



KERR WOOD LEIDAL
consulting engineers

Appendix H

Risk Matrix



Appendix H – Risk Matrix and Prioritization

Contents

E. Risk Matrix and Prioritization H-1

Tables

Table E-1: Likelihood of Failure (LoF) for Pipe Capacity H-2
Table E-2: Consequence of Failure (CoF) for Pipe Capacity H-3
Table E-3: Pipe Age Score (PAS) H-3
Table E-4: Pipe Condition Modifier (CM) Score..... H-4
Table E-5: Final Risk Prioritization Scores and Ranking H-4



Appendix H – Risk Matrix and Prioritization

H. Risk Matrix and Prioritization

The capital plan risk matrix was developed to include all trunk storm sewers requiring upgrade, with the greatest risk score assigned to pipes with a “very poor” pipe condition. Pipe age and condition data was provided by the City. Additional attributes used to evaluate and determine the risk of each pipe included:

- pipe level of service: minor or major drainage system;
- pipe condition assessment;
- lifespan: pipe life expectancy for pipe material; and
- pipe conveyance capacity: system failure, flooding, surcharging, and backwatering during various design storm model simulations.

The risk prioritization ranking matrix included the following categories:

- pipe age score (PAS) for the current year (2022);
- likelihood of failure (LoF) for conveyance capacity;
- consequence of failure (CoF) for conveyance capacity (flood, surcharge, and backwatering risk), for both existing and future scenarios;
- pipe condition modifier (CM) applies the pipe condition rankings provided by the City; and
- Major system consequence modifier, which augments the consequence rating by 1 for major system pipes and culverts.

Each trunk storm sewer was assigned a score in each category. For LoF, CoF, and PAS, each pipe was assigned a score between 1-5 for each category. The criteria for scoring the LoF can be found in Table H-1. The criteria for CoF scoring can be found in Table H-2. The criteria for PAS scoring can be found in Table H-3.



Appendix H – Risk Matrix and Prioritization

Table H-1: Likelihood of Failure (LoF) for Pipe Capacity

Likelihood Score	Description	PAS(% of Service Life in current year)	Inspection Condition(NAMS)	Capacity
5	Highly Likely (already occurring)	>130%	Very Poor	Road Surface Surcharge
4	Likely	110% to 130%	Poor	Surcharges (above crown - below road surface)
3	Possible	90% to 110%	Fair	Surcharges (above crown)
2	Unlikely	70-90%	Good	q/Q 80 to 100%
1	Never (extremely unlikely)	<70%	Very Good	Pipes - q/Q <80%



Appendix H – Risk Matrix and Prioritization

Table H-2: Consequence of Failure (CoF) for Pipe Capacity

Consequence Score	Description	Infrastructure damage	Length of Flooding time
5	Catastrophic	Road Wash Out; Culvert Collapse; Complete infrastructure failure	>60min
4	Major	Load Restrictions or road closure required until failing pipe or culvert replaced	30-60min
3	Moderate	Flooding inundates roadway; Significant sinkhole, regular road closures, repair required.	15-30min
2	Minor	Nuisance Road Flooding; Structure still in place and pipe is functioning, a single pothole or sinkhole may be observed.	<15min
1	Insignificant	No damage to infrastructure	No Flooding
+1	Major System Modifier	Add +1 to CoF Score for all components of major system	

Table H-3: Pipe Age Score (PAS)

Score	Percent of Service Life
5	>130%
4	1100% to 130%
3	90% to 110%
2	70% to 90%
1	<70%

The scores for the pipe condition modifier (CM) ranged from 1 to 5 as shown in Table H-4. The Condition modifier supersedes the likelihood of failure if it indicates higher likelihood of failure than the capacity.



Appendix H – Risk Matrix and Prioritization

Table H-4: Pipe Condition Modifier (CM) Score

Modifier Value	NAMS Pipe Condition
5	Very Poor
4	Poor
3	Fair
2	Good
1	Very Good

The next step was to calculate the final risk score, with all categories applied. An existing and future risk score were both calculated using the corresponding categories. The final risk score was determined using the following equation:

$$Risk\ Score = Max(LoF, CM) \times CoF$$

The final risk score ranging from 0 to 25 was then calculated for each pipe. Higher scores for the final risk score correspond to a greater priority for pipe upgrades.

All trunk storm sewers requiring upgrade were sorted into capital project groups based on location and connectivity. Pipes connected and in close proximity to each other were categorized into the same project group. The existing final risk score for each project group was determined by the pipe with the highest risk score in the group. A total project group score was also determined by adding together all the risk scores of each individual project group. The prioritization ranking was then determined by first the highest group score and in the case of a tie, the total group score.

Culverts were ranked individually and not grouped into projects as they are separate pieces of infrastructure and not connected in series as are sewer pipes. Therefore each culvert is a project and culverts have a project group total score that is the same as the risk score. Culverts all have a group project ID that starts with 'C'.

Table H-5: Final Risk Prioritization Scores and Ranking

Group	Highest Risk Score	Total Group Risk Score	Ranking	Pipe IDs in Group
CA	25	25	1	DCUL0001
CAO	24	24	2	DCUL0240
AT	20	98	3	DMAIN-38-0703, DMAIN-38-0704, DMAIN-38-0705, DMAIN-38-0706, DMAIN-38-0707, DMAIN-38-0708, DMAIN-38-0709, DMAIN-38-0710, DMAIN-38-0711, DMAIN-38-0712, DMAIN-38-2037
J	20	65	4	DMAIN-9-0001, DMAIN-9-0002, DMAIN-9-0003, DMAIN-9-0010, DMAIN-9-0011, DMAIN-9-0022
CP	20	20	5	DCUL0024_1
CQ	20	20	6	DCUL0024_2



Appendix H – Risk Matrix and Prioritization

CB	18	18	7	DCUL0002
CD	18	18	8	DCUL0006
CF	18	18	9	DCUL0014
CL	18	18	10	DCUL0020
CT	18	18	11	DCUL0046
CY	18	18	12	DCUL0162
CAB	18	18	13	DCUL0186
CAM	18	18	14	DCUL0237
CAV	18	18	15	DCUL0369
CBM	18	18	16	DCUL0618
BD	15	39	17	DMAIN-38-1033, DMAIN-38-2010, DMAIN-38-2011, DMAIN-38-2012
CC	15	15	18	DCUL0003
CK	15	15	19	DCUL0019
CAH	15	15	20	DCUL0218
CAK	15	15	21	DCUL0235
CAS	15	15	22	DCUL0351
Q	12	707	23	DMAIN-14-0001, DMAIN-14-0002, DMAIN-14-0003, DMAIN-14-0004, DMAIN-14-0005_1, DMAIN-14-0005_2, DMAIN-14-0006, DMAIN-14-0007_1, DMAIN-14-0007_2, DMAIN-14-0008, DMAIN-14-0009, DMAIN-14-0010, DMAIN-14-0012, DMAIN-14-0013, DMAIN-14-0014, DMAIN-14-0015, DMAIN-14-0016, DMAIN-14-0018, DMAIN-14-0019, DMAIN-14-0020, DMAIN-14-0023, DMAIN-14-0024, DMAIN-14-0025, DMAIN-14-0026, DMAIN-14-0027, DMAIN-14-0028, DMAIN-14-0029, DMAIN-14-0030, DMAIN-14-0033, DMAIN-14-0051, DMAIN-14-0052, DMAIN-14-0053, DMAIN-14-0058, DMAIN-14-0059, DMAIN-14-0062, DMAIN-14-0063, DMAIN-14-0070, DMAIN-14-0071, DMAIN-14-0083, DMAIN-14-0084, DMAIN-14-0085, DMAIN-14-0086, DMAIN-14-0087, DMAIN-14-0097, DMAIN-14-0098, DMAIN-14-0099, DMAIN-14-0100, DMAIN-14-0102, DMAIN-14-0102A, DMAIN-14-0106, DMAIN-14-0107, DMAIN-14-0108, DMAIN-14-0109, DMAIN-14-0110, DMAIN-14-0111, DMAIN-14-0112, DMAIN-14-0113, DMAIN-14-0114, DMAIN-14-0121, DMAIN-14-0122, DMAIN-14-0127, DMAIN-14-0128, DMAIN-14-0129, DMAIN-14-0130, DMAIN-14-0133, DMAIN-14-0134, DMAIN-14-0135, DMAIN-14-0136, DMAIN-14-0137, DMAIN-14-0140, DMAIN-14-0141, DMAIN-14-0142, DMAIN-14-0143, DMAIN-14-0173, DMAIN-14-0187, DMAIN-14-0188, DMAIN-14-0190, DMAIN-14-0198, DMAIN-14-0202
W	12	196	24	DMAIN-2-0001, DMAIN-2-0003, DMAIN-2-0004, DMAIN-2-0010, DMAIN-2-0011, DMAIN-2-0012, DMAIN-2-0013, DMAIN-2-0044, DMAIN-2-0047, DMAIN-2-0049, DMAIN-2-0050, DMAIN-2-0059, DMAIN-2-0064, DMAIN-2-0065, DMAIN-2-0066, DMAIN-2-0067, DMAIN-2-0068, DMAIN-2-0070, DMAIN-2-0072, DMAIN-2-0073, DMAIN-2-0074, DMAIN-2-0083
AV	12	192	25	DMAIN-31-0010, DMAIN-31-0011, DMAIN-31-0012, DMAIN-31-0013, DMAIN-31-0014, DMAIN-31-0015, DMAIN-31-0016, DMAIN-31-0017, DMAIN-31-0018, DMAIN-31-0019, DMAIN-31-0020, DMAIN-31-0021,



Appendix H – Risk Matrix and Prioritization

				DMAIN-31-0193, DMAIN-31-0224, DMAIN-31-0227, DMAIN-31-0228, DMAIN-31-0230, DMAIN-31-0231, DMAIN-31-0232, DMAIN-31-0321, DMAIN-31-0348, DMAIN-31-0369, DMAIN-31-0374, DMAIN-31-0375
AY	12	164	26	DMAIN-30-0001, DMAIN-30-0002, DMAIN-30-0003, DMAIN-30-0004, DMAIN-30-0005, DMAIN-30-0006, DMAIN-30-0007, DMAIN-30-0008, DMAIN-30-0009, DMAIN-30-0034, DMAIN-30-0035, DMAIN-30-0036, DMAIN-30-0048, DMAIN-30-0049, DMAIN-30-0050, DMAIN-30-0051, DMAIN-30-0052, DMAIN-30-0053, DMAIN-30-0067, DMAIN-30-0068, DMAIN-30-1041
C	12	163	27	DMAIN-15-0001, DMAIN-15-0002, DMAIN-15-0004, DMAIN-15-0005-1, DMAIN-15-0005-2, DMAIN-15-0006, DMAIN-15-0007, DMAIN-15-0008, DMAIN-15-0009, DMAIN-15-0010, DMAIN-15-0011, DMAIN-15-0012, DMAIN-15-0013, DMAIN-15-0014, DMAIN-15-0057, DMAIN-15-0117, DMAIN-15-0125
T	12	156	28	DMAIN-4-0001, DMAIN-4-0002, DMAIN-4-0003, DMAIN-4-0004, DMAIN-4-0007, DMAIN-4-0009, DMAIN-4-0011, DMAIN-4-0012, DMAIN-4-0013, DMAIN-4-0014, DMAIN-4-0088, DMAIN-4-0110, DMAIN-4-0111, DMAIN-4-0112, DMAIN-4-0113, DMAIN-4-0114, DMAIN-4-0142, DMAIN-4-0198, DMAIN-4-0202
D	12	90	29	DMAIN-16-0001, DMAIN-16-0002, DMAIN-16-0003, DMAIN-16-0004_1, DMAIN-16-0004_2, DMAIN-16-0005, DMAIN-16-0006, DMAIN-16-0007, DMAIN-16-0008, DMAIN-16-0009, DMAIN-16-0055
E	12	90	30	DMAIN-17-0001, DMAIN-17-0004, DMAIN-17-0005, DMAIN-17-0007, DMAIN-17-0008, DMAIN-17-0009, DMAIN-17-0018, DMAIN-17-0069, DMAIN-17-0076
F	12	90	31	DMAIN-10-0001, DMAIN-10-0002-1, DMAIN-10-0002-2, DMAIN-10-0003, DMAIN-10-0004, DMAIN-10-0005, DMAIN-10-0006, DMAIN-10-0007, DMAIN-10-0008, DMAIN-10-0009, DMAIN-10-0041
Z	12	78	32	DMAIN-50-0001, DMAIN-50-0002, DMAIN-50-0003, DMAIN-50-0004, DMAIN-50-0005, DMAIN-50-0010, DMAIN-50-0011, DMAIN-50-0050, DMAIN-50-0051, DMAIN-50-0052, DMAIN-50-0053
AZ	12	59	33	DMAIN-30-0121, DMAIN-30-0122, DMAIN-30-0123, DMAIN-30-0125, DMAIN-30-0126, DMAIN-30-0127, DMAIN-30-0128, DMAIN-30-0129, DMAIN-30-0130
U	12	59	34	DMAIN-3-0007, DMAIN-3-0008, DMAIN-3-0009, DMAIN-3-0028, DMAIN-3-0037, DMAIN-3-0041, DMAIN-3-0043
A	12	56	35	DMAIN-20-0018, DMAIN-20-0029, DMAIN-20-0030, DMAIN-20-0033, DMAIN-20-0034, DMAIN-20-0047
V	12	52	36	DMAIN-13-0001, DMAIN-13-0002, DMAIN-13-0003, DMAIN-13-0004_1, DMAIN-13-0004_2, DMAIN-13-0005
O	12	48	37	DMAIN-22-0915, DMAIN-22-0926, DMAIN-22-0927, DMAIN-22-0928
S	12	48	38	DMAIN-5-0002, DMAIN-5-0003, DMAIN-5-0004, DMAIN-5-0146, DMAIN-5-0147
AX	12	42	39	DMAIN-31-0258, DMAIN-31-0259, DMAIN-31-0260, DMAIN-31-0265, DMAIN-31-0368
AF	12	36	40	DMAIN-36-0046, DMAIN-36-0047, DMAIN-36-0048, DMAIN-36-0049



Appendix H – Risk Matrix and Prioritization

N	12	32	41	DMAIN-22-0920, DMAIN-22-0921, DMAIN-22-0922
AO	12	28	42	DMAIN-38-0323, DMAIN-38-0324, DMAIN-38-0325, DMAIN-38-0326
AA	12	26	43	DMAIN-21-0001, DMAIN-21-0002, DMAIN-21-0003
AQ	12	20	44	DMAIN-38-0200, DMAIN-38-0201
CI	12	12	45	DCUL0017
CJ	12	12	46	DCUL0018
CM	12	12	47	DCUL0021
CO	12	12	48	DCUL0023
CAJ	12	12	49	DCUL0234
CAL	12	12	50	DCUL0236
CAN	12	12	51	DCUL0238
CAW	12	12	52	DCUL0420
CBC	12	12	53	DCUL0583
CBE	12	12	54	DCUL0590
CBG	12	12	55	DCUL0593
CBI	12	12	56	DCUL0612_1
CBJ	12	12	57	DCUL0612_2
CBS	12	12	58	DCUL0654
AE	9	70	59	DMAIN-34-0002, DMAIN-34-0003, DMAIN-34-0005, DMAIN-34-0006, DMAIN-34-0007, DMAIN-34-0008, DMAIN-34-0010, DMAIN-34-0012, DMAIN-34-0015, DMAIN-34-0159, DMAIN-34-0161, DMAIN-34-0162, DMAIN-34-0163, DMAIN-34-0164, DMAIN-34-0174, DMAIN-34-0176
CR	9	9	60	DCUL0041
CAP	9	9	61	DCUL0253
CAQ	9	9	62	DCUL0347
CAU	9	9	63	DCUL0368
CBA	9	9	64	DCUL0581
CBD	9	9	65	DCUL0589
CBF	9	9	66	DCUL0591
AB	8	73	67	DMAIN-35-0019, DMAIN-35-0022, DMAIN-35-0023, DMAIN-35-0024, DMAIN-35-0034, DMAIN-35-0035, DMAIN-35-0057, DMAIN-35-0059, DMAIN-35-0063, DMAIN-35-0066, DMAIN-35-0067, DMAIN-35-0069, DMAIN-35-0070, DMAIN-35-0080
AL	8	66	68	DMAIN-36-0001, DMAIN-36-0002, DMAIN-36-0003, DMAIN-36-0004, DMAIN-36-0005, DMAIN-36-0006, DMAIN-36-0007, DMAIN-36-0008, DMAIN-36-0009



Appendix H – Risk Matrix and Prioritization

B	8	58	69	DMAIN-18-0001, DMAIN-18-0003, DMAIN-18-0004, DMAIN-18-0008, DMAIN-18-0009, DMAIN-18-0010, DMAIN-18-0011, DMAIN-18-0012, DMAIN-18-0014, DMAIN-18-0052, DMAIN-18-0061
L	8	52	70	DMAIN-7-0001, DMAIN-7-0002, DMAIN-7-0003, DMAIN-7-0004, DMAIN-7-0005, DMAIN-7-0006, DMAIN-7-0007
AS	8	51	71	DMAIN-38-0403, DMAIN-38-0404, DMAIN-38-0405, DMAIN-38-0412, DMAIN-38-0413, DMAIN-38-0414, DMAIN-38-0416_1, DMAIN-38-0416_2, DMAIN-38-0418, DMAIN-38-0419, DMAIN-38-2033, DMAIN-38-2051, DMAIN-38-2052, DMAIN-38-2058
AH	8	49	72	DITC-0729, DITC-0729_2, DMAIN-31-0286, DMAIN-31-0289, DMAIN-31-0289_2, DMAIN-31-0290, DMAIN-31-0304, DMAIN-31-0305, DMAIN-31-0312, DMAIN-31-0360
X	8	48	73	DMAIN-1-0001_1, DMAIN-1-0001_2, DMAIN-1-0003, DMAIN-1-0004, DMAIN-1-0012, DMAIN-1-0013, DMAIN-1-0014
M	8	40	74	DMAIN-6-0001, DMAIN-6-0002, DMAIN-6-0003, DMAIN-6-0014, DMAIN-6-0030
P	8	40	75	DMAIN-45-0008, DMAIN-45-0010, DMAIN-45-0016, DMAIN-45-0017, DMAIN-45-0018, DMAIN-45-0020
AP	8	38	76	DMAIN-38-0300, DMAIN-38-0301, DMAIN-38-0302, DMAIN-38-0307, DMAIN-38-2092, DMAIN-38-2093
AG	8	32	77	DMAIN-34-0022, DMAIN-34-0023, DMAIN-34-0024, DMAIN-34-0136
AM	8	28	78	DMAIN-43-0001, DMAIN-43-0002, DMAIN-43-0003, DMAIN-43-0004, DMAIN-43-0005
H	8	24	79	DMAIN-11-0001, DMAIN-11-0002, DMAIN-11-0003, DMAIN-11-0004
Y	8	24	80	DMAIN-23-0002, DMAIN-23-0003, DMAIN-23-0008, DMAIN-23-0035
K	8	20	81	DMAIN-8-0001, DMAIN-8-0002, DMAIN-8-0003
AD	6	58	82	DMAIN-34-0046, DMAIN-34-0049, DMAIN-34-0051, DMAIN-34-0052, DMAIN-34-0053, DMAIN-34-0054, DMAIN-34-0055, DMAIN-34-0056, DMAIN-34-0057, DMAIN-34-0058, DMAIN-34-0059, DMAIN-34-0060, DMAIN-34-0065, DMAIN-34-0068, DMAIN-34-0069, DMAIN-34-0070
BB	6	13	83	DMAIN-38-2081, DMAIN-38-2082, DMAIN-38-2083
AW	6	10	84	DMAIN-31-0376, DMAIN-31-0381
CS	6	6	85	DCUL0045
CAI	6	6	86	DCUL0231
CAZ	6	6	87	DCUL0536
AN	4	34	88	DMAIN-52-0170, DMAIN-52-0171, DMAIN-52-0172, DMAIN-52-0173, DMAIN-52-0174, DMAIN-52-0175, DMAIN-52-0176, DMAIN-52-0180, DMAIN-52-0181, DMAIN-52-0182, DMAIN-52-0183, DMAIN-52-0184, DMAIN-52-0186, DMAIN-52-0187
I	4	8	89	DMAIN-12-0001, DMAIN-12-0002
AK	4	4	90	DMAIN-31-0118



Appendix H – Risk Matrix and Prioritization

CE	4	4	91	DCUL0013
CG	4	4	92	DCUL0015
CH	4	4	93	DCUL0016
CN	4	4	94	DCUL0022
CZ	4	4	95	DCUL0168
CAC	4	4	96	DCUL0187
CAD	4	4	97	DCUL0188
CAE	4	4	98	DCUL0193
CAF	4	4	99	DCUL0203
CAT	4	4	100	DCUL0357
CAX	4	4	101	DCUL0438
CBB	4	4	102	DCUL0582
CBH	4	4	103	DCUL0598
CBK	4	4	104	DCUL0613
CBL	4	4	105	DCUL0617
CBN	4	4	106	DCUL0623
CBO	4	4	107	DCUL0624
CBR	4	4	108	DCUL0639
CBX	4	4	109	DCUL0673
CBW	4	4	110	DCUL0698
CBY	4	4	111	DCUL0699
CCA	4	4	112	DCUL0751
CCB	4	4	113	DCUL0752
CCC	4	4	114	DCUL0753
CCD	4	4	115	DCUL0754
CCE	4	4	116	DCUL0755
CCF	4	4	117	DCUL0756
CCG	4	4	118	DCUL0757
CCH	4	4	119	DCUL0758
CCI	4	4	120	DCUL0759
CCJ	4	4	121	DCUL0760
CCK	4	4	122	DCUL0761



Appendix H – Risk Matrix and Prioritization

CCL	4	4	123	DCUL0762
CCM	4	4	124	DCUL0763
AI	3	15	125	DMAIN-31-0039, DMAIN-31-0048_1, DMAIN-31-0048_2, DMAIN-31-0049, DMAIN-31-0053
BA	3	9	126	DMAIN-38-2067, DMAIN-38-2068, DMAIN-38-2069
BC	3	9	127	DMAIN-38-2062, DMAIN-38-2063, DMAIN-38-2063_2
AJ	3	6	128	DMAIN-31-0074, DMAIN-31-0077
CU	2	2	129	DCUL0132
CV	2	2	130	DCUL0133
CX	2	2	131	DCUL0134
CAA	2	2	132	DCUL0184
CAG	2	2	133	DCUL0205
CAR	2	2	134	DCUL0348
CAY	2	2	135	DCUL0535
CBP	2	2	136	DCUL0633
CBQ	2	2	137	DCUL0634
CBT	2	2	138	DCUL0657
CBU	2	2	139	DCUL0659
CBZ	2	2	140	DCUL0733