

Madison County, Kentucky
Madison County Emergency Response
Wet Fiber Hydraulic Analysis
February 2022

Project Scope:

The Madison County Fiscal Court (County) enlisted the help of HMB Professional Engineers, Inc. (HMB) to analyze the impact of the proposed wet fiber line would have upon existing water distribution systems for the Madison County Utilities District and Kirksville Water Association.

Project Area:

The proposed installation will occur in the following areas:

For Madison County Utilities District, the installation begins near the intersection of N. Keeneland Drive and US Highway 25 (Lexington Road), then runs parallel to US Highway 25 heading in northerly direction approximately 39,150 feet to a point of ending near the intersection of US Highway 25 and Interstate Drive.

For the Kirksville Water Association, the installation consists of two sections.

The first section begins near the intersection of KY 169 (Tates Creek Road) and Goggins Lane, then runs parallel to KY 169 (Tates Creek Road) in a north-westerly direction approximately 30,200 feet to a point near the intersection of KY 169 (Tates Creek Road) and KY 1985 (Whitlock Road), then in a westerly direction running parallel to KY 1985 (Whitlock Road) approximately 3,200 feet to a point of ending adjacent to KY 1985 (Whitlock Road).

The second section begins approximately 2,600 feet in a westerly direction from the point of ending of the first section adjacent to KY 1985 (Whitlock Road), then runs parallel to KY 1985 (Whitlock Road) for a distance of approximately 3,285 feet to the intersection of KY 1985 (Whitlock Road) and Jackson Branch Road, then continues running parallel to Jackson Branch Road in a southern direction for approximately 7,177 feet to the intersection of Jackson Branch Road and KY 1984 (Maple Grove Road), then continues in a westerly direction generally parallel to KY 1984 (Maple Grove Road) for a distance of approximately 3,246 to a point of ending.

Analysis:

The addition of a wet fiber line to the existing distribution system has the potential to adversely affect the water distribution systems of the Madison County Utilities District and Kirksville Water Association.

This report will identify the potential impacts as well as the magnitude of those impacts. Impacts can be broken into two categories, short term impacts and long-term impacts.

Short Term Impacts:

Those impacts which are experienced in the short term consist of interruptions of service and boiled water advisories. The installation process of the wet fiber line is demonstrated in, Attachment A: *CRALEY Fiber Quick Install Guide*. In the referenced guidance document installation of the fiber carrier pipe requires the existing water mains to be closed and opened again three times before the carrier pipe installation is complete. Upon opening the flow through the existing water main for the third time the water main will need to be flushed to remove as much contamination as possible. The fiber installation process, while an inconvenience to water customers, results in the same disinfection, flushing, and boiled water advisories that are required for any connection or main break repair and is commonplace with distribution system daily maintenance.

Long Term Impacts:

The impact expected in the long term is reduced water service in the form of lower pressure because of a decreased cross-sectional area and the increase of frictional impact from the introduction of an additional pipe within the existing water main. In order to determine how much of an impact, the proposed fiber carrier pipe would inflict upon the water distribution system the Darcy-Weisbach Equation was utilized (*see Equation 1 below*).

Equation 1

$$h_f = f \left[\frac{LP \left(\frac{Q}{A} \right)^2}{4A \times 2g} \right]$$

Definition of Terms

h_f : head-loss due to friction

f : Darcy-Weisbach friction coefficient

L : length of pipe (ft)

P : wetted perimeter (ft)

Q : Flow (ft³/s)

A : cross-sectional area (ft²)

G : gravitational acceleration (ft²/s)

The Darcy-Weisbach Equation is used to calculate the head loss in a pipe, tube, or duct. If it was attempted to calculate loss by utilizing the dimensions of a lesser diameter pipe that equated to the same area Equation 1 would fail to account for the increased wetted perimeter and increased sources of friction. Conversely, if you attempted to calculate loss by using a larger pipe that equated to the same wetted perimeter, it would fail to take into consideration the reduced area and the resulting increase in velocity. In order to account for the increased wetted perimeter and the reduced cross-sectional area a modified version of Darcy-Weisbach was utilized (*see Equation 2*).

Equation 2

$$h_f = f \left[\frac{LP \left(\frac{Q}{A_w - A_f} \right)^2}{4(A_w - A_f) \times 2g} \right]$$

Definition of Terms

A_w: Area of Water Line

A_f: Area of Fiber Carrier Pipe

P: Inner diameter of water line – outer diameter of fiber carrier pipe

Using Equation 1 the head-loss due to friction that is experienced by the water distribution system can be calculated. Table 1 below shows the calculated head-loss. For the purpose of this exercise velocity shall be held constant at 2.5 ft/s, which is the minimum velocity requirement of Ten State Standards.

Table 1 : Friction loss prior to Fiber Installation

Madison County Utilities District

Link Number	Carrier Pipe Dia. (in.)	w/o Fiber hf	Current Pressure PSI	Length L	Inner Dia. Dia.C (")	Q	Aw	g (32.2ft2/s)
01	12	2.07	63	743	11.25	1.725728	0.6909	32.2
02	12	3.92	63	1405	11.25	1.725728	0.6909	32.2
03	12	0.33	63	119	11.25	1.725728	0.6909	32.2
04	12	0.44	63	157	11.25	1.725728	0.6909	32.2
05	12	2.34	63	837	11.25	1.725728	0.6909	32.2
06	12	0.51	63	183	11.25	1.725728	0.6909	32.2
07	12	1.60	63	574	11.25	1.725728	0.6909	32.2
08	12	0.52	63	187	11.25	1.725728	0.6909	32.2
09	12	1.95	63	700	11.25	1.725728	0.6909	32.2
10	12	9.42	63	3373	11.25	1.725728	0.6909	32.2
11	12	8.45	40	3026	11.25	1.725728	0.6909	32.2
12	12	8.13	40	2912	11.25	1.725728	0.6909	32.2
13	12	3.51	40	1256	11.25	1.725728	0.6909	32.2
14	12	2.77	40	991	11.25	1.725728	0.6909	32.2
15	12	5.41	40	1938	11.25	1.725728	0.6909	32.2
16	12	1.88	40	672	11.25	1.725728	0.6909	32.2
17	12	10.26	86	3674	11.25	1.725728	0.6909	32.2
18	12	2.76	86	988	11.25	1.725728	0.6909	32.2
19	12	1.76	86	632	11.25	1.725728	0.6909	32.2
20	8	5.06	86	1340	7.61	0.789654	0.3276	32.2
21	10	1.70	86	562	9.49	1.228004	0.5097	32.2
22	10	5.38	86	1783	9.49	1.228004	0.5097	32.2
23	10	0.83	86	274	9.49	1.228004	0.5097	32.2
24	8	1.27	86	337	7.61	0.789654	0.3276	32.2
25	8	1.34	86	356	7.61	0.789654	0.3276	32.2
26	8	3.99	86	1058	7.61	0.789654	0.3276	32.2
27	8	4.03	86	1069	7.61	0.789654	0.3276	32.2
28	8	3.09	86	820	7.61	0.789654	0.3276	32.2
29	8	5.64	86	1494	7.61	0.789654	0.3276	32.2
30	8	5.54	86	1467	7.61	0.789654	0.3276	32.2
31	8	10.10	87	2676	7.61	0.789654	0.3276	32.2
32	8	3.89	88	1031	7.61	0.789654	0.3276	32.2
33	8	1.91	88	507	7.61	0.789654	0.3276	32.2

Continue Table 1 : Friction loss prior to Fiber Installation								
Kirksville Water Association								
Link Number	Carrier Pipe Dia.	w/o Fiber	Current Pressure	Length	Inner Dia.			
	(in.)	hf	PSI	L	Dia.C (")	Q	Aw	g (32.2ft ² /s)
01	4	7.79	112	994	4.072	0.226091	0.09	32.2
02	4	2.91	112	371	4.072	0.226091	0.09	32.2
03	4	11.54	112	1472	4.072	0.226091	0.09	32.2
04	4	9.47	112	1207	4.072	0.226091	0.09	32.2
05	4	21.57	112	2750	4.072	0.226091	0.09	32.2
06	4	29.76	112	3795	4.072	0.226091	0.09	32.2
07	4	19.90	120	2538	4.072	0.226091	0.09	32.2
08	4	17.44	120	2224	4.072	0.226091	0.09	32.2
09	4	27.58	125	3517	4.072	0.226091	0.09	32.2
10	4	21.09	120	2690	4.072	0.226091	0.09	32.2
11	4	1.70	125	217	4.072	0.226091	0.09	32.2
12	4	36.06	125	4598	4.072	0.226091	0.09	32.2
13	4	27.82	125	3547	4.072	0.226091	0.09	32.2
14	4	2.09	132	266	4.072	0.226091	0.09	32.2
15	4	3.71	132	473	4.072	0.226091	0.09	32.2
16	4	10.37	132	1323	4.072	0.226091	0.09	32.2
17	4	11.01	132	1404	4.072	0.226091	0.09	32.2
18								
19	4	15.03	112	1917	4.072	0.226091	0.09	32.2
20	4	10.73	112	1368	4.072	0.226091	0.09	32.2
21	4	28.55	112	3641	4.072	0.226091	0.09	32.2
22	4	27.73	112	3536	4.072	0.226091	0.09	32.2
23	4	16.44	112	2096	4.072	0.226091	0.09	32.2
24	4	9.02	112	1150	4.072	0.226091	0.09	32.2

In order to calculate the expected head-loss from the proposed fiber installation Equation 2 is utilized so that consideration for the total wetted perimeter and reduced cross-sectional area is included. Results are depicted in Table 2.

Table 2 : Friction loss with Fiber Installation

Madison County Utilities District

Link Number	Carrier Pipe Dia.	w/ Fiber	Pressure with increased head-loss								
	(in.)	hf	PSI	L	Dia.C (")	Dia.F (")	Pw	Q	AL	AS	g (ft2/s)
01	12	2.35	62.88	743	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
02	12	4.44	62.78	1405	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
03	12	0.38	62.98	119	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
04	12	0.50	62.98	157	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
05	12	2.64	62.87	837	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
06	12	0.58	62.97	183	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
07	12	1.81	62.91	574	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
08	12	0.59	62.97	187	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
09	12	2.21	62.89	700	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
10	12	10.66	62.46	3373	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
11	12	9.56	39.52	3026	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
12	12	9.20	39.54	2912	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
13	12	3.97	39.80	1256	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
14	12	3.13	39.84	991	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
15	12	6.12	39.69	1938	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
16	12	2.12	39.89	672	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
17	12	11.61	85.42	3674	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
18	12	3.12	85.84	988	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
19	12	2.00	85.90	632	11.25	1	3.26	1.725728	0.6909	0.00545	32.2
20	8	6.00	85.59	1340	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
21	10	1.93	85.90	562	9.49	1	2.79	1.228004	0.5097	0.00545	32.2
22	10	6.13	85.68	1783	9.49	1	2.79	1.228004	0.5097	0.00545	32.2
23	10	0.94	85.95	274	9.49	1	2.79	1.228004	0.5097	0.00545	32.2
24	8	1.51	85.90	337	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
25	8	1.59	85.89	356	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
26	8	4.74	85.68	1058	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
27	8	4.79	85.67	1069	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
28	8	3.67	85.75	820	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
29	8	6.69	85.55	1494	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
30	8	6.57	85.55	1467	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
31	8	11.98	86.19	2676	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
32	8	4.62	87.69	1031	7.61	1	2.29	0.789654	0.3276	0.00545	32.2
33	8	2.27	87.85	507	7.61	1	2.29	0.789654	0.3276	0.00545	32.2

Continue Table 2 : Friction loss with Fiber Installation											
Kirksville Water Association											
Link Number	Carrier Pipe Dia.	w/ Fiber	Pressure with increased head-loss								
	(in.)	hf	PSI	L	Dia.C (")	Dia.F (")	Pw	Q	AL	AS	g (ft2/s)
01	4	11.63	110.34	994	4.072	1	1.32	0.226091	0.09	0.00545	32.2
02	4	4.34	111.38	371	4.072	1	1.32	0.226091	0.09	0.00545	32.2
03	4	17.22	109.54	1472	4.072	1	1.32	0.226091	0.09	0.00545	32.2
04	4	14.12	109.98	1207	4.072	1	1.32	0.226091	0.09	0.00545	32.2
05	4	32.18	107.41	2750	4.072	1	1.32	0.226091	0.09	0.00545	32.2
06	4	44.40	105.66	3795	4.072	1	1.32	0.226091	0.09	0.00545	32.2
07	4	29.70	115.76	2538	4.072	1	1.32	0.226091	0.09	0.00545	32.2
08	4	26.02	116.28	2224	4.072	1	1.32	0.226091	0.09	0.00545	32.2
09	4	41.15	119.12	3517	4.072	1	1.32	0.226091	0.09	0.00545	32.2
10	4	31.48	115.51	2690	4.072	1	1.32	0.226091	0.09	0.00545	32.2
11	4	2.54	124.64	217	4.072	1	1.32	0.226091	0.09	0.00545	32.2
12	4	53.80	117.32	4598	4.072	1	1.32	0.226091	0.09	0.00545	32.2
13	4	41.50	119.07	3547	4.072	1	1.32	0.226091	0.09	0.00545	32.2
14	4	3.11	131.56	266	4.072	1	1.32	0.226091	0.09	0.00545	32.2
15	4	5.53	131.21	473	4.072	1	1.32	0.226091	0.09	0.00545	32.2
16	4	15.48	129.79	1323	4.072	1	1.32	0.226091	0.09	0.00545	32.2
17	4	16.43	129.65	1404	4.072	1	1.32	0.226091	0.09	0.00545	32.2
18											
19	4	22.43	108.80	1917	4.072	1	1.32	0.226091	0.09	0.00545	32.2
20	4	16.01	109.71	1368	4.072	1	1.32	0.226091	0.09	0.00545	32.2
21	4	42.60	105.92	3641	4.072	1	1.32	0.226091	0.09	0.00545	32.2
22	4	41.37	106.09	3536	4.072	1	1.32	0.226091	0.09	0.00545	32.2
23	4	24.52	108.50	2096	4.072	1	1.32	0.226091	0.09	0.00545	32.2
24	4	13.46	110.08	1150	4.072	1	1.32	0.226091	0.09	0.00545	32.2

By taking the head-loss calculated for the current system as depicted in Table 1 and comparing it to the head-loss expected with the addition of the fiber line it can be determined how much impact can be expected from the proposed fiber installation. Table 3 shows the existing and expected head-loss and pressure change, as well as percent change in working pressure.

Table 3 : Friction loss comparison

Madison County Utilities District

Link Number	Carrier Pipe Dia.	w/o Fiber	w/ Fiber	Increased Headloss (ft)	Increased Pressure Loss	Current Pressure	Pressure with increased head-loss	Pressure Loss
	(in.)	hf	hf	h_f	PSI	PSI	PSI	%
01	12	2.07	2.35	0.27	0.12	63	62.9	0.19%
02	12	3.92	4.44	0.52	0.22	63	62.8	0.35%
03	12	0.33	0.38	0.04	0.02	63	63.0	0.03%
04	12	0.44	0.50	0.06	0.02	63	63.0	0.04%
05	12	2.34	2.64	0.31	0.13	63	62.9	0.21%
06	12	0.51	0.58	0.07	0.03	63	63.0	0.05%
07	12	1.60	1.81	0.21	0.09	63	62.9	0.14%
08	12	0.52	0.59	0.07	0.03	63	63.0	0.05%
09	12	1.95	2.21	0.26	0.11	63	62.9	0.18%
10	12	9.42	10.66	1.24	0.54	63	62.5	0.85%
11	12	8.45	9.56	1.11	0.48	40	39.5	1.20%
12	12	8.13	9.20	1.07	0.46	40	39.5	1.16%
13	12	3.51	3.97	0.46	0.20	40	39.8	0.50%
14	12	2.77	3.13	0.36	0.16	40	39.8	0.39%
15	12	5.41	6.12	0.71	0.31	40	39.7	0.77%
16	12	1.88	2.12	0.25	0.11	40	39.9	0.27%
17	12	10.26	11.61	1.35	0.58	86	85.4	0.68%
18	12	2.76	3.12	0.36	0.16	86	85.8	0.18%
19	12	1.76	2.00	0.23	0.10	86	85.9	0.12%
20	8	5.06	6.00	0.94	0.41	86	85.6	0.47%
21	10	1.70	1.93	0.24	0.10	86	85.9	0.12%
22	10	5.38	6.13	0.75	0.32	86	85.7	0.38%
23	10	0.83	0.94	0.11	0.05	86	86.0	0.06%
24	8	1.27	1.51	0.24	0.10	86	85.9	0.12%
25	8	1.34	1.59	0.25	0.11	86	85.9	0.13%
26	8	3.99	4.74	0.74	0.32	86	85.7	0.37%
27	8	4.03	4.79	0.75	0.33	86	85.7	0.38%
28	8	3.09	3.67	0.58	0.25	86	85.8	0.29%
29	8	5.64	6.69	1.05	0.45	86	85.5	0.53%
30	8	5.54	6.57	1.03	0.45	86	85.6	0.52%
31	8	10.10	11.98	1.88	0.81	87	86.2	0.94%
32	8	3.89	4.62	0.72	0.31	88	87.7	0.36%
33	8	1.91	2.27	0.36	0.15	88	87.8	0.18%

Continue Table 3 : Friction loss comparison

Kirksville Water Association								
Link Number	Carrier Pipe Dia.	w/o Fiber	w/ Fiber	Increased Headloss (ft)	Increased Pressure Loss	Current Pressure	Pressure with increased head-loss	Pressure Loss
	(in.)	hf	hf	h_f	PSI	PSI	PSI	%
01	4	7.79	11.63	3.84	1.66	112	110.3	1.48%
02	4	2.91	4.34	1.43	0.62	112	111.4	0.55%
03	4	11.54	17.22	5.68	2.46	112	109.5	2.20%
04	4	9.47	14.12	4.66	2.02	112	110.0	1.80%
05	4	21.57	32.18	10.61	4.59	112	107.4	4.10%
06	4	29.76	44.40	14.64	6.34	112	105.7	5.66%
07	4	19.90	29.70	9.79	4.24	120	115.8	3.53%
08	4	17.44	26.02	8.58	3.72	120	116.3	3.10%
09	4	27.58	41.15	13.57	5.88	125	119.1	4.70%
10	4	21.09	31.48	10.38	4.49	120	115.5	3.74%
11	4	1.70	2.54	0.84	0.36	125	124.6	0.29%
12	4	36.06	53.80	17.74	7.68	125	117.3	6.14%
13	4	27.82	41.50	13.69	5.93	125	119.1	4.74%
14	4	2.09	3.11	1.03	0.44	132	131.6	0.34%
15	4	3.71	5.53	1.83	0.79	132	131.2	0.60%
16	4	10.37	15.48	5.11	2.21	132	129.8	1.67%
17	4	11.01	16.43	5.42	2.35	132	129.7	1.78%
18								
19	4	15.03	22.43	7.40	3.20	112	108.8	2.86%
20	4	10.73	16.01	5.28	2.29	112	109.7	2.04%
21	4	28.55	42.60	14.05	6.08	112	105.9	5.43%
22	4	27.73	41.37	13.65	5.91	112	106.1	5.27%
23	4	16.44	24.52	8.09	3.50	112	108.5	3.13%
24	4	9.02	13.46	4.44	1.92	112	110.1	1.72%

Conclusion:

Based on the findings of this report it can be determined that while the installation of a fiber line within the existing water distribution mains will cause inconvenience during installation in the form of interrupted service, decreased pressure, and boiled water advisories, these are temporary in nature and are already experienced within the system anytime there is a line breakage or new connection added to the system.

In terms of long-term impacts, the system will operate at a lower total dynamic head that results from the addition of another source of friction as well as the reduction of the cross-sectional area, but these impacts are minor. The largest reduction in pressure, 6.34 PSI, occurs in Link 06 of Kirksville Water Association's mains. In that line segment there will be a 5.66% loss in pressure, however that will only bring the pressure down to 105.7 PSI which still far exceeds the required minimum pressure of 20 PSI that is required by Ten State Standards.