add Underground Storage at park west of Monterey Ave, and predictive pumping to Weber Pond.

Table 2: Barr Engineer's Opinion of Probable Cost for Proposed Flood Mitigation Options

Option	Estimated Project Cost	Minimum Estimated Cost (-30%)	Maximum Estimated Cost (+50%)
Alt 2b	$4,469,000.00	$3,129,000.00	$6,704,000.00
Alt 3a	$5,069,000.00	$3,549,000.00	$7,604,000.00
Alt 4a	$3,444,000.00	$2,411,000.00	$5,166,000.00
Alt 5a	$31,681,000.00	$22,177,000.00	$47,522,000.00
Alt 7b	$8,507,000.00	$5,955,000.00	$12,761,000.00
Alt 8	$5,179,000.00	$3,626,000.00	$7,769,000.00
Alt 9	$13,786,000.00	$9,651,000.00	$20,679,000.00

Table 3: Number of Homes per Option with Greatest Benefit

Option	Homes with Greatest Benefit
Alt 3a	2 homes
Alt 5a	1 home
Alt 7b	69 homes
Alt 8	13 homes
Alt 9	11 homes

Table 4: Damage Risk Change from Existing Conditions

Option	Risk Increase	Risk Decrease
Alt 2b	15 homes	111 homes
Alt 3a	1 home	117 homes
Alt 4a	1 home	127 homes
Alt 5a		92 homes
Alt 7b	1 home	150 homes
Alt 8		74 homes
Alt 9		136 homes

The homes at increased risk are in the areas where the flood elevation increased as a result of increased water flow to the associated subwatershed as a result of increased drain size or predictive pumping. Berms or Flood Walls were included in the options to mitigate direct flood risk, but indirect flood risk may still be a factor. The increased risk is minimal (less than $1000 annualized for the worst case scenario).

Table 5: Homes at Risk of Flood Damage by Option

Option	Homes at Risk	Homes no longer at risk
Current	160 homes	
Alt 2b	134 homes	26 homes
Alt 3a	150 homes	11 homes
Alt 4a	154 homes	6 homes
Alt 5a	155 homes	5 homes
Alt 7b	123 homes	38 homes
Alt 8	155 homes	5 homes
Alt 9	126 homes	34 homes

Table 6: Simple Annualized Costs and Benefits by Option (assuming 60 year lifecycle and simple depreciation of capital cost and no ongoing maintenance)

Table: Condition	Annual Damage	Annual Benefit	Improvement Cost	Annual Improvement Cost	Benefit - Cost	Benefit Cost Ratio
Existing	$404,202	--				
Alt 2b	$287,348	$116,854	$4,469,000.00	$74,483.33	$42,370.82	1.57
Alt 3a	$271,606	$132,596	$5,069,000.00	$84,483.33	$48,112.68	1.57
Alt 4a	$335,313	$68,889	$3,444,000.00	$57,400.00	$11,489.43	1.20
Alt 5a	$326,616	$77,586	$31,681,000.00	$528,016.67	-$450,430.65	0.15
Alt 7b	$170,765	$233,437	$8,507,000.00	$141,783.33	$91,654.14	1.65
Alt 8	$337,045	$67,157	$5,179,000.00	$86,316.67	-$19,159.21	0.78
Alt 9	$190,566	$213,636	$13,786,000.00	$229,766.67	-$16,130.51	0.93

Overall Alt 7b has the greatest benefit, based on the benefit cost ratio, greatest benefit to homes, and number of homes improved or removed from flood risk. Options 5a, 8, and 9 are cost prohibitive, in which the cost outweighs the benefit. Reducing the assumed lifecycle below 60 years was tested and Option Alt 7b still is cost beneficial at a lifecycle of 40 years minimum. Increasing the improvement costs to the maximum estimated in Table 2 still results in Alt 7b being cost beneficial and having the greatest benefit of the proposed options, but wouldn't be cost beneficial at a lifecycle below 60 years.

Summary of Options:

None of the mitigation options will eliminate risk, but most will reduce risk with a few exceptions of increased risk to individual homes. Additional incentives for homeowners to decrease their risk are recommended such as backflow preventers and sump pumps, in addition to infrastructure improvement.

Alt 2b: This option has a favorable Benefit Cost Ratio (1.57) and improvement cost ($ 4.5MM), but puts 15 homes at greater risk, mostly in the Weber Park area from the larger storm drains upstream. There are other options that have greater impact.

Alt 3a: This option also has a favorable Benefit Cost Ratio (1.57) and reduces risk in 117 homes, but only removes 11 homes from risk.

Alt 4a: This option has the lowest improvement cost ($3.4 MM) and decreases risk to 127 homes, but only removes 6 homes from risk.

Alt 5a: The annualized cost outweighs the benefit for this option.

Alt 7b: This option has the highest Benefit Cost Ratio (1.65), removes the highest number of homes from risk (38 homes), and also reduces risk in the most homes of all options (150 homes). The only significant disadvantages are that it increases risk in one home and has the 3rd highest cost ($8.5 MM).

Alt 8: The annualized cost outweighs the benefit

Alt 9: The annualized cost outweighs the benefit

Home Sales Data Inquiry

We tested the hypothesis that homeowners that experience home flood inundation are more likely to sell their homes. To test for a correlation, sales data was obtained from the assessor's office for the Morningside neighborhood. This data was on all sales from 1/1/1970 through 4/27/2018 and included traditional sales, as well as bank sales, physical change sales ("flipping"), and estate sales. A pivot table was used to determine the number of sales per home and the data was then added to the ArcMap Building Data attribute table to calculate the mean number of sales for each flood condition.

Table 7: Morningside Mean Number of Sales per Home:

All homes	10% Surface Inundation Annual Risk	1% Surface Inundation Annual Risk	Under 1% Surface Inundation Annual Risk
2.92	**3.06**	2.63	2.97

There is a higher mean number of sales per home in the 10% surface risk category, which may show a correlation, but what this doesn't take into account is the age of homes built post-1970, which would have less overall tenure.

Morningside Mean Home Year Built in or post 1970

All homes	10% Surface Inundation Annual Risk	1% Surface Inundation Annual Risk	Under 1% Surface Inundation Annual Risk
2004	1999	1998	2006

Appendix A:

Year Built Statistics for Morningside Single Family Homes:

The Single Family Homes were selected by attribute and the following statistics were generated:

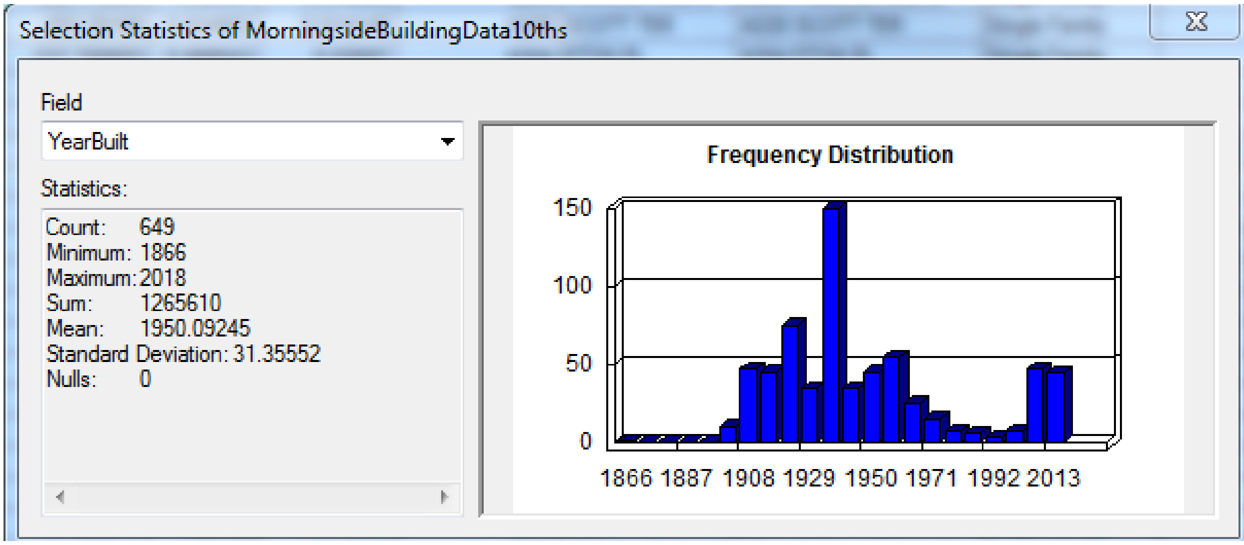


Figure 5: Chart of ArcGIS statistics showing the majority of Morningside homes were built between 1910 and 1960.

Appendix B GIS Methodology:

Home Elevation Methodology

The adjacent grade elevations were calculated in Arc Map, using the DEM (digital elevation map) and Building Footprint feature class. The DEM was clipped to the building footprints, converted into a polygon feature class, and then spatially joined back to the Building Footprint feature class to add minimum, average, and maximum elevations for each footprint. Since the DEM data needs to be in integers to be converted to a polygon feature class (ArcGIS limitation), the elevation data was converted from meters to feet and multiplied by 10, and converted to integers using the Map Algebra Tool before converting to a polygon feature class. Once converted, the data was divided by 10 to get elevation data to the nearest tenth.

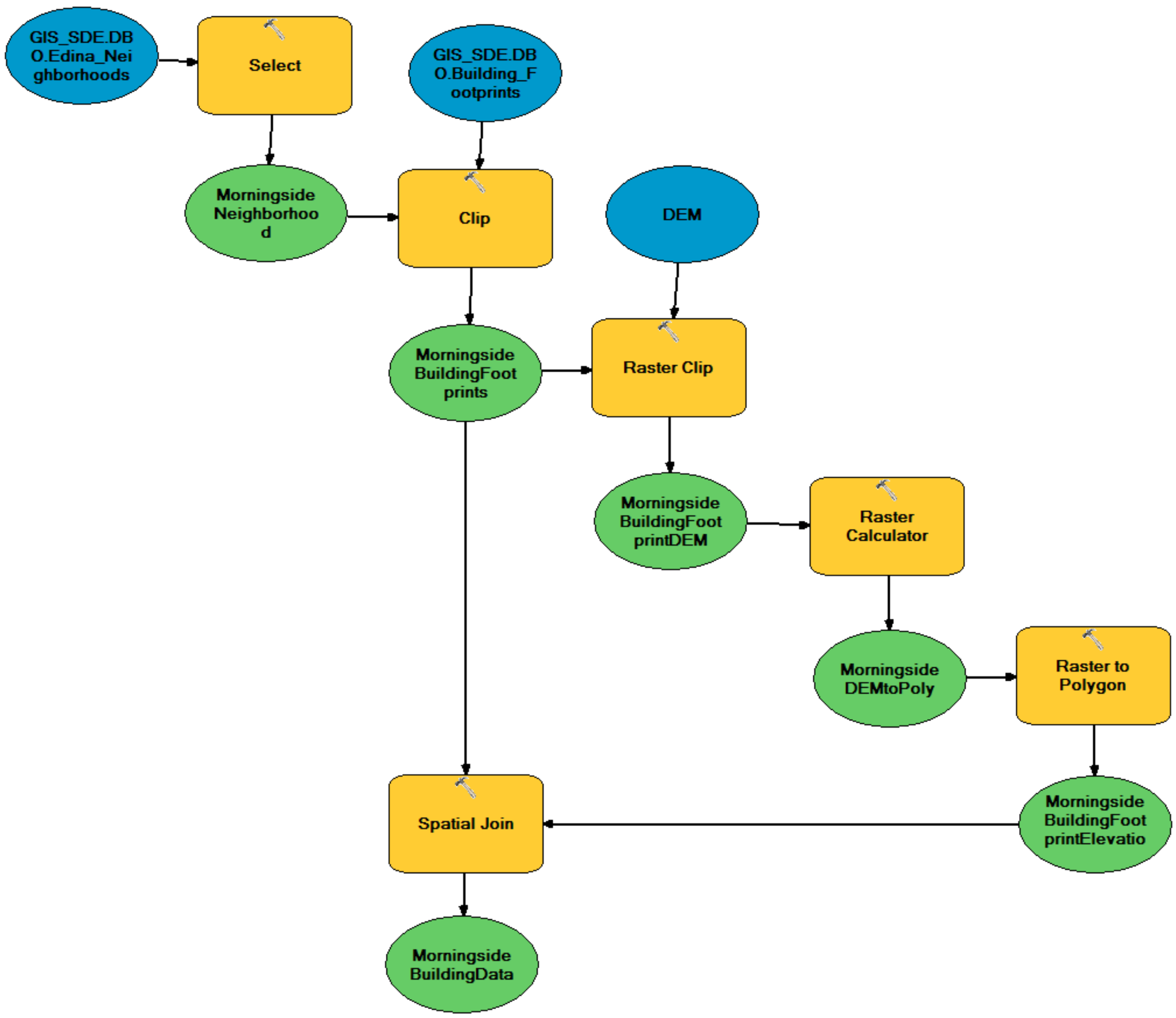
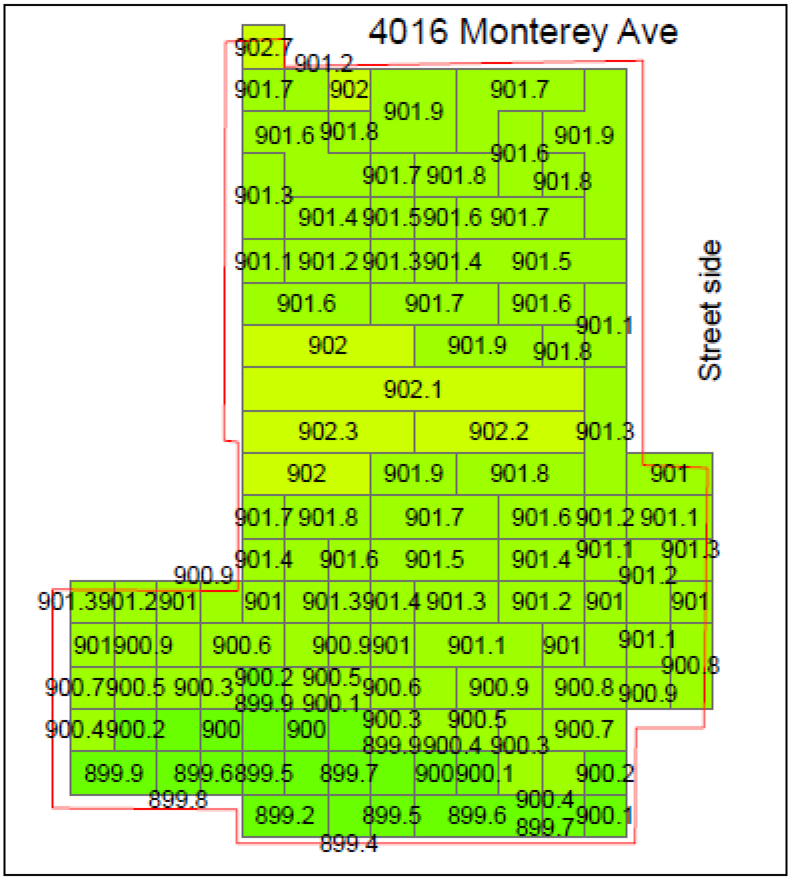


Figure 6: GIS Model of Adjacent Grade Elevation calculation process



Minimum Elevation: 899.2'
Maximum Elevation: 902.7'
Average Elevation: 901'
Elevation Difference: 3.5'
First Floor Elevation: 903.7'
Basement Elevation: 894.7'
First Floor Elevation Calculation: max + 1
Basement Elevation Calculation: max - 8

Figure 7: Example footprint with elevation data from DEM clip and derived data below.

The first floor and basement elevation data were obtained from the home lot surveys when possible. If the survey contained a top-of- foundation or TOB (top of block) elevation, 1 foot was added to that number to account for the sub-floor and floor. If basement elevation data wasn't available, 9 feet was subtracted from the First Floor Elevation.

If the lot survey was missing or didn't contain elevation data, the first floor elevation was calculated by adding 1 foot to the maximum footprint elevation from the DEM and the basement elevation was determined by subtraction 8 feet from that elevation (or 9 feet total from the first floor elevation). The critical structures at risk of surface inundation were also viewed using Street View to confirm the first floor elevations.

First Floor Elevation: Plan versus Calculated Differences

To test the confidence level of the First Floor Elevation calculation methodology above, the homes with known First Floor Elevations were selected (238 homes) and the calculated values subtracted from the plan values to create a difference data. The data was then exported to Excel to be statistically analyzed and summarized.

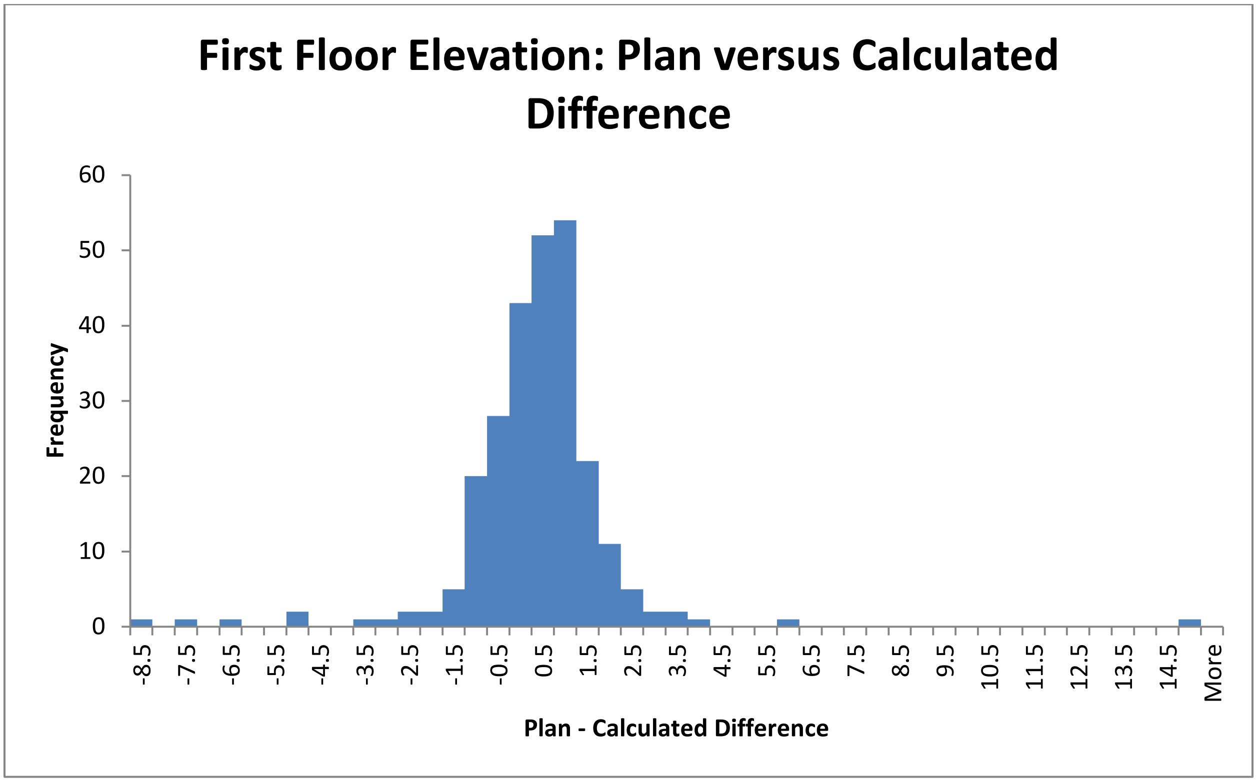


Figure 8: Histogram of Plan versus Calculated First Floor Elevation difference

The 95% Confidence Level is 0.2' with the Mean being 0.17' and a Standard Deviation of 1.72. 47.7% of home calculated FFE's were within ½' of the plan FFE and 76.4% of home calculated FFE's were within 1' of the plan FFE. This is close enough to use for our analysis and to use for future city-wide models.

The difference outlier homes were further analyzed:

The biggest difference home (14.8' plan above calculated FFE) was built after the LIDAR data was collected. The landscape was significantly raised to elevate the home out of the flood plain.

The other homes with negative differences were mostly split-level walkout basement homes with FFE's below the maximum elevation.

The Basement Elevation calculations were also compared against the plan IFE's in a total of 97 homes.

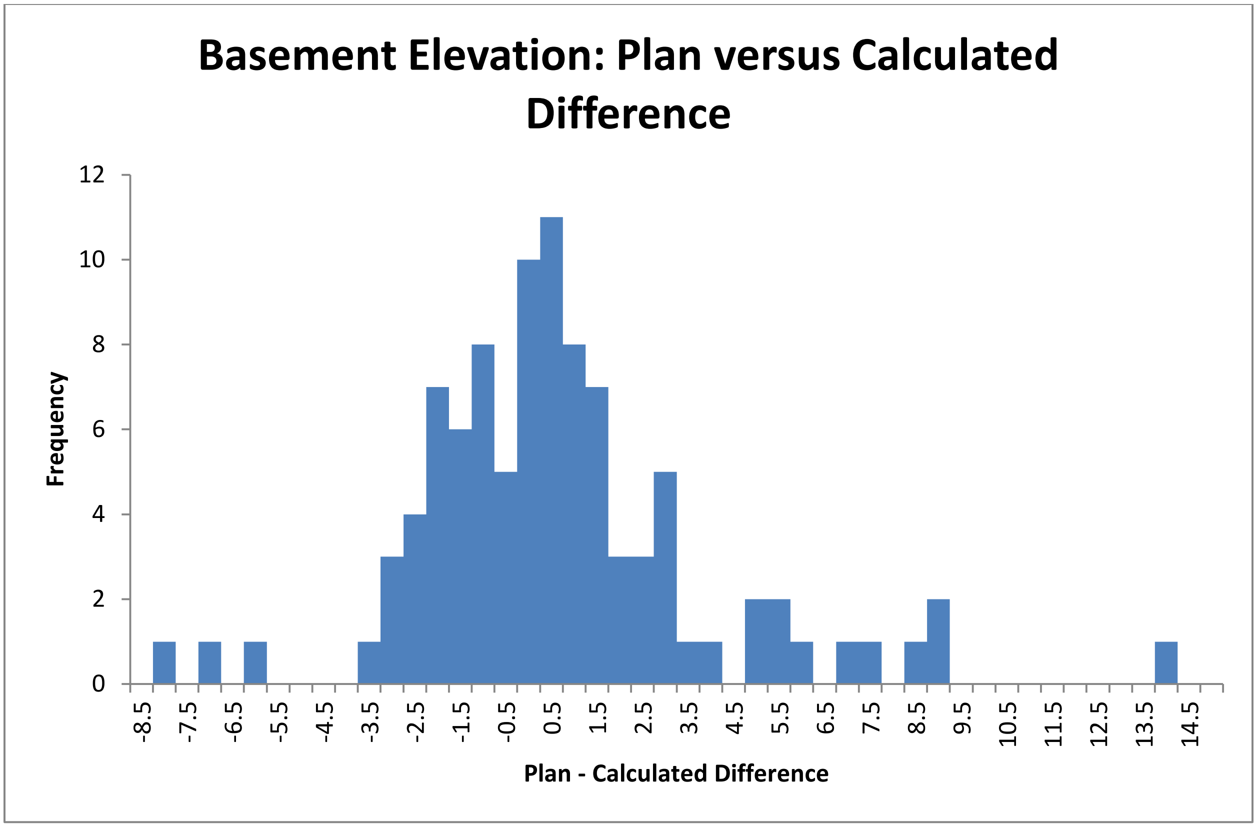


Figure 9: Histogram of Plan versus Calculated Basement Elevation difference:

The 95% Confidence Level is 0.66' with the Mean being 0.46' and a Standard Deviation of 3.28 . 26.8% of home calculated FFE's were within ½' of the plan FFE and 43.3% of home calculated FFE's were within 1' of the plan FFE.

The outlier homes correspond with the outliers in the FFE analysis.

Flood Risk GIS Methodology:

In ArcMap, the 1% and 10% inundation shape polygons were overlaid on an elevation relief map (from the DEM) and carefully inspected to remove false "artifacts" from the Barr model. Others were edited or removed when new build landscaping elevation was done to increase the home elevation and reduce the flood risk. Elevation contour lines from the plot surveys were used to reshape the polygons.

After editing the polygons, the structures were matched with their subwatersheds by selecting the structures that intersected each subwatershed polygon. The subwatershed 1% and 10% inundation elevations were added for each watershed. Since most structures overlapped 2 or more subwatersheds, the higher inundation elevation numbers were added, unless there was surface inundation risk by lower elevation inundation.

To determine surface flood risk, the structures overlapping the 1% and 10% inundation polygons were selected.

Direct Flood Risk GIS Methodology:
The data was selected using the commands below for each 1% and 10% risk:

Moderate Flood Risk: Type = 'Single Family' AND SurfaceFlood10%/1% = 'Yes' AND (FloodElevation10%/1% > Minimum Adjacent Elevation) AND (FloodElevation10%/1% </= Average Elevation)

Major Flood Risk: Type = 'Single Family' AND SurfaceFlood10%/1% = 'Yes' AND (FloodElevation10%/1% > Average_Elevation) AND (FloodElevation10%/1% </=Maximum_Elevation)

Severe Flood Risk: Type = 'Single Family' AND SurfaceFlood10%/1% = 'Yes' AND FloodElevation10%/1% > Maximum_Elevation

Indirect Flood Risk GIS Methodology:
The data was selected using the commands below for each 1% and 10% risk:

Minor: Type = 'Single Family'AND FloodElevation10%/1% <=(BasementElevation + 4) AND (FloodElevation10%/1% > BasementElevation)

Moderate: Type = 'Single Family'AND FloodElevation10%/1% >(BasementElevation + 4)

Sanitary Flood Risk Methodology
Moderate:

- Select by Attributes: DirectFloodRisk 10%/1% = 'Major' OR DirectFloodRisk 10%/1% = 'Severe'
- SanitaryRiskElevation10%/1% = BasementEvelation + 1. Sort the homes from lowest to highest sanitary risk elevation
- Create a 250' buffer around the selected homes, using the buffer tool
- Select by location the buildings intersecting the each buffer, starting with the buffer from the target home with the lowest sanitary elevation and work upwards, since there will be overlap.
- Then select by attributes from that selection Type = 'Single Family' AND Sewershed = [the one from the target home]
- Remove any other target homes with higher sanitary risk elevations from the selection, then copy the SanitaryRiskElevation for the target home to the rest of the homes in the buffer
- Then Select by Attributes from current selection: SanitaryRiskElevation10%/1% > BasementElevation. The selected homes will be your Moderate Risk homes

Major: Major is done similar to Moderate, with the following differences:

- Review Moderate flood risk buffers for clusters of over 3 homes with Major or Severe Direct Flood risk that are on the same sanitary main. Select the buffers of these homes and export selected to create a new feature class
- Then Select by Attributes: DirectFloodRisk 10%/1% = 'Major' OR DirectFloodRisk 10%/1% = 'Severe'
- SanitaryRiskElevation10%/1% = BasementElevation +5. Sort the homes from lowest to highest sanitary risk elevation

- Repeat the rest of the steps from the Moderate Sanitary Risk Methodology

Potential Mitigation Option Mapping

The Barr Engineering team helped created an Excel Macro-enabled spreadsheet to calculate and summarize the annualized risk to each home, based on current conditions and each potential mitigation option. The annualized risk data for each home and condition was then imported to ArcMap and merged with the home data feature class.

The risk change was calculated for each option by home by subtracting the risk for the option from the current condition risk. The homes removed from risk classifications were calculated by applying a selection criterion for the current risk not equal to zero and the improvement option equaling zero. These selections were exported as layers for creating the maps below.

3 sets of maps were made with this data:

- A single Greatest Impact map showing the at-risk homes categorized by the option that would yield the greatest improvement to existing conditions. The greatest improvement option for each home was calculated by selecting the option with the highest risk changes (positive). The homes that had multiple options with the same improvement were left out.
- A series of maps depicting the homes at risk for current and each improvement condition. The maps for the improvement conditions also included a category for the homes removed from risk for the specified condition. A color gradient was used to show the risk level to each home in $3000 increments (not noted on the maps to keep confidential).
- A series of maps showing the risk change from existing conditions for the improvement options. Some of the improvement options had a few homes with increased risk, which were depicted in red, while the improvement risk decrease amounts (in $3000 increments as above) were shown on a green gradient. A category showing the homes removed from risk was also shown for each option.

Resources

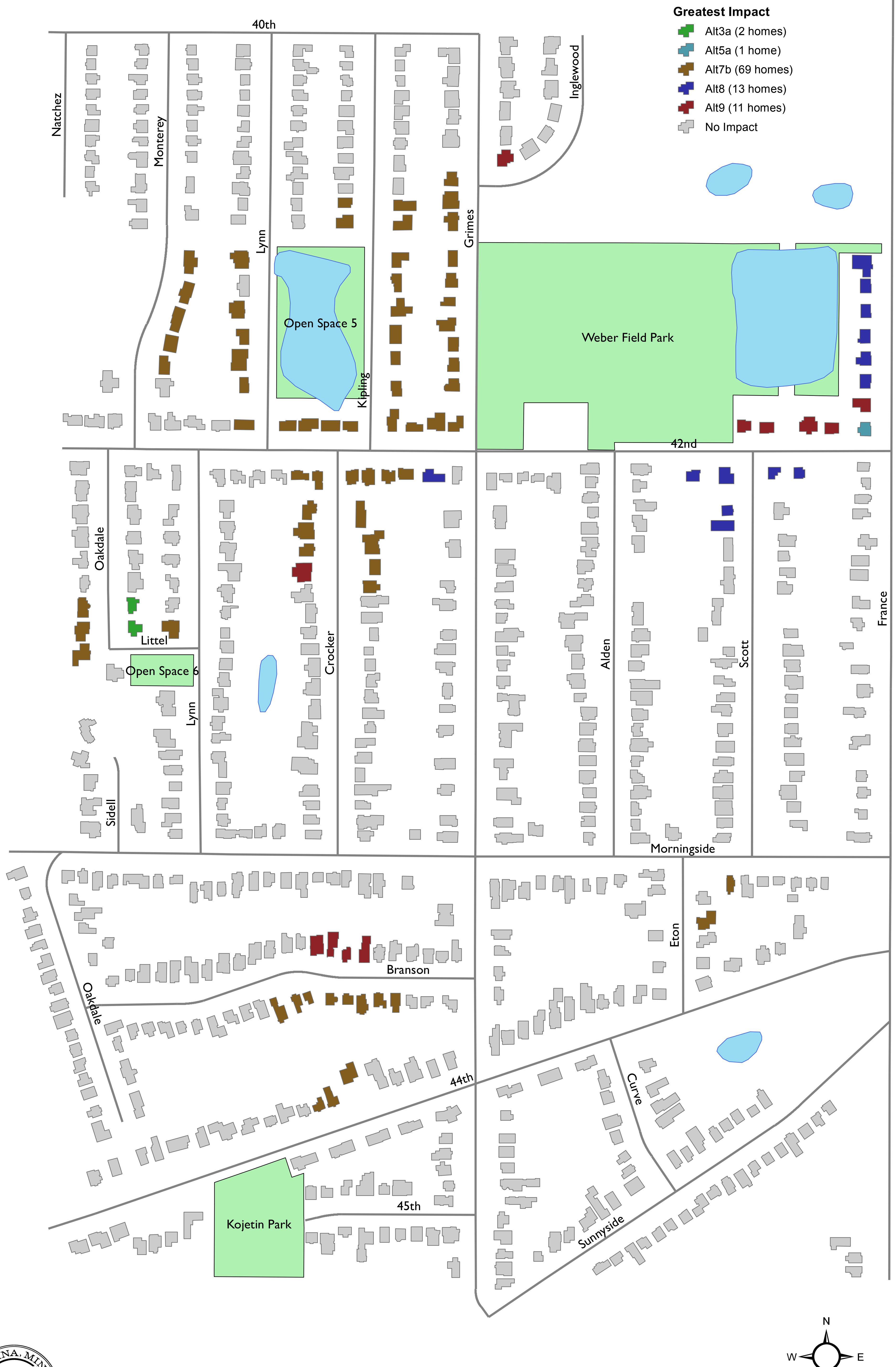
References for concept used in creating expected annual damage and damage-exceedance probability and cost curves;

https://www.nap.edu/read/21720/chapter/5

http://www.naic.org/documents/cipr_study_1704_flood_risk.pdf

https://www.tandfonline.com/doi/pdf/10.1623/hysj.52.5.1016

https://www.fema.gov/media-library-data/a10327c71a76f7c88d7cf403dcf60f4f/Actuarial_Methods_and_Assumptions_2013-09-04_508.pdf

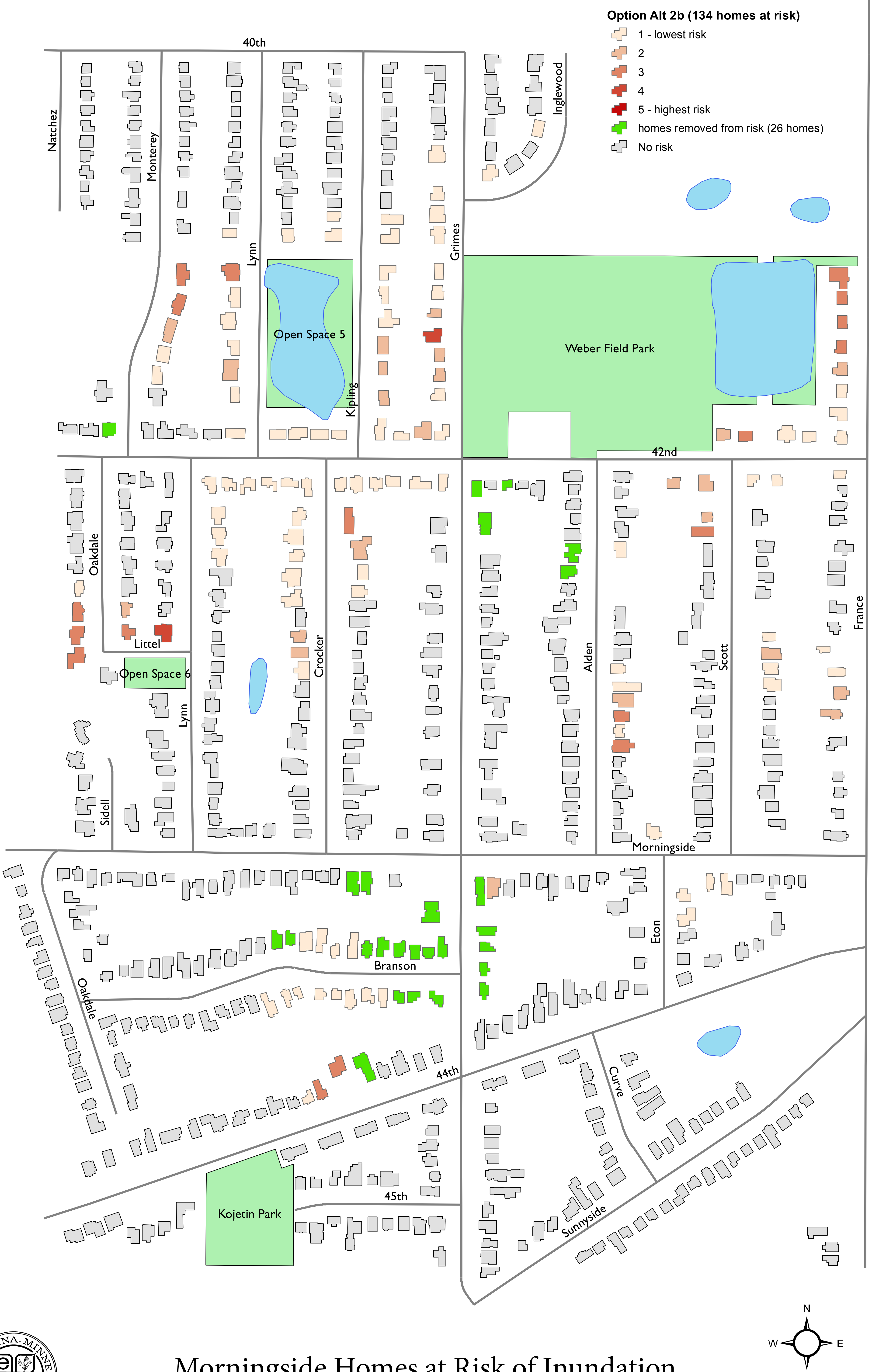


Morningside Greatest Impact Flood Mitigation Options

City of Edina Engineering Dept
Semptember 2018

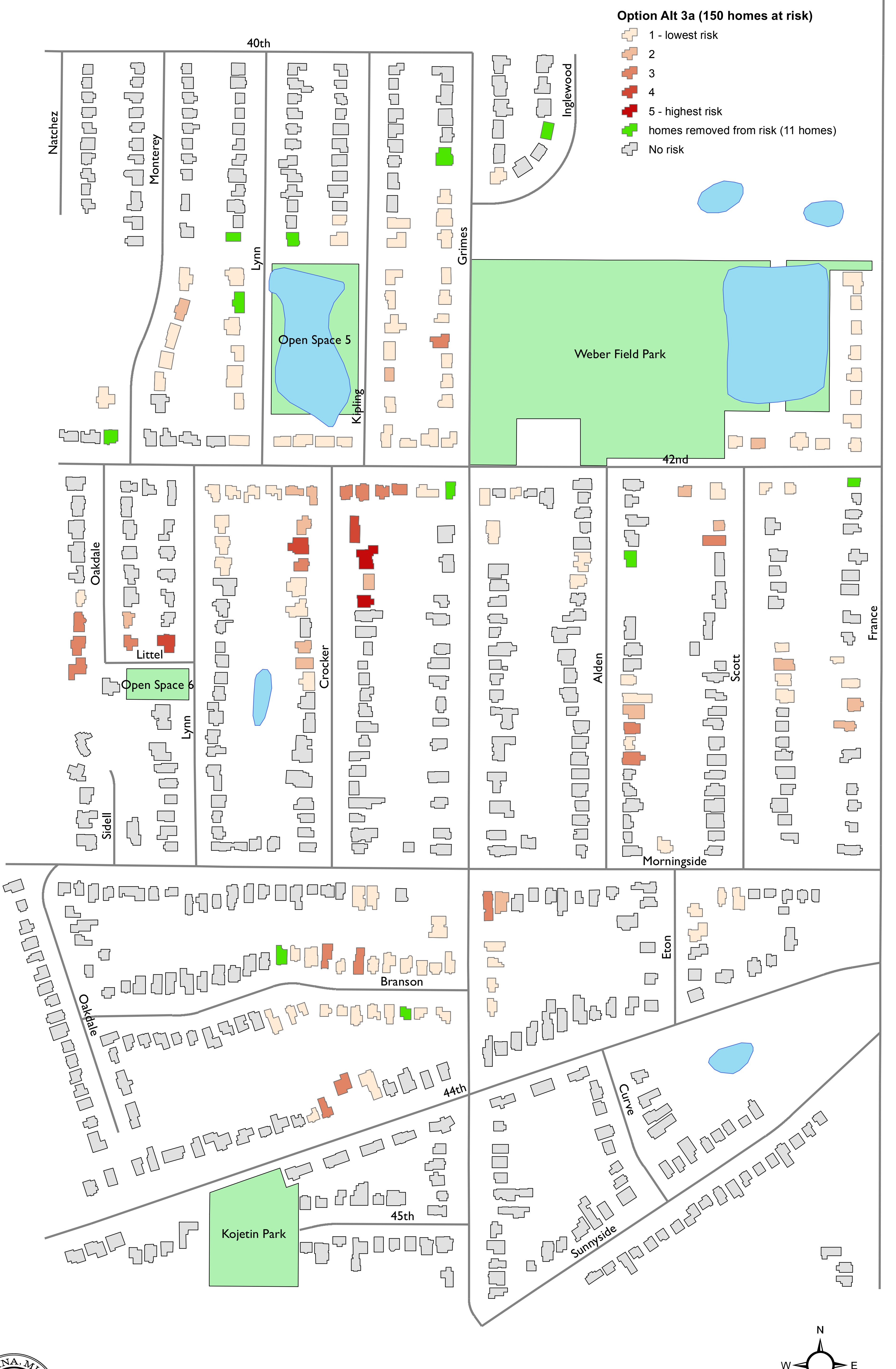
Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018



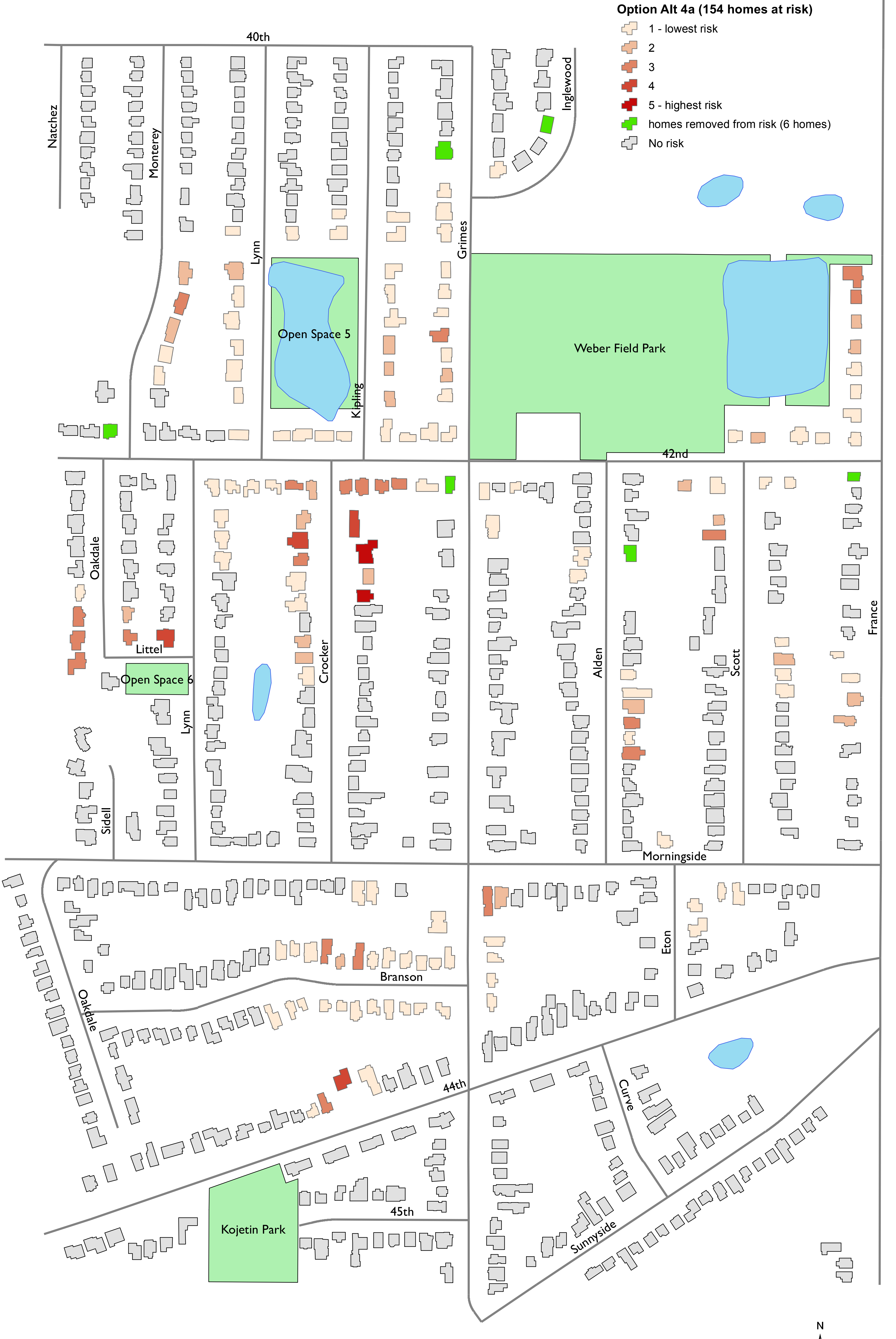
Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018



Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018

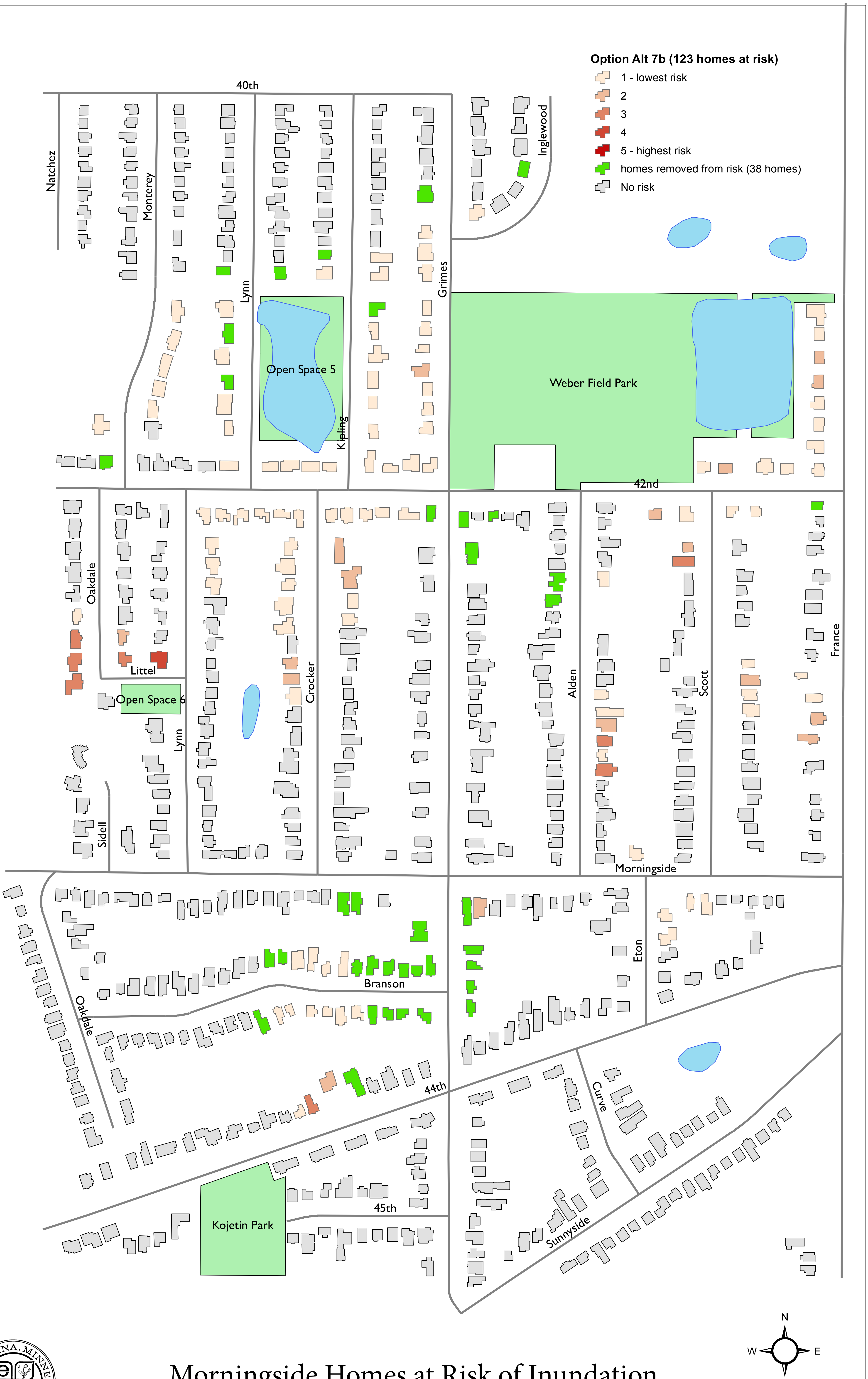


Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018

Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018

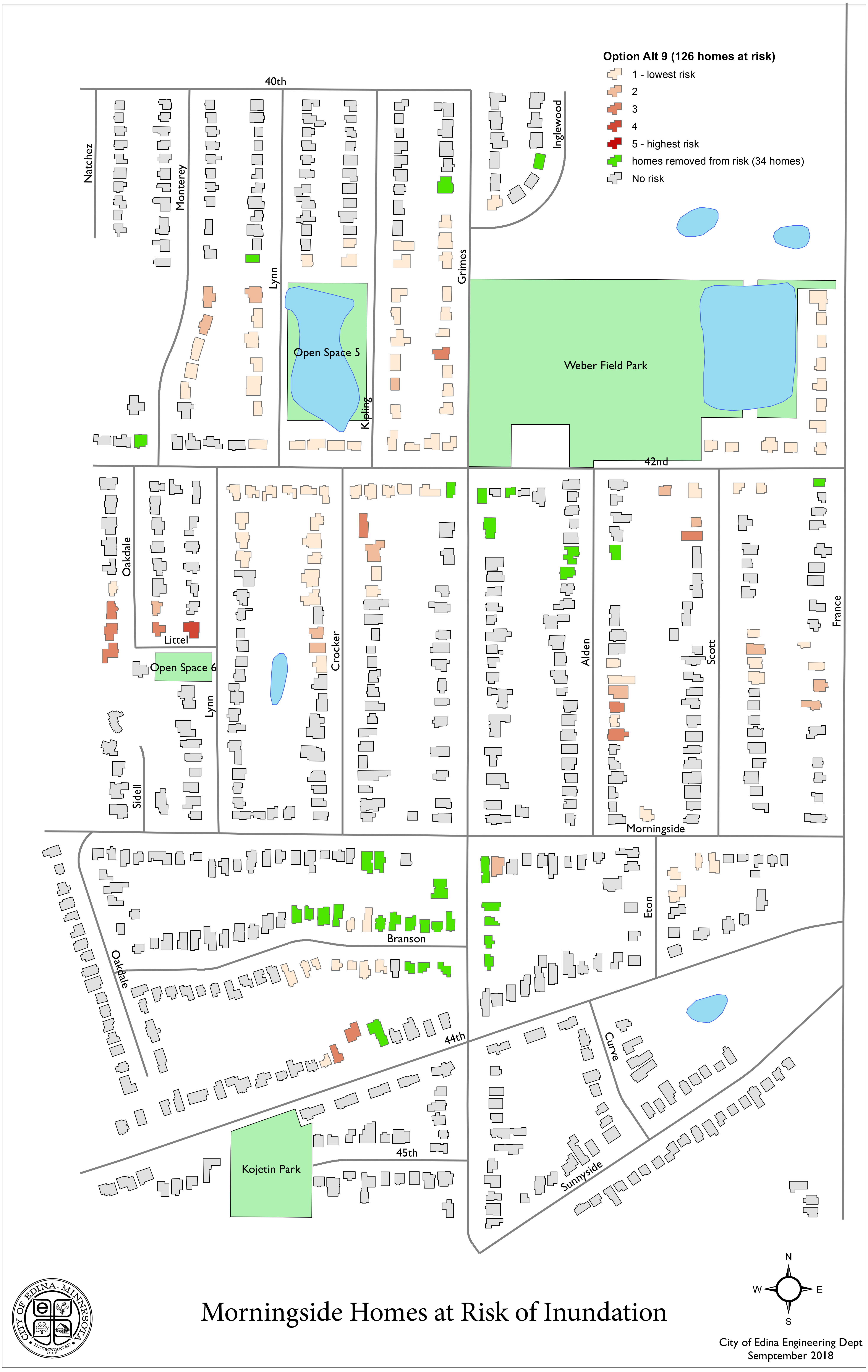


Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018

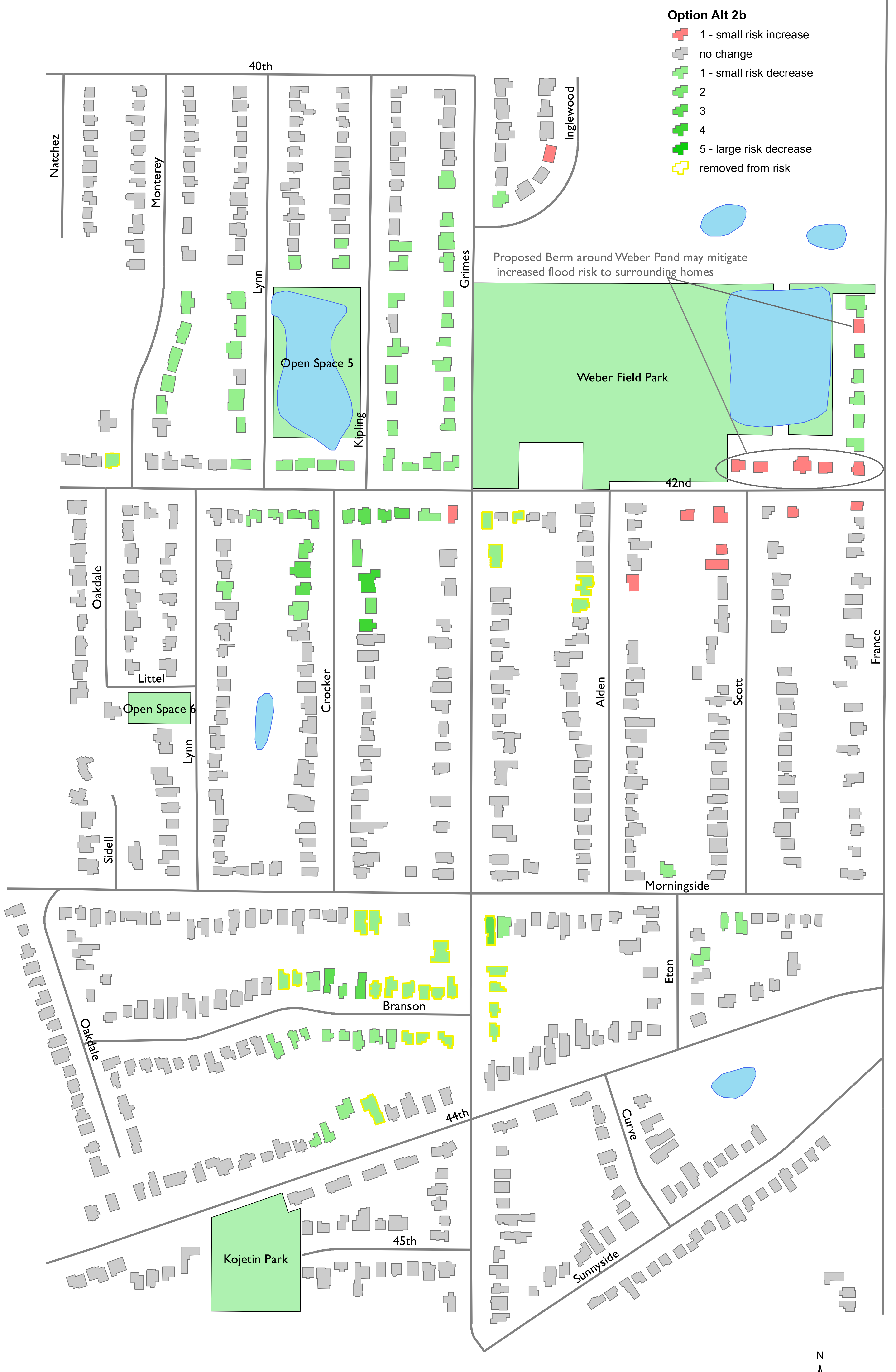
Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018



Morningside Homes at Risk of Inundation

City of Edina Engineering Dept
Semptember 2018

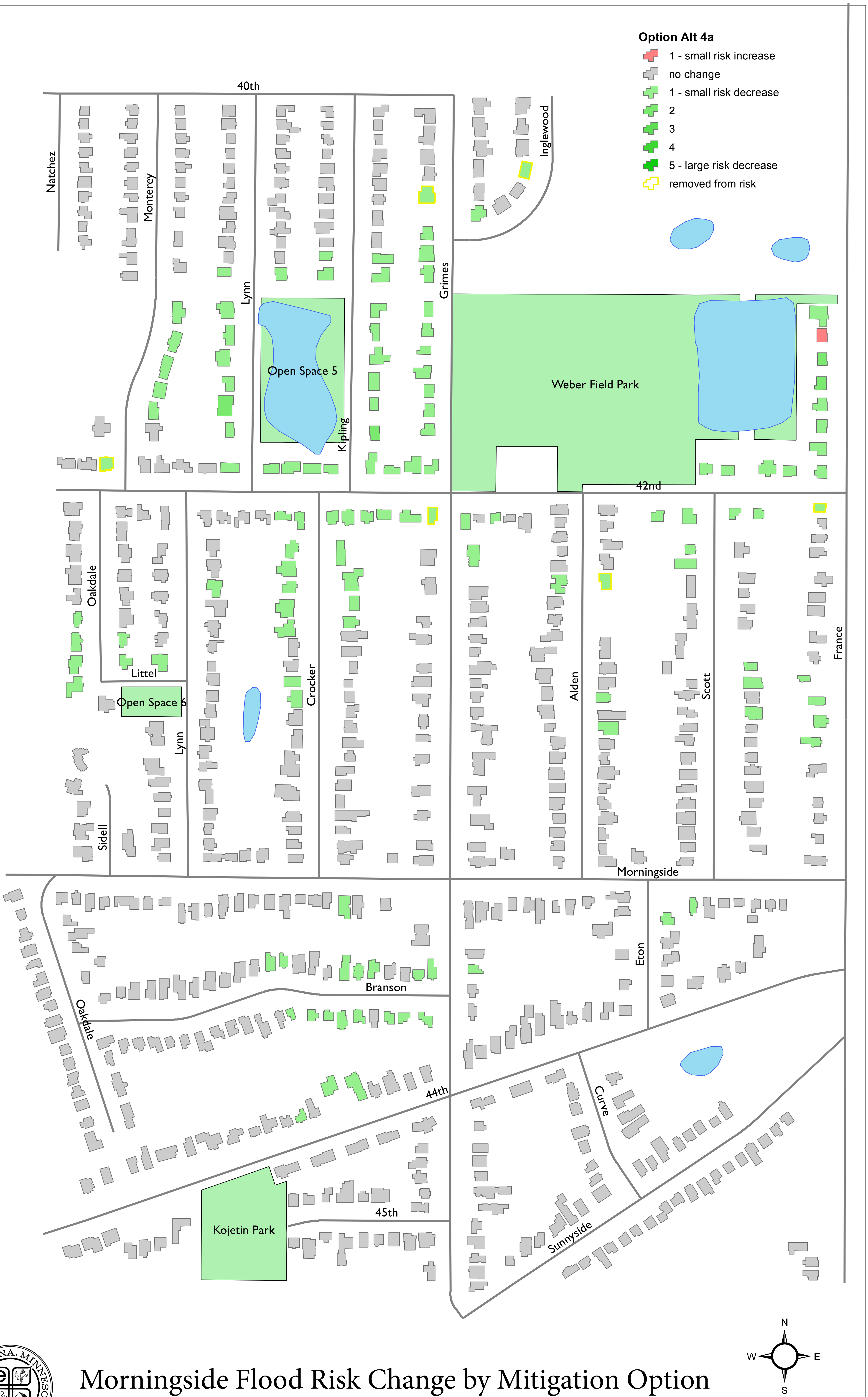


Morningside Flood Risk Change by Mitigation Option

City of Edina Engineering Dept
Semptember 2018

Morningside Flood Risk Change by Mitigation Option

City of Edina Engineering Dept
Semptember 2018



Morningside Flood Risk Change by Mitigation Option

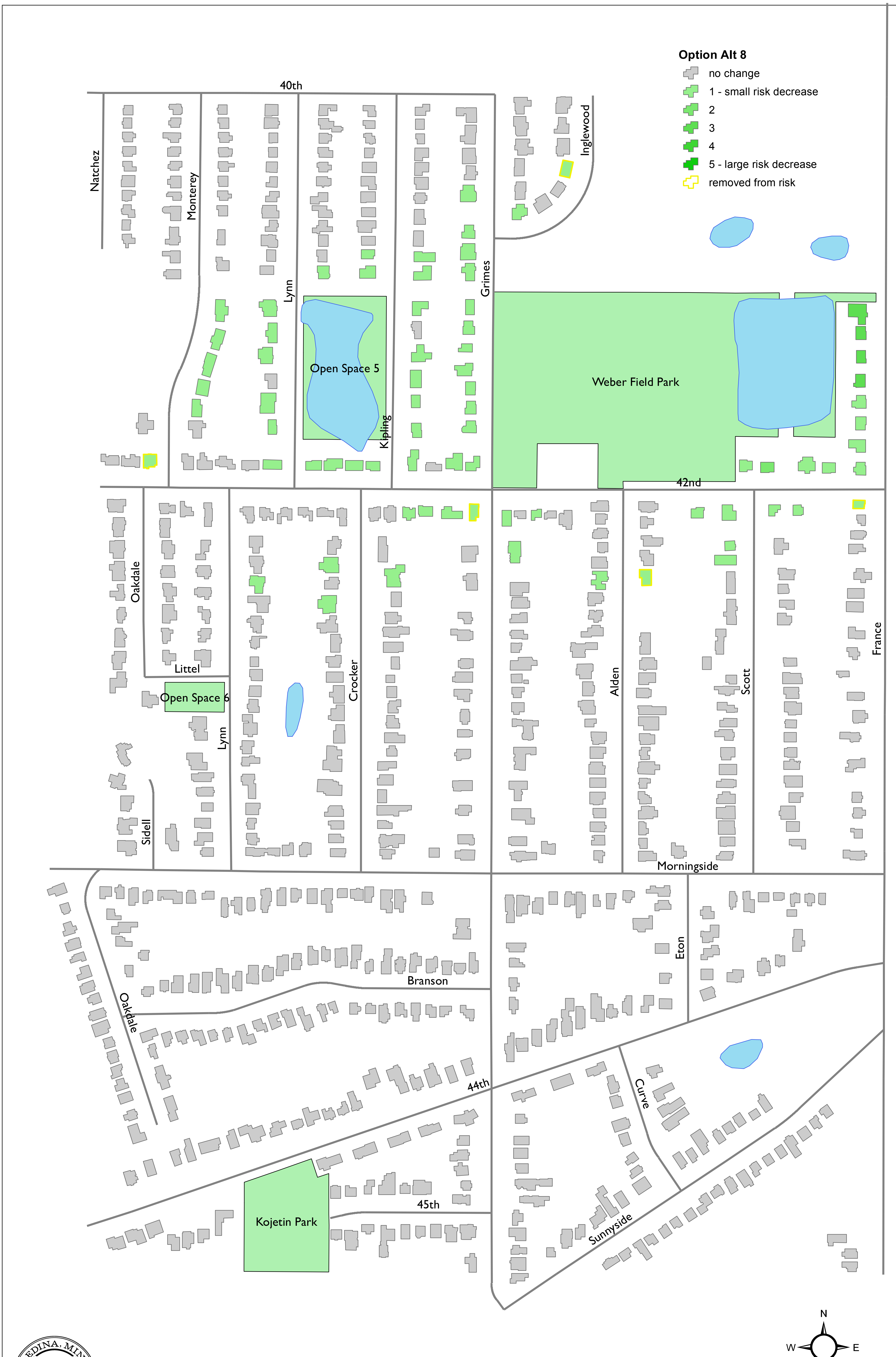
City of Edina Engineering Dept
Semptember 2018

Morningside Flood Risk Change by Mitigation Option

City of Edina Engineering Dept
Semptember 2018

Morningside Flood Risk Change by Mitigation Option

City of Edina Engineering Dept
Semptember 2018



Morningside Flood Risk Change by Mitigation Option

City of Edina Engineering Dept
Semptember 2018

Morningside Flood Risk Change by Mitigation Option

City of Edina Engineering Dept
Semptember 2018