Inflow and Infiltration

A Qualitative Approach to Determining Areas of Highest Inflow and Infiltration in the Milwaukee Metropolitan Sewerage District's Jurisdiction

Anna Boersma
GIS for Water Resources
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Abstract

Inflow and infiltration (I&I) is a problem that affects all wastewater conveyance systems. While conveyance districts know that I&I is problematic, quantifying the areas of highest inflow and infiltration can be very difficult due to large networks of sanitary pipes, the expense of water monitoring, and varying conditions such as pre-event soil saturation. This paper proposes a qualitative method using ESRI's Geographic Information System (GIS) and Microsoft Excel for determining areas with the highest levels of I&I to identify priority sewer segments while minimizing the locations of I&I field testing.

Pipe age, an empirical operating value, sewer classification, sewer subsystem and soil classification were the parameters used to determine probable areas of highest inflow and infiltration problems. The analysis used data from the Milwaukee Metropolitan Sewerage District's conveyance system. The final result shows 98 miles of sanitary interceptor sewers in the Milwaukee area that should be analyzed.

Contents

I. Introduction

Inflow and infiltration (I&I) is a problem that affects all wastewater conveyance systems. I&I inputs clean water into a wastewater conveyance system, producing additional water that needs to be treated by a wastewater treatment plant. In addition, high amounts of I&I can cause pipes to reach capacity during rain events, leading to flooding or basement back-ups. While conveyance districts know that I&I is problematic, quantifying the areas of highest inflow and infiltration can be very difficult due to large networks of sanitary pipes, the expense of water monitoring, and varying conditions such as pre-event soil saturation. This report proposes a qualitative model, using ESRI's Geographic Information System (GIS) and Microsoft Excel, that identifies the sewer segments most susceptible to the effects of I&I. Identifying these segments helps prioritize segments that need I&I field testing.

This report focuses on the Milwaukee Metropolitan Sewerage District's conveyance system. However, the following discussion and process could be extended for any sanitary conveyance system.

II. Background Information

A. MMSD

The Milwaukee Metropolitan Sewerage District (MMSD) is a governmental agency that operates the wastewater collection, conveyance and treatment of Milwaukee, Wisconsin and the surrounding suburbs. Figure 1 shows the locations of the sanitary sewers. The MMSD also oversees the area's stormwater management.[1]

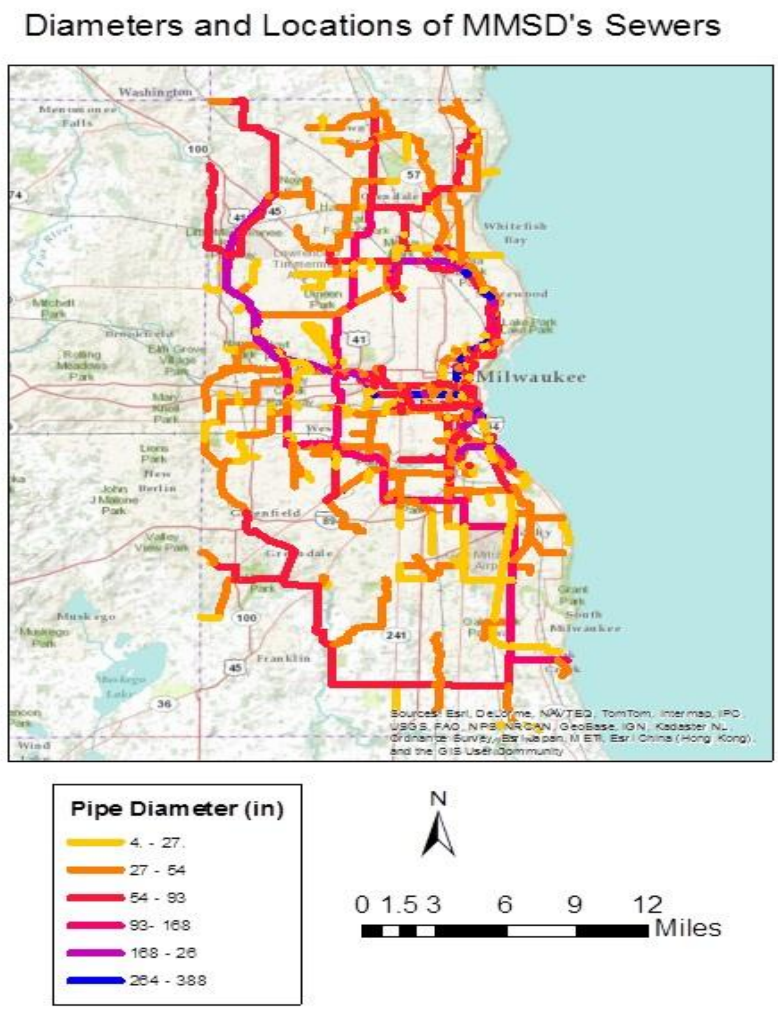

Figure 1. *Location and sizes of the Metropolitan Interceptor Sewers in the Milwaukee area. The large cluster of pipes is downtown Milwaukee. The local municipal sewers are not managed by the MMSD, and are not shown on this map.*

B. Inflow and Infiltration

Inflow and infiltration is uncontaminated water entering sewers. Inflow is clean water that enters sanitary sewers at direct points. Examples of inflow include openings in manhole covers, roof drains connected to sewers, and sump pumps connected to sewers. Infiltration is water entering sanitary sewers, but not at specific locations. Most infiltration comes from groundwater seeping through pipe cracks or pipe joints into the sewers; therefore, infiltration increases as the pipes deteriorate. While inflow and infiltration are different, it can be difficult to separate specific amounts of inflow and infiltration in the sewers so they are usually grouped together and referred to as I&I. A diagram describing different sources of I&I is shown below in Figure 2.

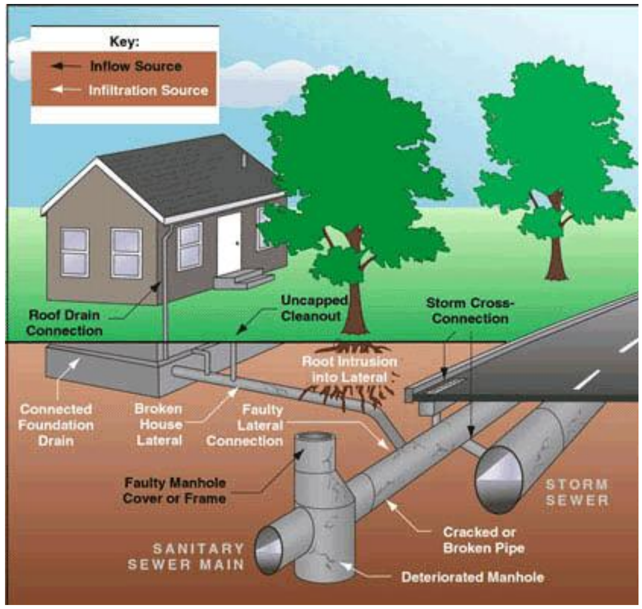

Figure 2. *Diagram of Inflow and Infiltration. Inflow happens at point sources, while infiltration happens over a general area.*[2]

I&I produces two major problems. First, I&I causes flooding. Most sewers contain a base flow amount of I&I for reasons such as illegal sanitary sewer connections and poorly joined sewer joints. However, during rain events the sewers obtain additional I&I from sump pumps, water flowing into manholes, and water infiltrating the soil. The additional I&I can overwhelm the sewer, creating sewer backups and overflows. Second, I&I can be costly to treat. The MMSD estimates that it costs $500 per year to treat every one gallon per minute of continual I&I.[a] Ultimately, this cost is passed onto the residents of the community who pay a wastewater utility bill.

[a]*.Note: This requires a continual, yearlong flow and is only an estimate. This cost can change based on precipitation amounts and many other treatment factors.*

III. Model Parameters

The model contains many different parameters that the user needs to input. Three of these parameters (pipe age, the empirical operating coefficient, and soil classification) are factors that produce more I&I in the sewer segments. The other two parameters (sewer classification and sewer subsystem) emphasize the effects of I&I.

More information about the individual parameters and how they were analyzed are discussed below.

A. Pipe Age

Pipe age can be a large contributor to infiltration. As pipes age, they deteriorate and form cracks, which then allows water to enter the sewer.

Determining the pipe age took three steps when using the MMSD's sewer shapefile. First, pipe segments were checked to verify that the segments under analysis were still active. Abandon pipe segments were left out of the calculations. Second, a GIS field calculator compared the construction year and the rehabilitation year. If the pipe had been rehabilitated, the output was the rehab year. For pipes not rehabilitated, the output was the construction year. Last, inputting Equation 1 into the field calculator produced the age for all sewers. The statistical results are shown below in Table 1 and are displayed in Figure 4.

Equation 1

Pipe Age = 2012-(construction year or rehabilitation year)

Table 1. Pipe Age Statistics

Number of Sections	6468
Youngest Age	3
Oldest Age	132
Average Age	43.77
Standard Dev.	27.6

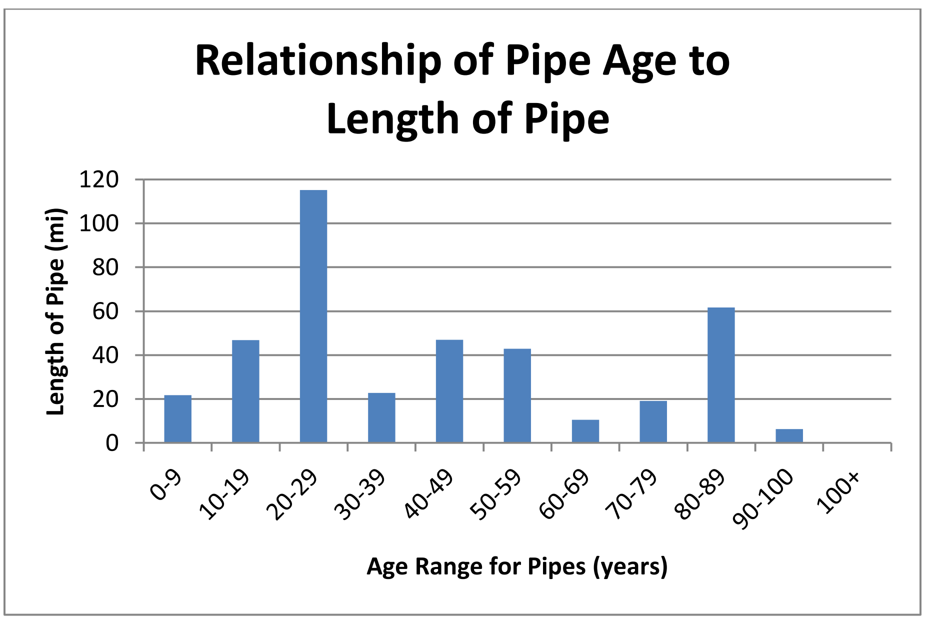

Figure 3. *Length of pipe for varying pipe ages. Notice that about half of the pipe segments are younger than 30 years old, while the other half is older than 30 years old.*

Figure 4. *Age of Sanitary Sewers. For the sewers that were rehabilitated, the age of the sewer displayed is the year of rehabilitation, not the year of construction.*

As the results demonstrate, the pipe age ranges from 3 to 132 years old, with an average age of approximately 44 years old. Generally, the pipes are older near downtown Milwaukee and younger in the suburbs.

B. Empirical Operating Coefficient

Chughati and Zayed (2007) published a paper providing an empirical regression model to quantify the operational performance of sanitary sewers. Their goal was to relate various pipe properties including pipe age, diameter, length, and slope to determine the sections of a conveyance system that would have the highest rates of I&I. Chughati and Zayed created a model to empirically analyze Montreal's collection system. Their equation (Equation 2) had a linear regression fit value of 0.879. In general, the model showed that the operational performance was related to the condition of the pipe; lower performance meant lower pipe condition and higher performance meant the pipe was in better condition.[3]

Equation 2

$$(Operational\ Preformance)^{0.63} = 0.308 + \frac{0.567 * \left(\frac{Age}{Diameter^{n}}\right) * Length^{Slope}}{Age^{0.63}}$$

Age – pipe age (years)
Diameter – pipe diameter (mm)
n – Manning's Coefficient (assumed 0.011 for analysis)
Length – length of pipe section (m)

Variables for the MMSD's sewers were entered into this operational performance equation to produce operational performance values for the MMSD. The age property from the Chughati and Zayed model was assigned as the pipe age parameter as described in the previous section. The pipe length is the asbuilt length of each pipe segment. The pipe length, slope, and diameter data were taken from the MMSD's sewer shapefile.

A map of the various performance values is shown below in Figure 6 and the range of operational performance values are shown below in Figure 5.

While the performance operating value may provide a useful estimate of which sewers with large amounts of inflow and infiltration, it is important to remember that this is only an estimate. The equation has only been fitted for Montreal's system. In addition, the equation does not include many important factors such as pipe material, quality of construction, and soil properties.

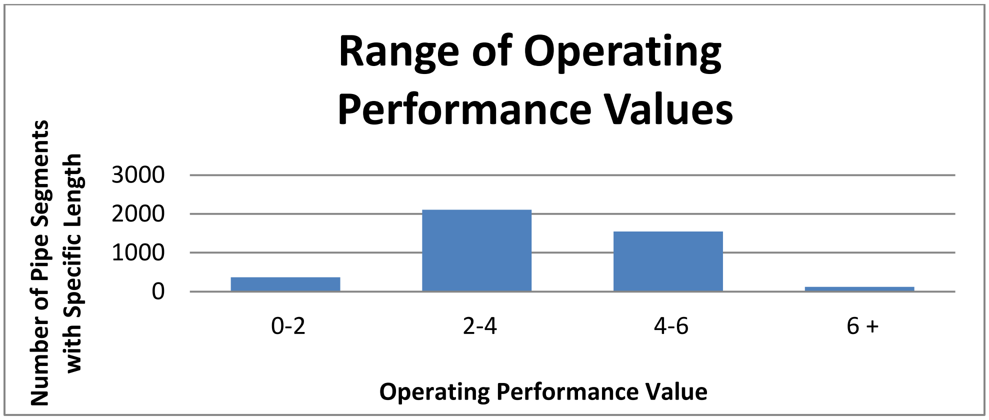

Figure 5. *Range of Operating Performance Values. The higher the performance value, the better the condition of the pipe. Note that the majority of operating performance values range between 2-4.*

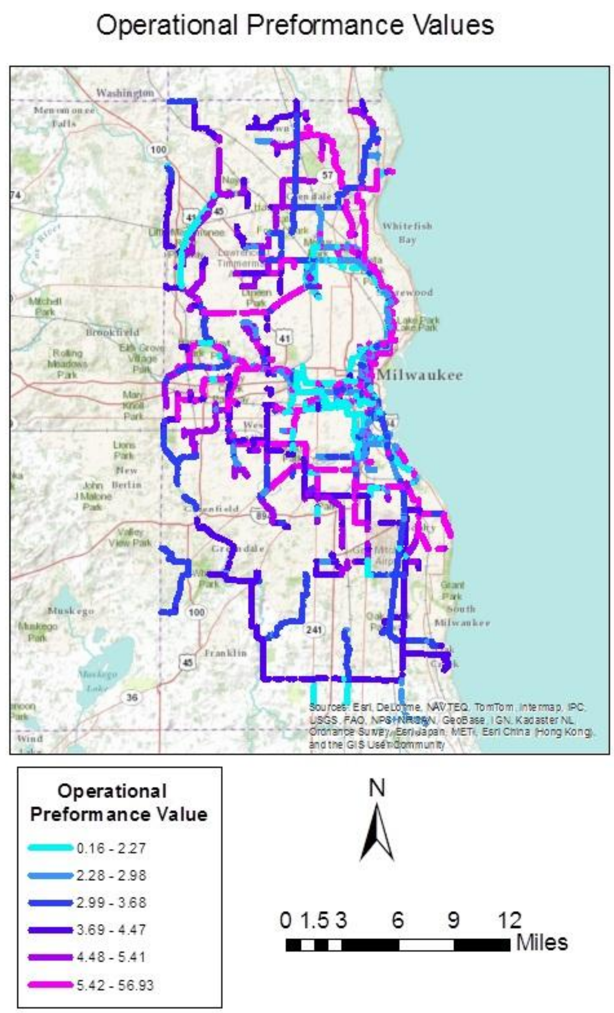

Figure 6. *Operational performance values. Generally, the performance values are the lowest (worse-performing) near downtown Milwaukee, and then increases outside of downtown Milwaukee. The sewers in purple typically have large performance values due to the sewer's steep slope.*

A. Soil Classification

Soil type can have a significant impact on infiltration. Soils with high infiltration rates, such as clay, have more water flowing through the soil and therefore a higher likelihood of infiltration into the sewer. The National Resource Conservation Service completed a soil survey for the majority of areas in the United States. The soils types surveyed by the Conservation Service are divided into hydrologic soil groups. These hydrologic soil groups range from A to D, with A soils having the highest infiltration capacity and D soils having the lowest infiltration capacity.

There were four major steps for determining the soil type for each pipe segment. First, the hydrologic soil group was determined from each soil name. Because each soil is labeled with the hydrologic soil group letter at the end (A,B,C, or D), Python coding was used to extract the hydrologic soil group. Second, a quarter foot *Buffer* was created around the pipelines to convert them from lines to polygons. Third, the tool *Merge* was used to combine the soils and pipeline files. Finally, the tool *Dissolve* was used to condense the soils into the separate hydrologic soil groups. The results are shown below in Figure 7. The large block of orange, surrounding downtown Milwaukee, did not have soil available. Milwaukee was assumed to have a soil in between C and B for use in the spreadsheet model. The majority of soils around Milwaukee are soil types A and B. However, Milwaukee also has lots of impervious areas due to pavement and buildings. These impervious areas allow minimal infiltration into the soil, similar to hydraulic group D. Therefore, the competing properties were averaged so the Milwaukee area could be included in the analysis.

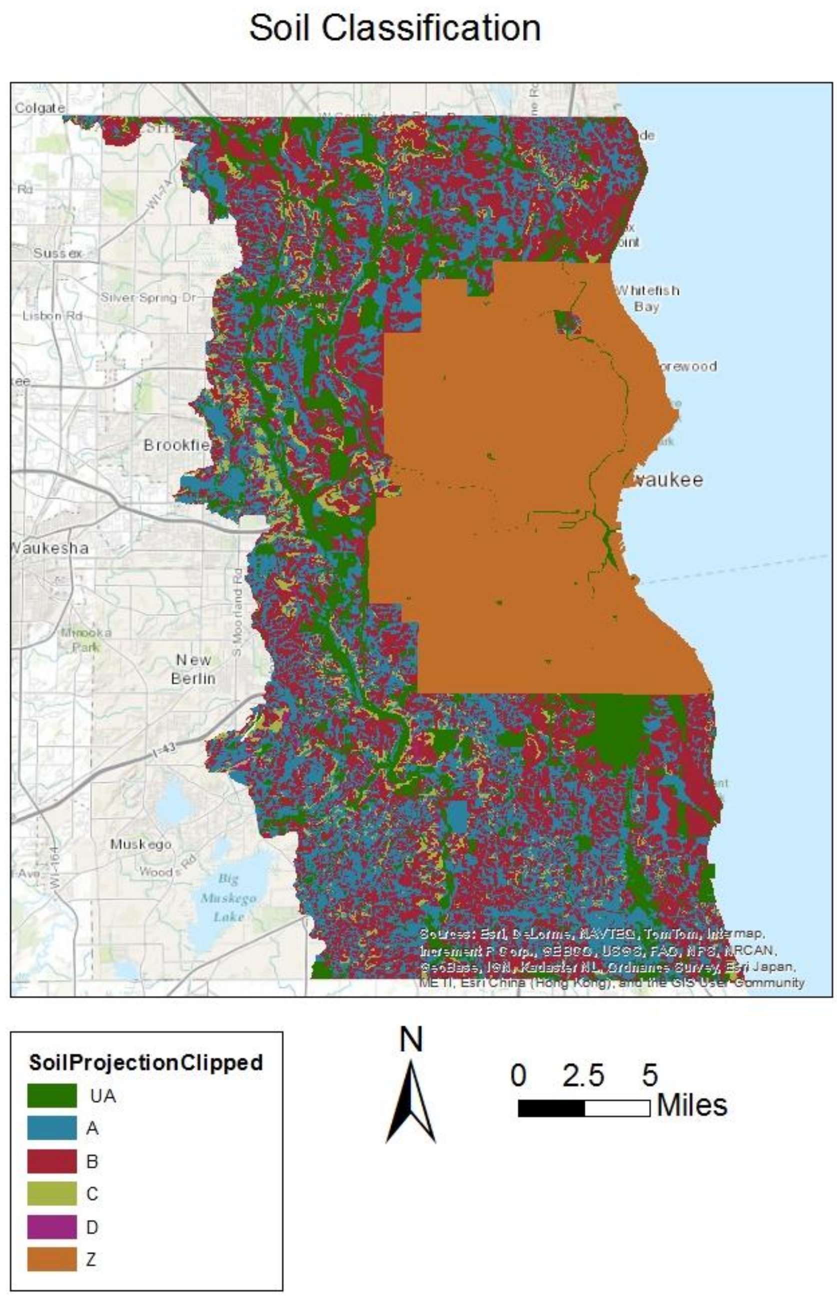

Figure 7. *Milwaukee area hydrological soil groups. Extracted from SSURGO data.[1]Group A soils allow the most infiltration, while Group D soils allow the least amount of infiltration.*

B. Sewer Classification

Any large conveyance system has many different types of sewers, ranging from sanitary laterals to interceptor sewers to force mains. The sewer classification is included in the I&I spreadsheet to allow emphasis to be put on different types of sewers. For example, a larger emphasis might be placed on a combined sewer overflow rather than a sanitary lateral. I&I entering combined sewer overflows might not have a significant impact on the overall conveyance system because the I&I will be quickly discharged into a river rather than decrease the capacity of a main sewer. Alternatively, excess I&I in a sanitary lateral could easily lead to a basement backup.

C. Sewer Subsystem

As mentioned previously, a problem with I&I is that the additional water decreases the sewer capacity. The decreased capacity then increases the probability that a sewer will surcharge during a rain event. A simple way to consider the impacts of subsystems in a sewer is to put more emphasis on areas that have higher histories of basement flooding. The MMSD's sewers are already divided into seven subsystems; these subsystems are the areas used in the project analysis.

IV. Model Interface

The purpose of the model is to merge the different parameters discussed above. In addition, a goal for the model was to be simple for users to manage, while still allowing the user large amounts of control over the inputs. In order to achieve both of these results, the model was created as an Excel spreadsheet.

Before an explanation of the model interface, it is important to note that the figures shown below are snapshots of the model. A complete picture and explanation of this model is given in Appendix A: Excel Spreadsheet Directions.

The model interface has three different portions. The first portion determines the overall weighted values for each parameter. For example, from Figure 8, the pipe age is 0.3. That means that 30% of the final result will be based on the pipe age. However, only 5% of the final result will be based on the empirical value. The user inputs a number for each of the parameters; the only limit for these numbers is that the sum of the numbers must equal one.

Weighted Portions

Pipe Age	0.3
Emperical Value	0.05
Sewer Type	0.15
Subsystem	0.2
Soil Type	0.3

Figure 8. *Weighted portions of the parameters. The user inputs the numbers, the only requirement is that the sum of the numbers equals one.*

The second portion of the interface is weighting the individual parameter values. Figure 9 shows a snapshot of this portion of the model. To use this, the user enters an identification number for the pipe segment under Main_NR. Then, the user enters the pipe age for each segment. After the pipe age input, a number ranging from one to ten appears in the column labeled value. A one means that the specific parameter is not a concern, while ten means that the specific parameter should be of large concern for the pipe segment. These values are pre-defined, but can be changed if needed. The rational for the values are shown in Appendix B: Individual .

In addition to the model producing a value, the model also produces a weighted value by multiplying the value parameter with the weighted parameter. For example, pipe segment P10 has a value of 4. Therefore, the model then multiplies the 4 by 0.3 (from Figure 8), to produce the 1.2 shown in the weighted value column. The process is then repeated for all five parameters.

MAIN_NR	Pipe Age	Value	Weighted Val.
P10	41	4	1.2
P100	79	7	2.1

Figure 9. *The second portion of the model. The user enters cells in yellow and the model produces the green cells.*

Finally, the model creates a total by summing the weighted values for each of the five parameters. The final result produces a number ranging from 1 to 10. Low numbers represent pipe segments with minimal susceptibility to I&I, while high numbers shows pipe segments with the most susceptibility to I&I. Table 2 gives the weighted values for the five parameters of pipe segment P10. The sum of the values is 4.5, showing that while this specific pipe segment probably has moderate amounts of I&I, it is probably not a pipe segment that should be given priority concern. If any of the pipe parameters are missing data, the final total equals zero.

Table 2. Weighted Values for Pipe Segment P10

Parameter	Weighted Value
Pipe Age	1.2
Empirical Value	0.35
Sewer Type	1.2
Subsystem	1
Soil Type	1.5
SUM	**5.25**

After this final total is produced, the user can upload the totals into GIS for analysis.

V. Results

After the user determined the final weighted value for each pipe segment and then uploaded the data back into GIS, GIS can become a very useful tool for analyzing the total weighted values produced by the spreadsheet model.

The result analysis for the MMSD's pipe segments happened in two stages. First, results were analyzed for specific overall weighted values. Second, four different sets of weighted values were used to compare the effect of the weighted values.

A. Empirical Quality Results

The first analysis used specific weighted values for the parameters. These are the values that represent the percentage of emphasis that each parameter has in the final program values. The values are associated with Figure 8, and are also shown below in Table 3 with reasoning for why the specific values were chosen.

Table 3. Parameters for Overall Analysis

Parameter	Value	Reasoning
Pipe Age	0.3	Pipe age is very important for pipe condition; an older pipe can have more cracks and higher levels of infiltration.
Empirical Value	0.05	While it is an interesting concept, the value has only been tested with Montreal's sewers
Sewer Type	0.15	This puts emphasis on sewer types that typically have higher levels on I&I. However, the sewer types can also be analyzed after the results from this.
Subsystem	0.2	This puts emphasis on areas that currently have higher levels of flooding than surrounding areas.
Soil Type	0.3	The larger the amount of infiltration for a given soil, the larger the volume of water that is available to enter the conveyance system through infiltration.

Figure 10 shows the results for the anlysis and Table 4 summarizes those result. Blue lines on the figure represent information for at least one of the parameters is missing. Then, the pipe line segments are color coded based on their final result from the model. The lower the number, the lower the susceptibility of the pieline to I&I.

Table 4. Final Results Summary

Final Result	Pipe Length (mi)
Missing Data	113.22
0 to 2	0.00
2 to 4	41.77
4 to 6	165.54
6 to 8	98.66
8 to 10	0.13

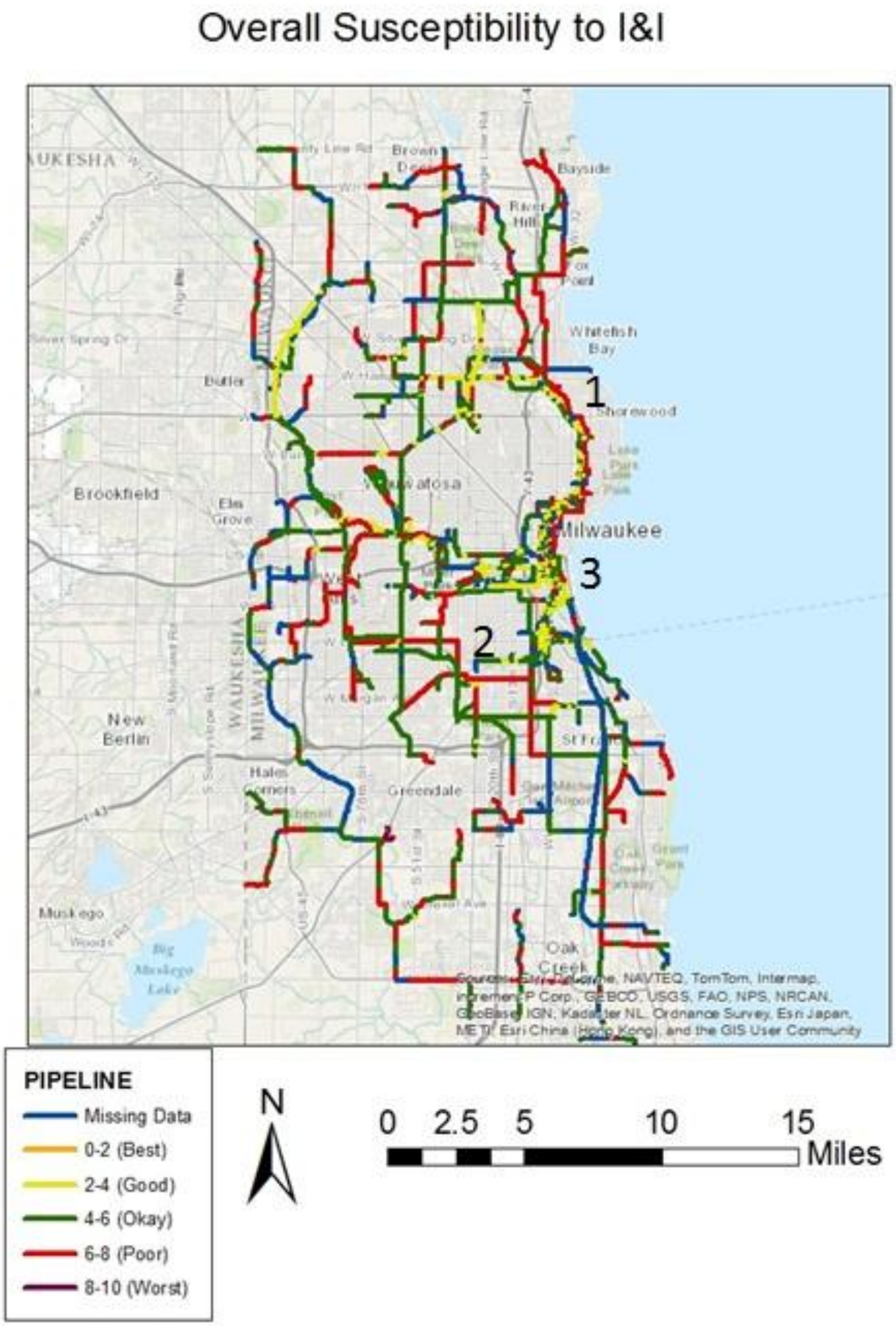

Figure 10. *Final results for pipe segment conditions. Blue pipe segments mean that needed information for the analysis is missing. Green pipe segments (total weighted values of 0 to 2) mean that those pipes are the least susceptible to I&I and the problems associated with it. Red pipe segments (total weighted values of 6 to 8)show pipes that are the most susceptible to I&I.*

Three specific areas of interest were labeled 1,2, and 3 in Figure 10. Section 1 has pipes with high susceptibility of I&I problems (total weighted values ranging from 6 to 8). Section 1 connects Whitefish Bay to downtown Milwaukee. Section 2 is another area of high suscebilitility to I&I. These pipes run from Honey Creek Parkway to the South Shore Wastewater Treatment Plant. Section 2 follows Lake Michigan from For sections 1 and 2, pipe age is the most significant parameter that causes these areas to have total weighted values ranging from 6 to 8. Section 3 is downtown Milwaukee. Downtown Milwaukee has a conglameration of total weighted values, but generally has lower values compared to other pipe sections.

While reivewing these results, it is important to remember that these figures only represent the conveyance sewers. The results do not account for the qualitity of the individual cities in the MMSD's jurisdiction.

B. Result Comparison

After analyzing the total weighted results from the previous section, the specific, parameter weighted values shown in Table 3 were changed to produce alternative results. These different results were uploaded into GIS for analysis.

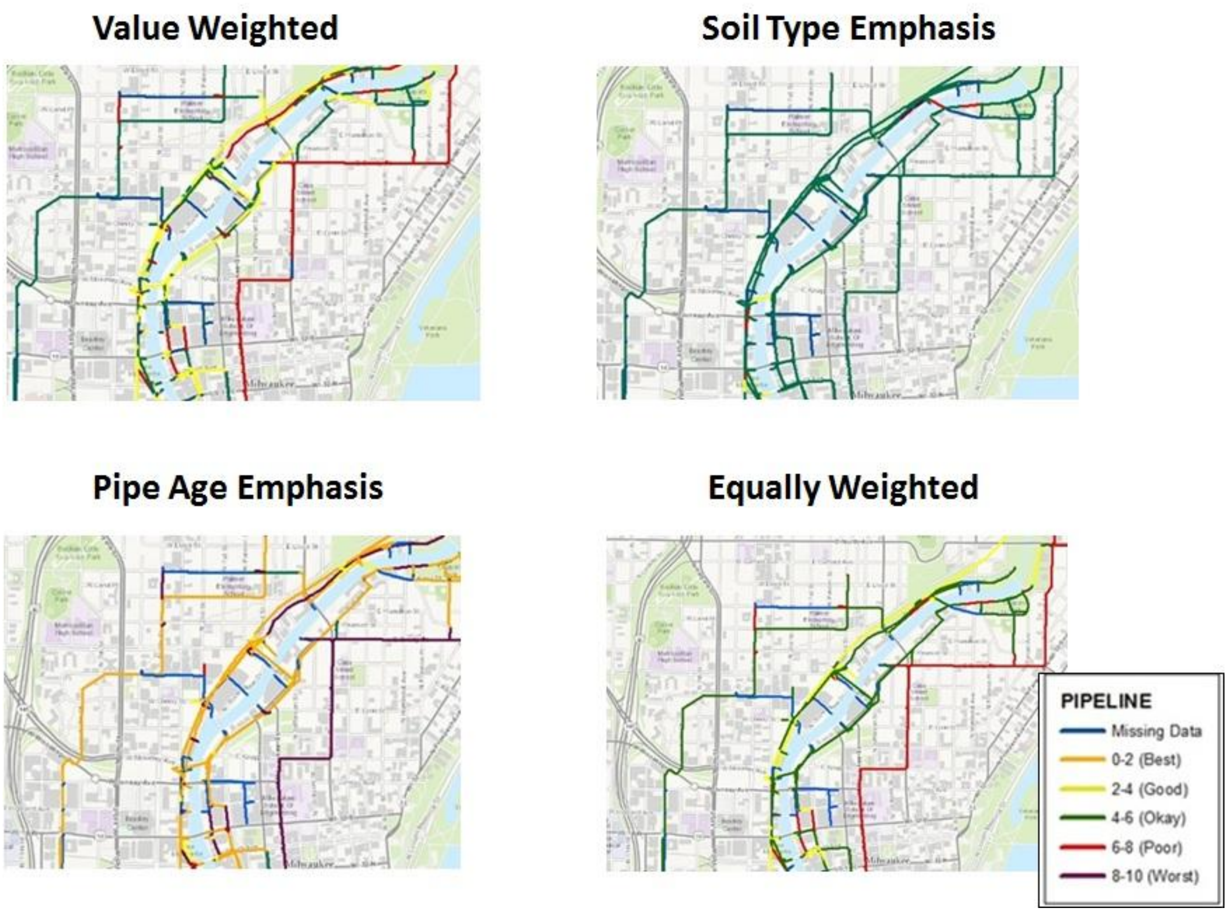

Figure ***12*** shows a portion of these results, with the red box in Figure 11 showing the area represented by

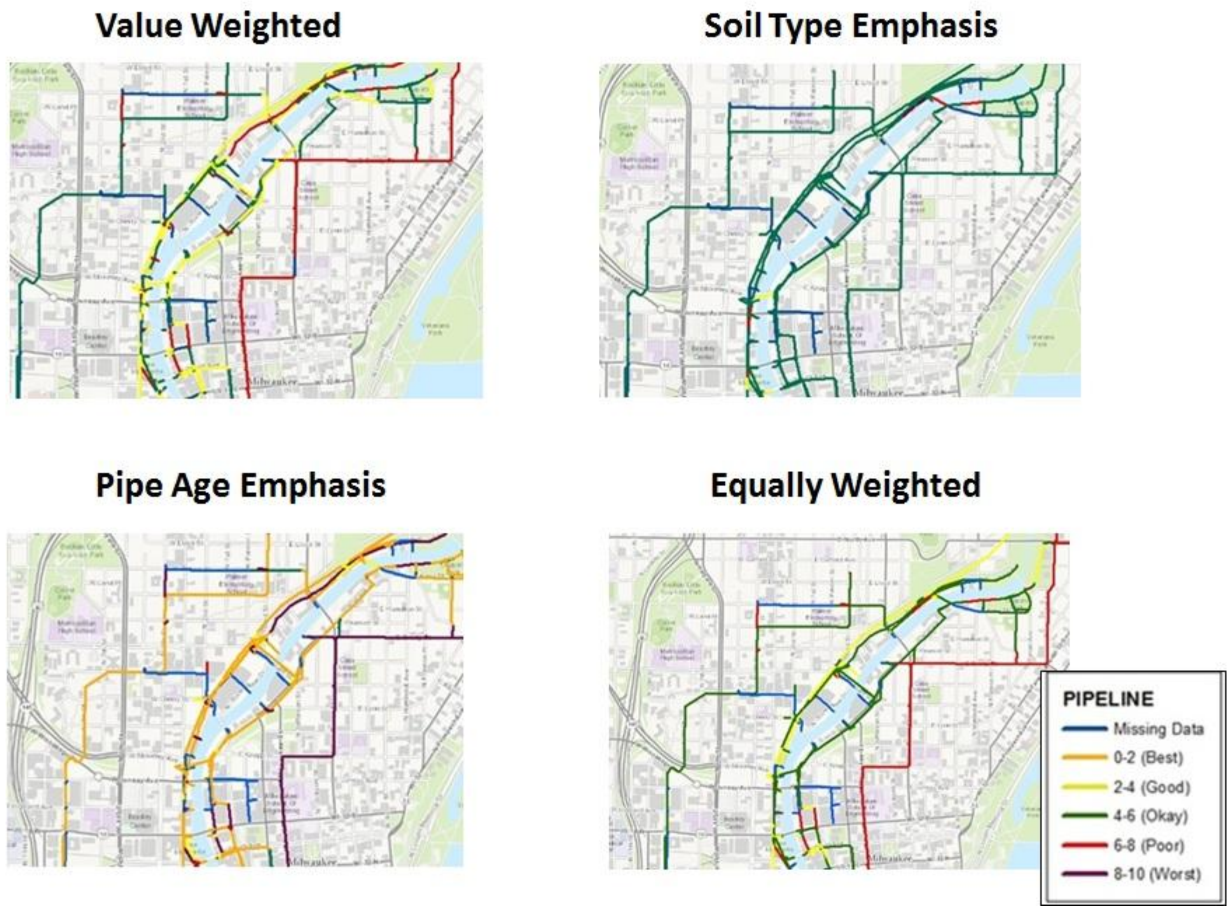

Figure ***12***.

As shown, the emphasis of the weighted values does affect the final results. For example, Figure 12 shows the sewer on the east (right) side of the map is in poor to worst condition for the value weighted, pipe age emphasis and equally weighted. However, for soil type emphasis, the sewer is in okay condition. This difference shows that the while the sewer is probably very susceptible to I&I problems, the reason for the susceptibility is not the soil type.

The variation in results demonstrates the importance of properly weighting the different parameters. In addition, these results also show the flexibility weighting different parameters to fit a specific system.

Table 5. Weighted Values for the Comparison Analysis

	Value Weighted*	**Soil Type Emphasis**	**Pipe Age Emphasis**	**Equally Weighted**
Pipe Age	0.3	0.1	0.6	0.2
Empirical Value	0.05	0.1	0.1	0.2
Sewer Type	0.2	0.1	0.1	0.2

Subsystem	0.15	0.1	0.1	0.2
Soil type	0.3	0.6	0.1	0.2

*The value weighted column has the same values as described in Table 3, and then has the same results.

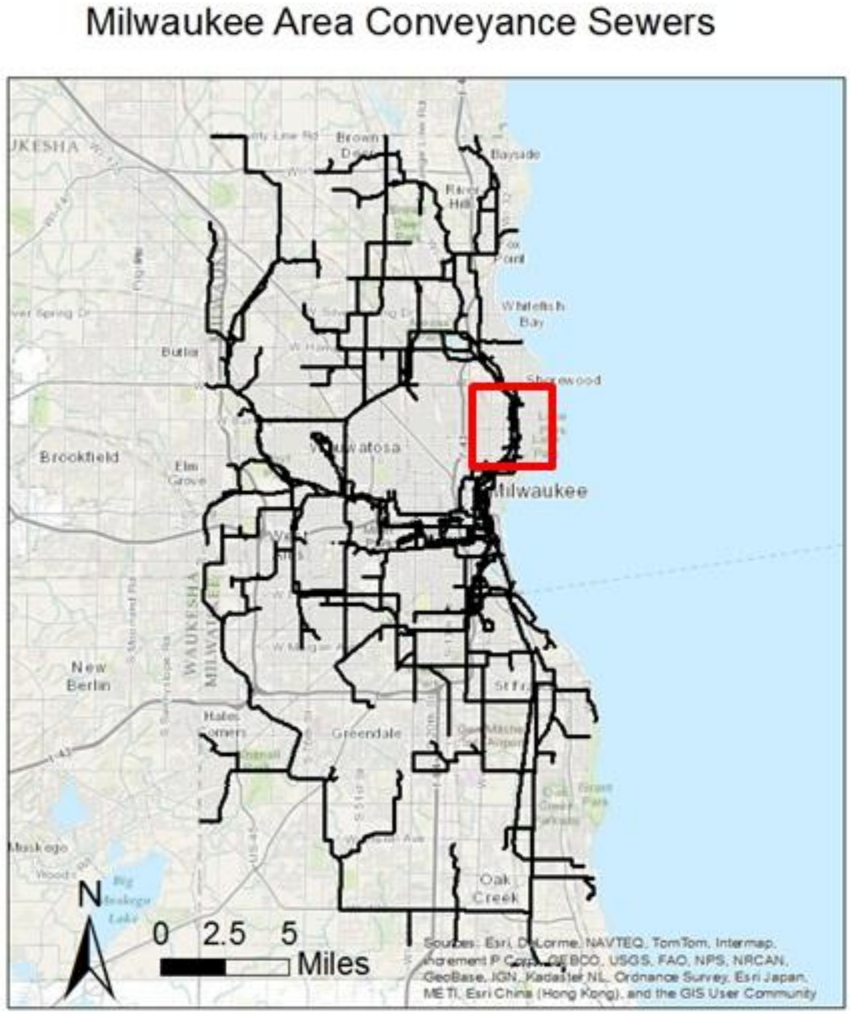

Figure 11. *The red box shows the area pictured in Figure 12.*

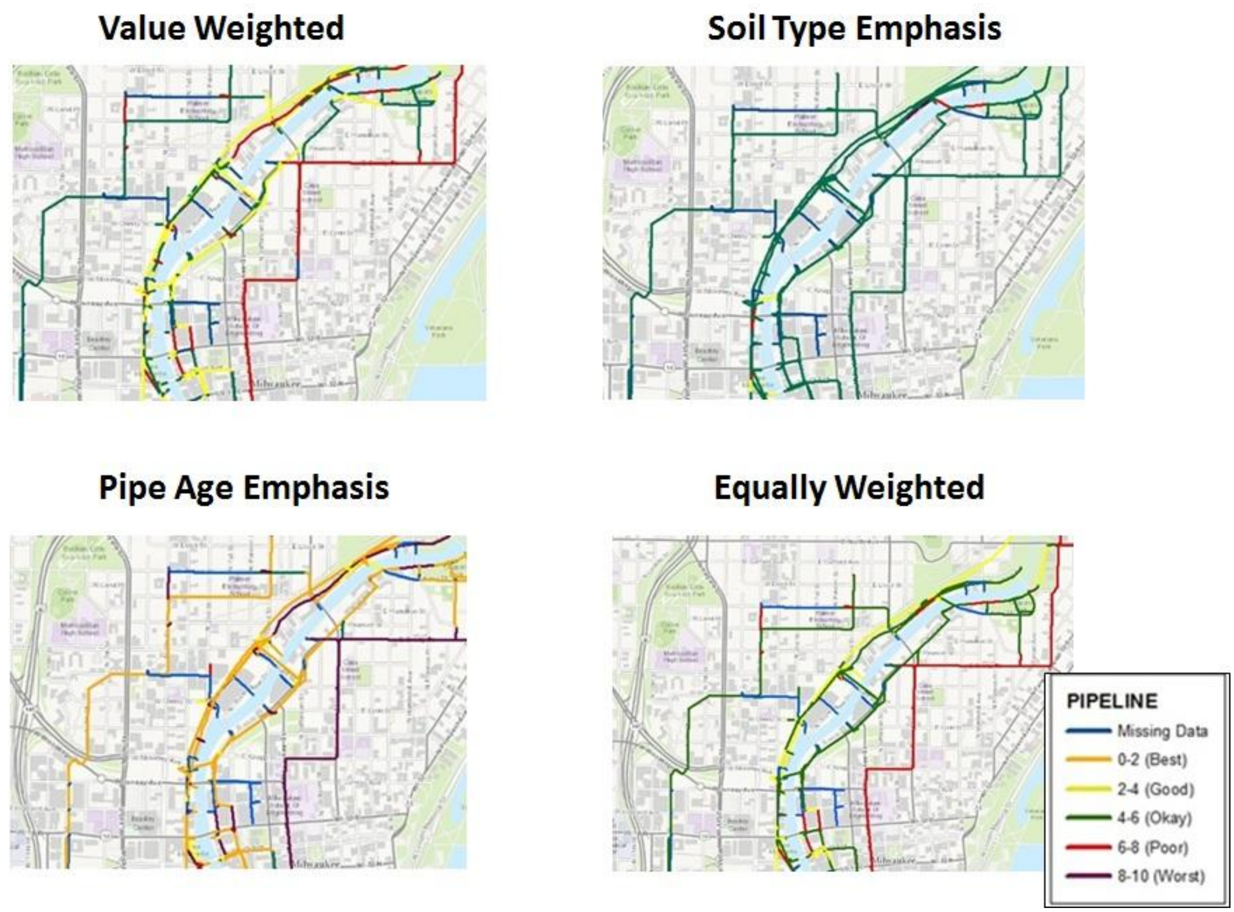

Figure 12. *Comparison using a specific area Milwaukee.*

VI. Conclusion

A. Importance of GIS

GIS was an essential part of my project for many reasons. First, much of the needed data was found in a feature class. It was much easier to extract data from a feature class than to sort through hundreds of maps to gather the needed data. In addition, through GIS, I could project the MMSD's sewers onto the different hydrologic soils to determine which sections of pipe were in the areas of highest soil infiltration. Third, GIS provides an excellent visual tool of the data. When determining the approximate locations of worst I&I, it is much easier to look at a map than to read through large amounts of data.

B. Final Notes and Future Work

The combination of GIS and the Excel spreadsheet provide a starting point for determining areas of highest I&I. The current analysis is only for the MMSD's sewers; however, the analysis could easily be broadened to compare the pipe conditions of the different cities within the MMSD. While doing the analysis, it is important to remember that the results should only be used as a starting point for analysis.

If future work would to happen, the next step would be using cameras to estimate levels of I&I for various pipes throughout the area, and then compare the actual values to the suggested areas of highest I&I from the spreadsheet. This field data could then be compared to the actual values suggested in the highest I&I regions indicated by spreadsheet model analysis.

Works Cited

[1] *Milwaukee Metropolitan Sewerage District*. Milwaukee Metropolitan Sewerage District, n.d. Web. 28 Oct. 2012. <http://www.mmsd.com>.

[2] "Tackling Inflow/Infiltration in Sanitary Sewers." Metropolitan Council, 11 Aug. 2011. Web. 29 Oct. 2012. <http://www.metrocouncil.org/directions/water/water2007/InflowInfiltrationDec07.htm>.

[3] Chughtai, Fazal, and Tarek Zayad. "Sewer Pipeline Operational Condition Prediction Using Multiple Regression." *Pipelines: Advances and Experiences with Trenchless Pipeline Projects* (2007). *American Society of Civil Engineers*. Web. 29 Oct. 2012.

[4] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for [Milwaukee and Waukesha Counties, WI]. Available online at http://soildatamart.nrcs.usda.gov. Accessed [10/31/2012].

Appendix A: Excel Spreadsheet Directions

A detailed explanation of the I&I spreadsheet is below. Following the instructions are images of the weighted values tab and the main spreadsheet.

1. In the weighted values tab, determine the values you want to assign to the different components of a parameter. The values range from 1 to 10, with 10 being the worst and 1 being the best. For example, you may decide that you have seen more conveyance problems with subsystem 1 rather than subsystem 2, so you could weight subsystem 1 as a ‘7’ and subsystem 2 has a ‘4’.
2. Go back to the main excel worksheet. Enter the pipe segment identification. (For this analysis, the Main Group Number was used). Then, enter the parameters for each pipe segment. For example, for pipe segment P10, enter the pipe age as 41, the sewer type as 5, etc… This step can easily be done by copying and pasting data from the GIS attributes tables.
3. At the top left corner of the main tab, enter the weighted value you want each parameter to have. The sum of the parameters should add up to 1. For example you could have:
   Pipe Age: 0.3
   Empirical Value: 0.05
   Sewer Type: 0.15
   Subsystem 0.2
   Soil Type: 0.3
   Total = 1

   The following distribution would not work, because the total value does not add up to one.
   Pipe Age: 0.4
   Empirical Value: 0.05
   Sewer Type: 0.15
   Subsystem 0.2
   Soil Type: 0.35
   Total = 1.15

4. Compare the different total values (blue column) for the different pipe segments. These final values range from zero to ten. Pipes segments with a ten are predicted to be in the worst condition while pipe segments with a value of one are predicted to be in the best conditions.
5. A suggested method for analysis is uploading these values back into GIS, so that the different values can be displayed on a map.

Individual Parameter Values Tab

Pipe Age	Value	Emperical	Value	Sewer Type	Value	Subsystem	Value
1 to 10	0	0	0	Clearwater	1	1	5
11 to 20	1	1	10	CSO	1	2	5
21 to 30	2	2	9	ISP	8	3	5
31 to 40	3	3	8	ISS	0	4	5
41 to 50	4	4	7	MIS	8	5	5
51 to 60	5	5	6	NSC	5	6	5
61 to 70	6	6	5	SSFM	8	7	4
71 to 80	7	7	4	RS	0	8	4
81 to 90	8	8	3			9	4
91 to 100	9	9	2				
100+	10	10	1				

Portion of main spreadsheet.

Weighted Portions	
Pipe Age	0.3
Emperical Value	0.05
Sewer Type	0.15
Subsystem	0.2
Soil Type	0.3

														Soils		
MAIN_NR	Pipe Age	Value	Weighted Val.	Emperical No.	Value	Weighted Val.	Sewer Type	Type	Value	Weighted Val.	Subsystem	Value	Weighted Val.	Type	Weighted Val.	TOTAL
P10	41	4	1.2	3.96	7	0.35	5	MIS	8	1.2	4	5	1	5	1.5	5.25
P100	79	7	2.1	5.59	5	0.25	5	MIS	8	1.2	5	5	1	4	1.2	5.8
P1000	0	0	0	5.58	5	0.25	5	MIS	8	1.2	0	0	0	5	1.5	0.0
P10000	31	3	0.9	3.34	7	0.35	5	MIS	8	1.2	2	5	1	4.25	1.3	4.7

Appendix B: Individual Parameter Values

Below is an explanation for the individual value that were used in this analysis. These values can be changed for future analysis, if needed.

<u>A.Pipe Age</u>

Pipe Age	Value
1 to 10	0
11 to 20	1
21 to 30	2
31 to 40	3
41 to 50	4
51 to 60	5
61 to 70	6
71 to 80	7
81 to 90	8
91 to 100	9
100+	10

The pipe age value is the first digit of the two digit pipe age. For example, a pipe age of 52 would have a value of 5, since 5 is the first digit in the pipe age. This is a simplistic, yet consistent way to adjust pipe age to values.

<u>B.Empirical Value</u>

Empirical	Value
0	0
1	10
2	9
3	8
4	7
5	6
6	5
7	4
8	3
9	2
10	1

The empirical value was designed so the smaller the value, the worse of a pipe operating condition. Therefore, as the empirical value increased, the value used for future calculations decreased.

C.Soil Classification

Soil Group	Value
A	10
B	7
C	3
D	1
Downtown Area	5

Soils with a hydrologic soil group of A have the most infiltration, so they were assigned the highest value because the more infiltration the soil allows, the more water there is flowing through the soil that can infiltrate into the pipe. Soils with a hydrologic soil group of D have the least infiltration, so they have the lowest value of 1. Soil groups B and C are values in-between the 10 and 1. Soil data was available for downtown Milwaukee, and so a value of 5 was assumed. Because the majority of soil surrounding the Milwaukee area has hydrologic soil groups of A or B, the soil in Milwaukee is probably in hydrologic soil groups A and B. However, Milwaukee has lots of impervious areas due to roads and buildings. Impervious surfaces allow minimal infiltration into the soil, producing a value around 1 or 2. An average was taken between probably soil groups and imperious surfaces to produce the value of 5.

D.Sewer Type

Sewer Type	Value
Clearwater	1
CSO	1
ISP	8
ISS	0
MIS	8
NSC	5
SSFM	8
RS	0

Remote storage (RS) and inline storage system (ISS) were given values of zero because it would not be economical to fix any I&I into those sections of the conveyance system. The clearwater and combined sewer overflows (CSO) were given values of one. Because CSO's discharge water into the river, any I&I into a CSO will be exiting the conveyance system momentarily, and will not need to be treated. The near surface collectors were given a value of 5, showing they should be taken into consideration. Yet, they are still not as important as the ISP and MIS, which are given a value of 8.

<u>E.Sewer Subsystem</u>

Subsystem	Value
1	5
2	5
3	5
4	5
5	5
6	5
7	4
8	4
9	4

Subsystems 1 through 6, which generally are separated sewers were given a slightly higher value than subsystems 7-9, the combined sewers. This is because the combined sewers already have rainwater entering the systems. However, because this argument could easily be changed, the difference in values is only one.