October 20, 2022

Michael T. Hinman, GS-12, WI ANG
Architect, 115th Civil Engineering Squadron
Madison WI

Subject: Summary of Groundwater Monitoring and Sampling at Truax Field Building 430 Site Located in Madison, Wisconsin

On November 18th & 19th, 2021, ORIN performed a pilot scale chemical injection. Following the injection work, groundwater was monitored for specific parameters, and groundwater samples were collected. Groundwater sampling was performed at 1, 3, and 5 weeks post injection, and then switching to a monthly collection basis. All four wells within the pilot study area were tested over this time frame.

Monitoring and sampling was performed using a peristaltic pump, HDPE tubing, a Hanna Instruments Multi-meter, and a flow-through cell. The groundwater parameters monitored for were depth to groundwater, pH, dissolved oxygen, ORP, conductivity, total dissolved solids, and temperature. The list of parameters that were tested for were the Wisconsin DNR PFAS List of 33 compounds plus three additional compounds (10:2 FTS, GenX, and PFHxDA).

Summary

When evaluating PW-2 and PW-4, we can see substantial reductions were achieved even at the periphery of the treatment zone. See Table 1 and Table 2.

When considering PW-4, note that it has the smallest treatment area upstream of all the monitoring wells. There is excellent reduction in all PFAS compounds during the testing period in spite of the reduced treatment area.

While starting concentrations are very similar to PW-4, the additional treatment area in front of PW-2 results in a much better reduction in PFAS compounds found during sampling events as can be seen in Table 2.

PW-1 is in the heart of the trial treatment zone. We see excellent reduction in PFAS compounds with many having orders of magnitude reductions as shown in Table 3. While initial concentrations are similar in PW-4, PW-2, and PW-1, much lower concentrations are achieved in PW-1 which demonstrates the additional treatment capacity of the larger treatment area upstream of PW-1.

PW-3 is located directly downstream from the entire treatment area and demonstrates the ability to decrease PFAS concentrations when groundwater flux is taken into consideration for proper treatment zone sizing. While the initial concentrations in PW-3 (Table 4) were lower than that of the other three wells by roughly one-third, post treatment concentrations are more than commensurately Total PFAS concentrations are reduced by 91% or better for the duration of the sampling period presented.

Adsorbable OrganoFluorine (AOF) concentrations can be seen rising in all samples.

AOF testing involves high temperature combustion on a combustion ion chromatogram. These tests can have difficulty detecting PFAS compounds due to their flame-resistant characteristics. The emergence of measurable AOF indicates that the backbone of the PFAS compounds have been compromised allowing the remaining fluorinated organic compounds to be oxidized by the AOF tests flame detection, i.e. those compounds are have been rendered flammable by the biological remediation processes.

PW-2 and PW-4 have higher concentrations of AOF detected when compared to PW-1 and PW-3. PW-2 and PW-4 are on the periphery of the treatment zone while PW-1 and PW-3 are near the center and near the "end" of the treatment zone, respectively. PW-3 receives the full benefit of the entire treatment area. As a result, AOF concentrations are lower in PW-3 than PW-1, PW-2, and PW-4. Generally, AOF concentrations are higher in monitoring wells with smaller treatment zones. PW-4, having the smallest treatment zone has the highest concentrations. PW-2, generally, has lower concentrations followed by PW-1 and PW-3 with the lowest.

These results indicate that the larger treatment areas associated with their respective wells are capable of further degradation of fluorinated organic compounds being produced as byproducts of the biological remediation process. PW-4 has the smallest treatment zone and results in the highest concentrations while PW-3 has the largest treatment zone and has the lowest

concentrations. PW-1 and PW-2 produce concentrations commensurate with their having the second and third largest treatment zones, respectively.

Results demonstrate PFAS remediation is possible and proper treatment zone sizing greatly reduces the potential for residual short chain fluorinated organic compounds as a byproduct of treatment.

The following tables show the analytical data collected from 1 week post-injection through September 1, 2022, as well as the groundwater parameters collected on the sampling dates.

If you have additional questions or comments, please feel free call our office at (608) 838-6699 [redacted]

Sincerely,

Larry Kinsman
Principal
ORIN Technologies, LLC.

Appendix

ORIN Technologies, LLC.
405 Investment Court, Verona, WI 53593 Phone 608-838-6699 Fax 608-838-6695

ORIN Technologies

Table 1. PW-2 Analytical Data

	PW-2											
Analyte ng/l	PW-2 10/26/21	PW-2 11/29/21	PW-2 12/16/21	PW-2 12/30/21	PW-2 2/1/22	PW-2 3/1/22	PW-2 4/5/22	PW-2 5/4/22	PW-2 6/1/22	PW-2 7/7/22	PW-2 8/4/22	PW-2 9/1/22
PFBA	390.0	140.0	170.0	240.0	180.00	260.00	230.0	490.0	290.0	220.0	240.0	250.0
PFPeA	1,300.0	250.0	390.0	540.0	370.00	370.00	670.0	1,200.0	860.0	590.0	650.0	540.0
PFBS	560.0	57.0	180.0	250.0	170.00	160.00	240.0	230.0	150.0	190.0	230.0	160.0
4:2 FTS	20.0		14.0	20.0	13.00	8.20	7.0		1.6	2.0	0.0	1.3
PFHxA	1,400.0	120.0	360.0	570.0	390.00	410.00	760.0	1,300.0	960.0	490.0	730.0	580.0
PFPeS	880.0	32.0	190.0	300.0	210.00	39.00	310.0	430.0	270.0	270.0	320.0	210.0
HFPO-DA	0.0								1.2			
PFHpA	380.0	17.0	76.0	140.0	110.00	99.00	200.0	400.0	260.0	140.0	170.0	120.0
PFHxS	7,000.0	130.0	1,300.0	1,800.0	1,500.00	410.00	2,500.0	3,300.0	3,300.0	2,200.0	2,300.0	1,500.0
6:2 FTS	1,400.0	41.0	550.0	940.0	670.00	380.00	520.0	410.0	200.0	150.0	95.0	62.0
PFOA	560.0	21.0	200.0	240.0	180.00	140.00	240.0	250.0	180.0	160.0	170.0	120.0
PFHpS	410.0		41.0	64.0	51.00	39.00	120.0	110.0	98.0	91.0	54.0	66.0
PFNA	170.0		13.0	20.0	22.00	23.00	81.0	88.0	64.0	40.0	52.0	32.0
PFOSA	8.2				0.81	0.88	1.9		2.5	2.0	0.0	1.4
PFOS	16,000.0	120.0	1,800.0	3,100.0	2,900.00	3,000.00	9,700.0	8,300.0	6,700.0	4,900.0	5,700.0	4,100.0
PFDA	0.0			0.74	0.62		0.96		0.91	1.3		0.49
8:2 FTS	150.0	0.0	36.0	46.0	50.00	38.00	59.0	42.0	29.0	27.0	14.0	13.0
PFNS	0.0			6.4		5.40	27.0	18.0	21.0			
NMeFOSAA	0.0								1.6			
PFUnA	0.0									0.68		
PFDS	0.0									0.8		
10:2 FTS	0.0									0.98		
TOTAL	**30,628.2**	**928.0**	**5,320.0**	**8,277.1**	**6,817.43**	**5,382.48**	**15,666.9**	**16,568.0**	**13,389.8**	**9,475.8**	**10,725.0**	**7,756.2**

ORIN Technologies, LLC.
405 Investment Court, Verona, WI 53593 Phone 608-838-6699 Fax 608-838-6695

ORIN Technologies

Table 2. PW-4 Analytical Data

	PW-4											
Analyte ng/l	PW-4 10/26/21	PW-4 11/29/21	PW-4 12/16/21	PW-4 12/30/21	PW-4 2/1/22	PW-4 3/1/22	PW-4 4/5/22	PW-4 5/4/22	PW-4 6/1/22	PW-4 7/7/22	PW-4 8/1/22	PW-4 9/1/22
PFBA	390.0	360.0	460.0	460.0	380.0	390.00	980.0	2,000.0	1,100.0	710.0	660.0	1,100.0
PFPeA	1,500.0	670.0	1,600.0	1,400.0	1,400.0	1,400.00	4,800.0	8,300.0	4,900.0	3,700.0	3,200.0	4,900.0
PFBS	650.0	98.0	150.0	200.0	320.0	380.00	500.0	1,000.0	450.0	480.0	500.0	460.0
4:2 FTS	51.0	5.8	4.4	8.5	13.0	21.00	12.0	18.0	12.0	20.0	0.0	13.0
PFHxA	1,600.0	350.0	710.0	870.0	1,000.0	1,300.00	3,900.0	6,200.0	3,300.0	2,400.0	2,000.0	2,800.0
PFPeS	1,000.0	120.0	300.0	390.0	540.0	620.00	1,300.0	2,700.0	1,200.0	990.0	810.0	1,100.0
HFPO-DA	0.0											
PFHpA	510.0	85.0	140.0	220.0	280.0	320.00	950.0	1,700.0	880.0	590.0	490.0	760.0
PFHxS	8,500.0	1,200.0	3,200.0	3,500.0	4,700.0	4,900.00	22,000.0	48,000.0	19,000.0	11,000.0	7,400.0	14,000.0
6:2 FTS	3,100.0	710.0	2,200.0	2,300.0	2,600.0	2,200.00	4,800.0	21,000.0	3,700.0	3,700.0	5,100.0	3,700.0
PFOA	1,100.0	130.0	250.0	300.0	280.0	490.00	1,300.0	3,700.0	1,400.0	770.0	660.0	740.0
PFHpS	350.0	48.0	220.0	230.0	180.0	210.00	950.0	3,700.0	1,100.0	560.0	330.0	1,000.0
PFNA	93.0	13.0	50.0	43.0	38.0	46.00	290.0	820.0	290.0	130.0	110.0	270.0
PFOSA	88.0		7.9	11.0	41.0	29.00	69.0	120.0	94.0	90.0	91.0	78.0
PFOS	18,000.0	2,300.0	6,700.0	6,700.0	6,600.0	7,900.00	18,000.0	53,000.0	16,000.0	13,000.0	16,000.0	19,000.0
PFDA	6.6			4.5	6.5	5.60		19.0	9.1	7.5	0.0	9.9
8:2 FTS	350.0	36.0	98.0	130.0	180.0	220.00	150.0	170.0	160.0	290.0	300.0	180.0
PFNS	0.0		4.2		11.0		32.0	17.0	4.6	4.8		
NMeFOSAA	0.0			1.3	1.1	1.30						
PFUnA	0.0			0.65	1.6							
PFDS	0.0		8.3	9.1	34.0	5.60			15.0			
10:2 FTS	0.0				1.2	2.40		12.0	8.8	12.0		
TOTAL	**37,288.6**	**6,125.8**	**16,102.8**	**16,778.1**	**18,607.4**	**20,440.90**	**60,033.0**	**152,476.0**	**53,623.5**	**38,454.3**	**37,651.0**	**50,110.9**

ORIN Technologies, LLC.
405 Investment Court, Verona, WI 53593 Phone 608-838-6699 Fax 608-838-6695

Table 3. PW-1 Analytical Data

	PW-1											
Analyte ng/l	PW-1 10/26/21	PW-1 11/29/21	PW-1 12/16/21	PW-1 12/30/21	PW-1 2/1/22	PW-1 3/1/22	PW-1 4/5/22	PW-1 5/4/22	PW-1 6/1/22	PW-1 7/7/22	PW-1 8/4/22	PW-1 9/1/22
PFBA	350.0	150.0	280.0	250.0	290.0	190.00	330.0	330.0	250.0	190.0	200.0	200.0
PFPeA	1,500.0	300.0	450.0	580.0	430.0	470.00	930.0	1,100.0	680.0	550.0	640.0	660.0
PFBS	610.0	5.9	6.2	7.1	12.0	160.00	47.0	97.0	200.0	190.0	210.0	180.0
4:2 FTS	50.0	0.0	0.7	0.99	1.1	13.00	4.4	5.4	11.0	13.0	18.0	18.0
PFHxA	1,600.0	77.0	110.0	140.0	93.0	500.00	390.0	450.0	480.0	470.0	560.0	560.0
PFPeS	930.0	0.0	5.8	7.5	12.0	200.00	46.0	100.0	240.0	230.0	220.0	210.0
HFPO-DA	0.0	0.0						1.7				
PFHpA	510.0	14.0	18.0	26.0	19.0	190.00	91.0	99.0	130.0	150.0	180.0	190.0
PFHxS	6,900.0	29.0	43.0	43.0	86.0	1,800.00	280.0	450.0	1,400.0	1,500.0	1,400.0	1,600.0
6:2 FTS	3,500.0	290.0	260.0	460.0	140.0	820.00	1,200.0	990.0	1,000.0	710.0	1,000.0	670.0
PFOA	1,500.0	7.8	8.4	11.0	23.0	470.00	91.0	96.0	290.0	340.0	380.0	430.0
PFHpS	310.0	0.0	1.1	0.98	2.4	76.00	7.6	12.0	47.0	67.0	53.0	86.0
PFNA	73.0	0.0	0.65	0.54	0.99	27.00	3.6	5.8	14.0	16.0	19.0	19.0
PFOSA	18.0	6.0	1.7	3.0	0.61	0.51	9.0	6.1	1.3	1.9	0.0	1.7
PFOS	14,000.0	100.0	79.0	94.0	150.0	4,400.00	560.0	540.0	2,500.0	3,000.0	4,000.0	4,100.0
PFDA	7.3	0.0		0.53		2.80	1.3	1.0	1.4	2.6	0.0	2.8
8:2 FTS	670.0	17.0	6.1	11.0	8.2	260.00	59.0	36.0	110.0	250.0	270.0	390.0
PFNS	0.0					27.00	0.54		12.0			1.9
NMeFOSAA	0.0					2.10				1.3		3.1
PFUnA	0.0									0.61		
PFDS	0.0											
10:2 FTS	0.0					0.92				1.6		
TOTAL	**32,528**	**996.7**	**1,270.7**	**1,636**	**1,268**	**9,609.33**	**4,050.4**	**4,320.0**	**7,366.7**	**7,684.0**	**9,150.0**	**9,322.5**

ORIN Technologies, LLC.
405 Investment Court, Verona, WI 53593 Phone 608-838-6699 Fax 608-838-6695

Table 4. PW-3 Analytical Data

	PW-3											
Analyte ng/l	PW-3 10/26/21	PW-3 11/29/21	PW-3 12/16/21	PW-3 12/30/21	PW-3 2/1/22	PW-3 3/1/22	PW-3 4/5/22	PW-3 5/4/22	PW-3 6/1/22	PW-3 7/7/22	PW-3 8/4/22	PW-3 9/1/22
PFBA	210.0	0.0	100.0	110.0	76.0	110.00	51.0	160.0	110.0	91.0	54.0	130.0
PFPeA	790.0		45.0	70.0	33.0	230.00	92.0	270.0	210.0	55.0	9.8	210.0
PFBS	320.0		2.3	5.3	1.5	110.00	38.0	84.0	72.0	11.0	1.9	88.0
4:2 FTS	37.0					3.70	2.8	4.7	4.1	0.83		2.7
PFHxA	950.0		4.1	10.0	3.0	260.00	100.0	180.0	170.0	25.0	4.6	180.0
PFPeS	420.0			1.1		100.00	43.0	74.0	68.0	16.0	3.0	93.0
HFPO-DA	0.0							1.6	0.8			
PFHpA	340.0			0.52		61.00	27.0	46.0	45.0	9.3	2.0	42.0
PFHxS	3,800.0		0.84	2.4	1.7	590.00	280.0	410.0	420.0	120.0	31.0	460.0
6:2 FTS	2,600.0					120.00	100.0	150.0	150.0	66.0	12.0	110.0
PFOA	1,000.0			0.49		68.00	46.0	69.0	63.0	18.0	4.7	55.0
PFHpS	230.0					9.40	5.6	9.8	10.0	3.6	1.0	14.0
PFNA	44.0					2.70	2.2	3.0	3.0	1.3		3.0
PFOSA	0.0	11.0				0.70			0.66	1.8	0.64	1.2
PFOS	12,000.0		2.8	1.7	2.1	400.00	260.0	310.0	370.0	180.0	62.0	630.0
PFDA	6.3	7.5										
8:2 FTS	860.0							1.5	1.8	1.7		8.5
PFNS	0.0					2.70						
NMeFOSAA	5.7											
PFUnA	0.0											
PFDS	0.0											
10:2 FTS	0.0									1.3		
TOTAL	**23,613.0**	**18.5**	**155.0**	**201.5**	**117.3**	**2,068.20**	**1,047.6**	**1,773.6**	**1,698.4**	**601.8**	**186.6**	**2,027.4**

ORIN Technologies, LLC.
405 Investment Court, Verona, WI 53593 Phone 608-838-6699 Fax 608-838-6695

ORIN Technologies

Table 5. Groundwater Parameter Data

PW-1	PW-1 10/26/21	PW-1 11/29/21	PW-1 12/16/21	PW-1 12/30/21	PW-1 2/1/22	PW-1 3/1/22	PW-1 4/5/22	PW-1 5/4/22	PW-1 6/1/22	PW-1 7/7/22	PW-1 8/4/22	PW-1 9/1/22
Depth to Water (ftbgs)	6.75	-	7.4	7.49	7.65	7.73	6.49	6.47	7.01	6.34	6.69	6.68
pH	6.88	12.69	12.65	12.61	12.03	7.5	11.17	10.95	7.6	7.3	6.82	6.74
ORP	21	-34	-18	-57.1	36.5	-116.7	67.5	38.1	-152.1	-109	-97.7	-87.9
DO (mg/L)	0.06	15.48	6.38	3.77	2.44	2.84	1.53	1.08	2.3	1.58	0.6	1.74
Conductivity (mS/cm)	0.983	4.167	4.292	3.861	1.871	0.857	0.787	0.53	0.93	0.851	0.863	0.821
Total Disolved Solids (ppm)	491	2641	2137	1931	943	427	394	259	461	428	432	410
Temp. (°C)	15.49	13.88	13.36	12.72	11.36	10.77	9.28	10.14	12.16	14.16	15.21	15.2
PW-2	PW-2 10/26/21	PW-2 11/29/21	PW-2 12/16/21	PW-2 12/30/21	PW-2 2/1/22	PW-2 3/1/22	PW-2 4/5/22	PW-2 5/4/22	PW-2 5/31/22	PW-2 7/7/22	PW-2 8/4/22	PW-2 9/1/22
Depth to Water (ftbgs)	6.68	-	7.22	7.34	7.53	7.59	6.32	6.25	6.53	6.19	6.54	6.52
pH	6.94	9.6	7.5	7.16	6.82	6.8	7.18	7.19	7.13	7.19	6.84	6.91
ORP	22.8	96.1	128.1	180.6	164.2	134.8	158.6	160.4	128.4	88.3	164.4	131.5
DO (mg/L)	1.51	12.91	0.94	1.04	1.83	2.15	4.14	4.8	4.77	3.52	1.83	2.34
Conductivity (mS/cm)	0.805	0.892	0.894	0.84	0.871	0.863	0.818	0.668	0.714	0.74	0.738	0.732
Total Disolved Solids (ppm)	403	446	446	420	436	432	409	334	357	370	369	366
Temp. (°C)	16.98	14.48	13.24	13.09	11.91	11.62	9.25	10.75	13.53	15.08	16.09	16.59
PW-3	PW-3 10/26/21	PW-3 11/29/21	PW-3 12/16/21	PW-3 12/30/21	PW-3 2/1/22	PW-3 3/1/22	PW-3 4/5/22	PW-3 5/4/22	PW-3 6/1/22	PW-3 7/7/22	PW-3 8/4/22	PW-3 9/1/22
Depth to Water (ftbgs)	7.47	-	7.97	8.08	8.2	8.27	7.05	6.97	6.25	6.91	7.27	7.2
pH	7.03	12.3	12.52	12.55	12.44	8.4	7.91	7.01	7.22	7.38	7.47	7.13
ORP	42.9	-7.6	-1.4	-46.4	-30.5	35.7	95.8	-126.5	-87.1	56.2	126.9	158.8
DO (mg/L)	0.24	11.85	2.52	0.65	3.38	2.42	2.63	1.24	1.24	1.52	0.55	1.58
Conductivity (mS/cm)	0.85	2.531	2.734	2.542	3.496	0.671	0.738	0.807	0.801	0.754	0.735	0.701
Total Disolved Solids (ppm)	425	1269	1214	1280	1777	336	369	403	401	378	367	351
Temp. (°C)	15.64	14.22	12.29	11.45	10.11	9.28	8.2	9.65	11.64	13.91	15.35	16.76

PW-4	PW-4 10/26/21	PW-4 11/29/21	PW-4 12/16/21	PW-4 12/30/21	PW-4 2/1/22	PW-4 3/1/22	PW-4 4/5/22	PW-4 5/4/22	PW-4 6/1/22	PW-4 7/7/22	PW-4 8/4/22	PW-4 9/1/22
Depth to Water (ftbgs)	7.33	-	7.91	8.03	8.16	8.2	7.02	7.02	7.15	6.88	7.2	7.22
pH	7.09	7.25	7.39	7.24	6.8	6.74	7.12	6.99	7.15	7.2	6.83	6.91
ORP	57	194	153.4	62.2	-18.5	-50.4	19.8	59.2	42.4	-5.7	17.1	102.5
DO (mg/L)	0.71	<0.5	<0.5	<0.5	1.05	1.43	3.23	2.03	1.24	2.97	0.39	1.63
Conductivity (mS/cm)	0.768	0.474	0.493	0.498	0.635	0.687	0.659	0.611	0.594	0.68	0.588	0.595
Total Disolved Solids (ppm)	384	237	247	249	318	344	329	305	297	340	294	298
Temp. (°C)	15.74	13.94	11.84	12.04	10.8	9.89	7.49	9.26	11.27	15.21	14.47	15.69

Table 6. AOF Concentrations

Adsorbable OrganoFluorine Concentrations (ug/L)												
	10/26/21	11/29/21	12/16/21	12/30/21	2/1/22	3/1/22	4/5/22	5/4/22	6/1/22	7/7/22	8/4/22	9/1/22
PW-1	0	NS	0	12	2.7	13	9	9.5	14	12	13	16
PW-2	0	NS	0	7.7	10	11	18	16	17	14	12	13
PW-3	0	NS	0	1.7	1.6	8.5	3.5	6.6	11	ND	1.2	3.2
PW-4	0	NS	0	22	28	28	9	150	88	61	49	72