PARSONS

ENGINEERING REPORT
OLD OUTFALL 002 GAC PILOT STUDY RESULTS
CHEMOURS FAYETTEVILLE PLANT
FAYETTEVILLE, NORTH CAROLINA

Prepared for:

The Chemours Company FC, LLC
Corporate Remediation Group
1007 Market Street, Room 13116A
Wilmington, Delaware 19801

Prepared by:

PARSONS
4701 Hedgemore Drive
Charlotte, North Carolina 28209

September 2019

Parsons PN 449338

This page intentionally left blank

TABLE OF CONTENTS

APPENDICES

This page intentionally left blank

ACRONYMS

Acronym	Definition / Description
BF-01A/02A	Cartridge Filters BF-01A and BF-02A
BL-001	Blower BL-001
Chemours	The Chemours Company FC, LLC
CO	Consent Order
DWR	(NCDEQ) Division of Water Resources
EPA	Environmental Protection Agency
F400	(Calgon) Filtrasorb 400
GAC	Granulated activated carbon
g/L	Gram(s) per liter
gpm	Gallon(s) per minute
HFPO-DA	Hexafluoropropylene oxide dimer acid
IEX	Ion exchange
L/min	Liter(s) per minute
µg/L	Microgram(s) per liter
µm	Micrometer
mg/L	Milligram(s) per liter
mL	Milliliter(s)
MMF	Multimedia filters
NCDEQ	North Carolina Department of Environmental Quality
NPDES	National Pollutant Discharge Elimination System
OOF2	Old Outfall 002
P-001	Dry-Mounted Centrifugal Pump 001 (also P-003A, P-003B)
P-004A	GAC Feed Pump P-004A
PFAS	Perfluoroalkyl and polyfluoroalkyl substances
PFD	Process flow diagram
PFMOAA	Perfluoro-2-methoxyacetic acid
PMPA	Perfluoromethoxypropionic acid
SU	Standard unit (pH)
T-001	Test Water Storage Tank
T-002	Batch Treatment Tank T-002
T-003A/003B	Batch Holding Tanks T-003A and T-003B
T-004	Treated Water Holding Tank 004
w/v	Weight by volume

This page intentionally left blank

1.0 INTRODUCTION

On February 25, 2019, The Chemours Company FC, LLC (Chemours) entered a Consent Order (CO) with the State of North Carolina and Cape Fear River Watch to address perfluoroalkyl and polyfluoroalkyl substances (PFAS) at its Fayetteville Works site (the Site). Studies conducted at the Site have determined that groundwater containing PFAS constituents is discharging to a stormwater channel on the property referred to as the Old Outfall 002 (OOF2). The channel was historically used to discharge process wastewater but was abandoned when the current outfall was constructed. There is currently no wastewater discharge from the Site into this former outfall.

As required by paragraph 12.e of the CO, Parsons performed a pilot study demonstrating treatment for PFAS compounds in OOF2. The pilot study was conducted from June through September 2019 to provide at least three months of data demonstrating PFAS treatment as required by the CO. Parsons has prepared this report to present the results of the study.

This page intentionally left blank

2.0 BACKGROUND

Paragraph 12.e of the CO specifies capture and treatment of water in OOF2 at the "Option B location (proposed dam)" by September 30, 2020. The CO further requires: "The treatment system shall meet such discharge standards as shall be set by DEQ[1], and shall, in addition and at a minimum, be at least 99% effective in controlling indicator parameters, Gen X and PFMOAA[2]." The CO also requires the completion of a pilot study, as follows: "by September 30, 2019, Chemours shall complete pilot scale testing of treatment equipment to determine its control efficiency for all PFAS identified in Old Outfall 002. The results of this pilot testing shall be supported by at least three (3) months of sampling data and submitted to DWR[3] for review and approval." This report serves as the required deliverable to the NCDEQ.

Preparations for implementing a treatment system to capture and treat water at OOF2 included the following elements:

- Bench-scale granular activated carbon (GAC) and ion exchange resin treatability studies
- National Pollutant Discharge Elimination System (NPDES) permit application, including:
    - Environmental Protection Agency (EPA) Form 1 and 2D preparation
    - Preparation of an Engineering Report on Treatment Testing summarizing bench-scale treatment results
- 401/404 permit application and associated submittals for capture of OOF2 flow.

2.1 OOF2 Treatment System Requirements

The requirements for treating captured flow from OOF2 are summarized below:

- Removal of PFAS compounds per Consent Order and NPDES permit criteria
- Removal of iron and solids to prevent fouling of the treatment process used for removing PFAS
- Management of solids generated during iron and solids removal

2.2 Bench-Scale Testing

Bench-scale testing was performed to evaluate the most efficient means for removing the target PFAS compounds from OOF2 flow. Isotherm adsorption tests were performed to determine the adsorption capacities of GAC and several ion exchange (IEX) resins for the range of PFAS compounds tracked at the Site. Testing was performed using water collected from the proposed treatment location at OOF2, thereby capturing matrix and competitive adsorption effects that will be present during treatment of this flow. Test procedures, results, and conclusions were presented in the Engineering Report on Wastewater Treatability submitted with the OOF2 NPDES Permit Application and Engineering Alternatives Assessment report in July 2019. The following summarizes the primary conclusions developed from this testing:

[1] DEC – North Carolina Department of Environmental Quality (NCDEQ)
[2] PFMOAA – perfluoro-2-methoxyacetic acid
[3] DWR – NCDEQ Division of Water Resources

- Calgon Filtrasorb 400 (F400) GAC and IEX resins demonstrated effective removal of indicator PFAS compounds PFMOAA and HFPO-DA.
- F400 GAC provided generally better performance for other tracked and reported PFAS compounds as demonstrated by lower projected utilization rates for GAC versus IEX.
- PFMOAA governed utilization rates for both F400 GAC and IEX resins.

Estimated utilization rates of F400 GAC to provide 99% removal of the indicator compound PFMOAA would result in at least 99% removal of the total reported PFAS compounds.

2.3 OOF2 Treatment System Description

The full-scale treatment system will incorporate a series of individual treatment processes which results in effective removal of target constituents from captured OOF2 flow. The preliminary design of the full-scale treatment system will include the following individual treatment processes:

- Chemical precipitation.
- Flocculation.
- Clarification.
- Filtration.
- GAC Adsorption.
- Solids Management.
- Backwash Systems.

Chemical precipitation, flocculation, clarification, and filtration will be implemented to remove iron and solids which would otherwise cause fouling / plugging in the GAC adsorption process. The preliminary design of chemical precipitation treatment process includes aeration to oxidize iron (forming iron hydroxides) followed by pH adjustment to 7.5 – 8.0 to precipitate the iron at the minimum solubility of the iron hydroxides. Following chemical precipitation, polymer will be applied to cause influent and precipitated solids to agglomerate into larger “flocs” during the flocculation step. The agglomerated solids will then be allowed to settle during the clarification step. Following settling, the clarified “supernatant” will be pumped through the filtration step to remove fugitive solids ahead of GAC adsorption. The water will proceed through a series of GAC contact vessels arranged in series to remove PFAS compounds. The GAC adsorption process design will maximize the efficiency of GAC utilization while providing hydraulic loading rates in the range prescribed by sound engineering design for this application. The treated flow will then be discharged downstream of the capture dam.

Solids generated during chemical precipitation and captured in the clarification process will be pumped from the bottom of the clarification treatment process vessel to a sludge holding tank. The sludge will undergo thickening followed by dewatering, after which the dewatered solids cake will be transferred into hoppers and disposed off-site to a landfill certified to accept the solids. The GAC contact vessels will have backwash capability to allow periodic removal of any accumulated solid material. (The filtration treatment process will also include backwash capability if multimedia filters are used.) Backwash water will be transferred back into the treatment system prior to the flocculation treatment step.

2.4 Pilot Treatment System Design Description

The pilot treatment system incorporated batch pretreatment through the chemical precipitation, flocculation, clarification, and filtration processes to remove iron and solids; followed by continuous treatment of batch-treated effluent through granular activated carbon (GAC). A process flow diagram (PFD) and equipment general arrangement (GA) of the pilot treatment system is included in Appendix A. The following briefly describes each pilot treatment system component. The sequence of operations detailing specific equipment and process information is presented in Section 3 of this report.

Batch Pretreatment. Chemical precipitation was implemented by aeration using a rotary blower and diffusion grid to oxidize iron into iron hydroxides, followed by addition of 50% sodium hydroxide (NaOH) to adjust pH to 7.5 – 8.0. Polymer was mixed into the chemically-precipitated batch with the assistance of a tank-mounted mixer; latent mixing following shutoff of the mixer promoted flocculation of the solids into larger flocs. The batch then underwent a period of settling following flocculation to allow the agglomerated solids to settle, after which supernatant was pumped forward; settled solids were periodically pumped out to dedicated holding / thickening totes. Supernatant was pumped forward through two cartridge filters arranged in series to remove fugitive solids ahead of the GAC adsorption columns, and into treated batch holding tanks.

GAC Adsorption. Pretreated water was pumped continuously through four GAC columns arranged in series; the system included two separate GAC column trains ('A' and 'B') which allowed parallel evaluation of different GAC products from the same treated batches. Each column was constructed from 2" ID PVC pipe.

The pilot system was designed to treat 0.11 gallons per minute (gpm) or 0.42 liters per minute (L/min), providing a target hydraulic loading rate across the GAC columns of 5 gpm/ft^2. The use of smaller diameter columns in GAC column studies has been widely used over the past 50 years and is recommended by Calgon, the leader in manufacture of GAC adsorption systems. The average column-diameter to GAC-granule-diameter ratio for the pilot system was greater than 20:1 which ensures minimization of wall effects during the conduct of the pilot study. The hydraulic loading rate in the pilot system was similar to what would be used in a full-scale system. The length of the pilot GAC adsorption columns was sufficient to fully delineate the target solute breakthrough wave-front reflecting the progression of the mass-transfer zone. The results of the pilot study will be directly scalable to a full-sized GAC adsorption system.

Although a full-scale treatment system will incorporate a GAC backwash system, the implementation of backwash during pilot testing would disrupt the evolution of the solute wavefront. As such, backwashing during wave-front propagation was not performed.

This page intentionally left blank

3.0 PILOT STUDY SEQUENCE OF OPERATIONS

The OOF2 GAC pilot treatment system was designed to reflect the overall treatment process (e.g., chemical precipitation, filtration, GAC adsorption, etc.) which would be present in a full-scale treatment system treating captured OOF2 flow. The pilot system design also provided for the ability to analyze one or two adsorbents in parallel and facilitated management of treatment testing residuals including treated effluent and solids generated during treatment. As such, the pilot treatment system encompassed the following unit treatment process:

- Influent storage
- Pretreatment for nuisance iron and solids, including:
  - Chemical precipitation and settling
  - Filtration
- GAC adsorption for PFAS compounds
- Treated water storage
- Sludge management

Since the proposed capture location at OOF2 is in a remote and wooded area with no existing utilities, the pilot system was located inside an unused warehouse within the active manufacturing area of the Site. The following briefly describes the pilot treatment system sequence of operations. Process flow diagram (PFD) and equipment general arrangement drawings are provided in Appendix A for reference.

3.1 Influent Storage

Water from the proposed capture location (just west of Bill Hall Road) was collected by field personnel and transported via truck to an 18,000-gallon FRAC tank (designated the Test Water Storage Tank [T-001]). This tank provided several weeks of sample volume from each fill, thereby providing a consistent quality of water to the pilot treatment system and reducing the frequency of trips required to collect the water from OOF2.

3.2 Chemical Precipitation

Raw water from T-001 was pretreated in batches in the Batch Treatment Tank (T-002). The total volume of T-002 was 1,550 gallons with a working volume of approximately 1,400 gallons. Batches of water were transferred from T-001 to T-002 by a dry-mounted centrifugal pump (P-001) operating at a flow rate of approximately 40 gpm. P-001 was switched off when T-002 was filled to its working volume. The batch treatment process consisted of the following steps:

- Aeration: The batch underwent aeration for approximately 30 minutes through operation of Blower BL-001, which supplied air through a field-fabricated diffuser assembly. BL-001 was switched off after aeration.
- Mixing: Tank mixer T-001 was switched on.
  - pH Adjustment: The pH in the batch was adjusted to a target of 8.0 standard units (SUs) with 50% (weight by volume [w/v]) sodium hydroxide to precipitate iron.

- Polymer Addition: After pH stabilized in the target range, anionic polymer was added at an applied dose of 0.5 to 1.0 milligram per liter (mg/L) to enhance flocculation of precipitated solids. Following addition of polymer solution to T-001, the batch underwent mixing for 15 minutes to ensure the polymer was completely mixed into the batch. The anionic polymer was pre-prepared from neat polymer (40% active polymer ingredient) with distilled water to an intermediate dosing solution concentration of 6.83 grams per liter (g/L) (2.73 g/L as active polymer ingredient) to allow the polymer to age. The polymer was then further diluted in approximately 3 gallons of distilled water to facilitate homogenization and stored in T-002.

- Flocculation and Settling: Mixer M-001 was turned off, and latent mixing momentum promoted agglomeration of floc particles followed by quiescent settling.

3.3 Filtration

Following the period of quiescent setting, supernatant from T-002 was pumped by dry-mounted centrifugal pump P-003A through two cartridge filters (BF-01A/-02A) installed in parallel, and into Batch Holding Tank T-003A. With two GAC column trains in operation, supernatant was pumped through BF-01A/02A to Batch Holding Tank T-003A using P-003A. Supernatant was also pumped through BF-01B/02B to Batch Holding Tank T 003B using P-003B through a separate suction line from T-002.

3.4 GAC Adsorption

Pre-treated water in Tank T-003A was pumped continuously by GAC Feed Pump P-004A through carbon columns GAC-1A, -2A, -3A, and -4A operating in series. The GAC columns contained Calgon F400 GAC installed in 2-inch-diameter polyvinyl chloride piping. P-004A was a programmable diaphragm metering pump which transferred water at a clean column flow rate of 0.11 gpm (0.42 L/min), providing a target hydraulic loading rate across the GAC columns of 5 gpm/ft^2. The empty bed contact time in each column at the clean column flow rate was 5 minutes. Each column contained 2.45 pounds of F400 based on these design conditions and the density of F400. The GAC in each column was held in place by glass wool supported by pea gravel. A three-way sampling valve was installed on GAC 1A to facilitate sampling of pretreated water from T-003A prior to flowing into the GAC columns and between each GAC column to facilitate sampling of water from GAC-1A through GAC-3A. GAC-4A was sampled from the effluent line which transferred column effluent to the Treated Water Holding Tank T-004.

The GAC adsorption process in the second treatment train ('B' Side) was operated identically to the first treatment train ('A' train) using the corresponding equipment as shown in the PFD. The second treatment train was used to test Calgon DSR-A, a regenerated GAC product which is used in industrial and remediation applications.

3.5 Treated Water Storage

GAC-treated water was transferred directly during treatment to the Treated Water Holding Tank T-004. The water in T-004 was periodically removed by Chemours site personnel for off-site disposal. T-004 provided the same working volume as Batch Treatment Tank T-002 to match overall batch processing rates.

3.6 Sludge Management

Supernatant in Tank T-002 was decanted down to the level at which the P-003A and P-003B suction lines were installed. The remaining volume in T-002 was transferred to the Sludge Storage Totes (T-006) to allow additional settling of solids and provide some reserve pretreated test volume. Sludge from each series of tests was harvested for analysis and follow-on sludge studies to assist with treatment system design.

This page intentionally left blank

4.0 PILOT TREATMENT SYSTEM OPERATION

4.1 Test Water Collection

Water was collected from OOF2 using an MQ Model QP3TH 3-inch outlet diameter trash pump which was pumped to a 2,000-gallon Ford F750 water truck. The water was dispensed from the water truck to tank T-001 using a second trash pump through a 2-inch-diameter discharge hose. Prior to system startup, approximately 7,000 gallons of water were collected during the week of June 10th to supply water for the first phase of testing. A second FRAC tank was filled during the course of the study with approximately 16,000 gallons of water to supply water during the second phase of testing.

4.2 Startup and Operation

The first batch of OOF2 water was pumped over to Batch Treatment Tank T-002 on June 13, 2019. A jar test was performed in one-liter aliquots of water from Tank T-002 to determine the quantity of sodium hydroxide which would be required to achieve the target pH of 8 SUs and to determine the optimum dose of polymer to achieve efficient settling. Based on jar testing, approximately 450 milliliters (mL) of 50% (w/v) sodium hydroxide were required per 1,500-gallon batch of OOF2 water, and a polymer dose of 0.5 mg/L (as active polymer ingredient) was found to provide optimal settling. Pilot treatment started up on Friday, June 14th, when the first batch of OOF2 water underwent pretreatment including aeration, pH adjustment, polymer addition, and settling. Following settling, the pre-treated water was pumped through bag filters BF-01A/01B to Batch Holding Tank T-003. Pumping through the GAC columns was then initiated and the pumping rate adjusted to provide a target flow rate of 0.11 gpm (0.42 L/min).

Continuous pumping of water through the GAC columns was achieved by pre-treating and filtering batches of OOF2 water from T-001 to maintain a constant supply of pre-treated and filtered water in the batch holding tanks. The first phase of testing was performed using water from the first FRAC tank and maintaining continuous flow through the first train (‘A’ Train) through August 6, 2019. Calgon F400 GAC was tested in the carbon columns. The second phase of testing was initiated on August 7, 2019, using water inventoried in a second FRAC tank as described above. During the second phase of testing, batches of pretreated and filtered water were transferred in parallel to Batch Holding Tanks T-003A and T-003B for simultaneous treatment through the ‘A’ and ‘B’ series of carbon columns. During the second phase of testing, Calgon F400 was tested in the ‘A’ train, and Calgon DSR-A, a regenerated carbon, was tested in the ‘B’ train. This provided the opportunity to (1) provide a replicate study with F400; and (2) provide a direct comparison between F400 and an alternative GAC product using the same influent and pretreated water.

4.3 Monitoring and Maintenance

The pressure at the inlet to the first column along each operational treatment train was monitored daily, and the flow rate of effluent transferred to Treated Water Holding Tank T-004 was measured. Pressure was observed to build up due to the deposition of residual iron, other metal oxides (e.g., manganese oxide, aluminum oxide) and/ or formation of a biological growth within the first carbon column. In a full-scale treatment system, the buildup of material in a carbon column would be removed by backwashing the column; however, backwashing was not an option before the adsorption capacity was saturated since backwashing would disrupt the mass transfer zone. Therefore, as

an alternative which alleviated most of the pressure, the buildup of fouling material was periodically removed by agitating the top few inches of the carbon column to liberate the material building up in the front end of the column. It was assumed that the top few inches would be saturated by the time this maintenance was required during testing. The liberated material was pumped out using a peristaltic pump. After maintenance, the pressure and flow rate were re-measured. All monitoring and maintenance information was recorded in a dedicated operations field book.

4.4 Sampling

Parsons developed a sampling schedule intended to (1) provide information on breakthrough of target constituents through the four columns; and (2) provide relevant pretreatment information including iron, total suspended solids (TSS), and total organic carbon (TOC) removal. In summary:

- Table 3+ samples (including HFPO-DA) were collected daily in the effluent from the first GAC column, at least three time a week from the second GAC column, and twice a week from the third and fourth GAC columns. Table 3+ samples were also collected weekly from the untreated stored influent (prior to pretreatment) and from each pretreated/filtered batch. Table 3+ samples were submitted to Chemours' on-site laboratory for analysis.
- EPA Mod 537 MAX samples were collected two to three times a week from each GAC column during the first phase of testing, and one to three times a week during the second phase of testing. EPA Mod 537 MAX samples were also collected weekly from the untreated influent (prior to pretreatment) and from each pretreated/filtered batch. EPA Mod 537 MAX samples were submitted to TestAmerica Laboratories in Sacramento, California.
- Field duplicates for Table 3+ and EPA Mod 537 MAX (including HFPO-DA) were collected periodically and submitted to TestAmerica Laboratories in Sacramento. Samples were collected at a frequency of at least one field duplicate per 20 samples in accordance with project Quality Assurance Plan. The frequency of field duplicates was increased during the second phase of testing.
- Samples for conventional parameters including TOC, total iron/metals, field-filtered iron/metals, and TSS were also collected.
    - TOC samples were generally collected from the columns at the same time as PFAS samples.
    - Total iron/metals and field-filtered iron/metals were collected approximately weekly from each column. TSS was collected approximately weekly (first phase of testing) and bi-weekly (second phase of testing).
    - Conventional parameters were also collected regularly from influent and from pretreated batches.

The sample points were identified as follows:

Sample Point #	Sample Point ID	Description
SP-1	INF	Untreated Stored Influent
SP-2	PRE-A	Pretreated/Filtered Batch (‘A’ Train)
SP-3	GAC 1A	Column 1 Effluent (‘A’ Train)
SP-4	GAC 2A	Column 2 Effluent (‘A’ Train)
SP-5	GAC 3A	Column 3 Effluent (‘A’ Train)
SP-6	GAC 4A	Column 4 Effluent (‘A’ Train)
SP-7	GAC B	Pretreated/Filtered Batch (‘B’ Train)
SP-8	GAC 1B	Column 1 Effluent (‘B’ Train)
SP-9	GAC 2B	Column 2 Effluent (‘B’ Train)
SP-10	GAC 3B	Column 3 Effluent (‘B’ Train)
SP-11	GAC 4B	Column 4 Effluent (‘B’ Train)

This page intentionally left blank

5.0 RESULTS

Results available as of September 30, 2019 are summarized below and presented in the following appendices:

- Appendix B – Conventional parameter figures
- Appendix C – Comprehensive PFAS treatment results tables.
- Appendix D – Breakthrough curves for PFMOAA, HFPO-DA, and select additional parameters demonstrating progression of treatment through the GAC columns

5.1 Conventional Parameters

The figures in Appendix B show the removal of TOC, total iron, and soluble iron during pretreatment/filtration and GAC adsorption. Overall removal rates are summarized as follows:

Parameter	Pretreatment	Column 1	Column 2
TOC	< 5%	60%	> 71%
Total Iron	82%	95%	99%
Soluble Iron	> 98%	> 98%	> 98%

Most of the influent TOC remained following chemical precipitation, clarification, and settling, suggesting that most of the TOC was soluble and not amenable to removal by oxidation or coagulation by iron. There was no apparent trend of TOC breakthrough during GAC treatment which correlated with PFAS compound breakthrough. On average, around 60% of influent TOC was removed through the first GAC column, and treatment through the second column generally resulted in concentrations below the method detection limit.

Most iron was removed during chemical precipitation and filtration, although some remained (average of 18% of influent) going into the GAC columns. Changes in TSS between untreated and pretreated conditions demonstrated that some level of post-treatment oxidation occurred in the batch holding tanks just ahead of the GAC columns, and that sampling during transfer to the GAC columns may capture latent settling within these tanks. The ongoing buildup of material in the columns described above appears to reflect this effect. In a full-scale system, buildup of solid material in GAC vessels will be mitigated with a dedicated backwashing system.

5.2 PFMOAA

Pretreatment. Influent concentrations analyzed by the analytical laboratory were measured at an average of around 31 micrograms per liter (µg/L) in the first study and 25 µg/L in the second study. Pretreated and filtered flow concentrations decreased to around 22 µg/L in both studies, reflecting a decrease of around 12 to 32% during chemical precipitation and filtration. It should be noted that influent and pretreated samples showed considerable variability in analysis and, as such, any actual loss was inconclusive.

GAC Treatment and Breakthrough. PFMOAA started to break through F400 in Column 1 (GAC 1A) at around 8,000 liters treated and reached saturation in Column 1 at

approximately 22,600 liters treated. The onset of breakthrough at around 8,000 liters was demonstrated in both Test 1 and Test 2A; demonstrating repeatability of treatment with F400 GAC.

PFMOAA broke through F400 in Column 2 (GAC 2A) at a concentration approaching 1% of influent concentration (reflecting 99% removal) at approximately 24,200 liters. Additional data are pending to determine if similar breakthrough occurs in the second column (GAC 2A) as in the first test. No breakthrough in Columns 3 and 4 was demonstrated within the duration of each study.

PFMOAA broke through DSR-A more rapidly than through F400; breakthrough was observed in all four columns, with effluent concentrations approaching influent levels observed in GAC 1B and GAC 2B even before any breakthrough was detected in the corresponding F400 GAC columns along the 'A' train.

Field Duplicates. A comparison of results provided by the on-site analytical laboratory to results of field duplicate samples collected at the same time and analyzed by Chemours' contract independent analytical laboratory is provided in Appendix E. The ratio of results for PFMOAA at the PRE-A and GAC 1A effluent sample locations in the 1st phase of the study is summarized as follows:

- PRE-A: 3.75
- GAC 1A: 4.13

However, while this issue requires further investigation, the low bias was consistently observed; therefore, comparisons of influent and effluent changes remain valid. The biased-low results observed in the samples analyzed by the on-site laboratory do not change the breakthrough profile of PFMOAA and the other compounds; the progression of breakthrough to saturation would be reflected when column effluent concentrations approached the pretreated concentrations entering each column train as long as these data were all derived from the same analytical data set. Calculations of mass loading onto the GAC do require the unbiased commercially-provided results; the analysis of field duplicates has allowed a bias factor to be estimated and applied to provide the estimated concentrations used in these calculations presented below. Commercial certified laboratory analyses were used for isotherm test results which provided initial estimates of GAC utilization.

Estimated GAC Utilization. Estimated GAC utilization was calculated using data from the 1st phase of the study by assuming replacement of the lead carbon vessel upon saturation with PFMOAA. This calculation takes into account the complete exhaustion of the GAC in the 1st column (GAC 1A) plus the additional utilization of GAC in the 2nd column (GAC 2A) attributed to the PFMOAA present in the effluent from GAC 1A over the same period. This calculation was performed as follows:

- Calculate the GAC utilization in the 1st Column (GAC 1A) at saturation;
- Calculate the additional GAC utilization in the 2nd Column (GAC 2A) over the same period.

The on-site analytical data was scaled using the bias factor for PRE-A and GAC 1A samples cited above. The GAC utilization calculations are summarized as follows:

- Volume treated until saturation: 22,605 L (6,016 gal)
- Mass of carbon in GAC 1A: 2.48 lb
- PFMOAA mass loading onto GAC 1A: 1,832 mg
- Mass loading ratio (x/m) = 1,832 mg/[(2.48 lb)*(453.6 g/lb)] = 1.63 mg per g GAC
- Design basis influent PFMOAA concentration: 85 µg/L
- GAC Usage Rate = (85 µg/L)*(1 mg/1000 µg)/(1.63 mg/g) = 0.052 g/L
- Carbon Utilization in 1st column @ 500 gpm:
    - (0.052 g/L)*(3.785 L/gal)*(500 gal/min)*(1440*365 min/yr) = 114,400 lb/yr
- PFMOAA mass loading onto 2nd column = 633 mg (due to PFMOAA in GAC 1A effluent during same period)
- Carbon utilization in 2nd column = (633 mg/1,832 mg)*(114,400 lb/yr) = 39,500 lb/yr
- Total GAC Utilization @ 500 gpm = 114,400 + 39,500 lb/yr = **154,000 lb/yr**
- Total GAC Utilization @ 1,000 gpm = (1,000/500)*153,900 = **308,000 lb/yr**

It should be noted that the pilot system consistently demonstrated treatment of > 99% removal of PFMOAA in the effluent from the downstream columns GAC 3A and 4A. A similar analysis using data for the 2nd phase of the study will be provided in an addendum to this report.

5.3 HFPO-DA and Other Compounds

HFPO-DA. HFPO-DA concentrations were generally consistent in Studies #1 and #2 at approximately 4.6 to 4.7 µg/L, with no appreciable decrease during pretreatment/filtration. In the first study using F400 in the carbon columns, HFPO-DA started to break through F400 in Column #1 at around 12,000 liters treated; no breakthrough was detected through the second column. As such, PFMOAA would drive utilization based on adsorption kinetics, and the estimated GAC utilization calculated for PFMOAA would be expected to provide at least the required level removal of HFPO-DA.

HFPO-DA demonstrated relatively rapid breakthrough when treated through DSR-A (second study, 'B' train), although the rate and degree of breakthrough was not nearly as pronounced as it was for PFMOAA. This notable difference in breakthrough rates demonstrates that the rapid breakthrough observed through the DSR-A GAC was not a result of short-circuiting but rather reflected limitations in adsorption kinetics.

Perfluoromethoxypropionic acid (PMPA). During pilot testing with F400 GAC, PMPA started to break through the first column after approximately 7,000 liters treated, which is somewhat earlier than breakthrough of PFMOAA; a similar result was observed in the 1st and 2nd phases of the study Saturation of PMPA was reached at approximately 20,000 liters treated. PMPA started to break through the second column at approximately 23,000 liters treated, also slightly sooner than PFMOAA.

Estimated GAC utilization for PMPA treatment was calculated similarly to PFMOAA treatment in the event PMPA were to drive utilization, using data from the 1st phase of the study. The utilization calculations for PMPA treatment used the following bias-

factors based on a comparison of on-site analytical and contract laboratory field duplicate results for PMPA:

- PRE-A: 1.80
- GAC 1A: 1.75

The GAC utilization calculations for PMPA treatment are presented as follows:

- Volume treated until saturation: 19,802 L (5,232 gal)
- Mass of carbon in GAC 1A: 2.48 lb
- PMPA mass loading onto GAC 1A: 97.4 mg
- Mass loading ratio (x/m) = 97.4 mg/[(2.48 lb)*(453.6 g/lb)] = 0.087 mg per g GAC
- Design basis influent PMPA concentration: 5.4 µg/L
- GAC Usage Rate = (5.4 µg/L)*(1 mg/1000 µg)/(0.087 mg/g) = 0.062 g/L
- Carbon Utilization in 1st column @ 500 gpm:
    - (0.062 g/L)*(3.785 L/gal)*(500 gal/min)*(1440*365 min/yr) = 136,700 lb/yr
- PMPA mass loading onto 2nd column = 32.9 mg (due to PMPA in GAC 1A effluent during same period)
- Carbon utilization in 2nd column = (32.9 mg/97.4 mg)*(136,700 lb/yr) = 46,250 lb/yr
- Total GAC Utilization @ 500 gpm = 136,700 + 46,250 lb/yr = **183,000 lb/yr**
- Total GAC Utilization @ 1,000 gpm = (1,000/500)*182,950 = **366,000 lb/yr**

As with PFMOAA, PMPA was consistently removed by > 99% in the effluent from columns GAC 3A and 4A. It should be noted that influent concentrations of PMPA are over an order of magnitude lower than PFMOAA.

As with PFMOAA, PMPA demonstrated rapid breakthrough in DSR-A (second study, 'B' train).

Other Table 3+ PFAS Compounds. Breakthrough curves for other Table 3+ compounds which demonstrated breakthrough in F400 GAC including PFO2HxA, PFO3OA, PFO4DA, and PEPA are also presented in Appendix D. These compounds all started to break through Column 1 after approximately 12,000 to 20,000 liters treated, did not reach saturation in the first column, and did not show breakthrough in the second column during the study. Therefore, these compounds would undergo effective removal in a system whose GAC utilization was governed by PFMOAA treatment.

These other compounds also demonstrated more rapid breakthrough in DSR-A (second study, 'B' train) relative to F400. The varying rates between compounds provided evidence that the rapid breakthrough reflected adsorption kinetics limitations in the DSR-A and not short-circuiting.

Other PFAS Compounds (Method Mod 537 MAX). Other PFAS (Mod 537 MAX) compounds which showed some degree of breakthrough in the first column utilizing F400 GAC included PFBA, PFPeA, PFHxA, and PFHpA. Breakthrough curves of PFBA and PFPeA are presented for illustration. None of the Mod 537 MAX compounds were observed to break through the second column. It should also be noted that influent concentrations of these compounds were generally over two orders of magnitude lower than PFMOAA.

6.0 PILOT TREATMENT TEST CONCLUSIONS

The following conclusions were developed based on the pilot study.

- Chemical precipitation using oxidation and pH adjustment provided effective precipitation of native iron, which underwent nearly complete removal following polymer addition and filtration. Some residual iron oxidation and precipitation likely did occur which provided a degree of fouling in the GAC columns.
- DSR-A GAC did not demonstrate effective removal of the indicator and other PFAS compounds as evidenced by rapid breakthrough.
- F400 GAC demonstrated effective removal of the indicator compounds PFMOAA and HFPO-DA along with other tracked and reported PFAS compounds.
- Estimated F400 GAC utilization based on PFMOAA treatment was 154,000 to 308,000 pounds/year for a flow rate of 500 to 1,000 gpm.
- Estimated F400 GAC utilization based on PMPA treatment was 183,000 to 366,000 pounds/year based on a flow rate of 500 to 1,000 gpm.

This page intentionally left blank

APPENDIX A
PILOT TREATMENT SYSTEM
PROCESS FLOW DIAGRAM AND
EQUIPMENT GENERAL ARRANGEMENT

NO.	DESCRIPTION	DATE	DRAWN	CHK'D	APPV'D
1	AS-BUILT	9/13/2019	JHG	KCK	THS

DRAWN BY	JHG	DATE 5/14/19
CHECKED BY	KCK	DATE 5/14/19
APPROVED BY	THS	DATE 5/14/19
PROJECT MGR.	–	DATE –

SEAL

PARSONS
OFFICE
301 PLAINFIELD ROAD
SYRACUSE, NY 13212
(315) 451-9560

JOB 449338
WBS 01050

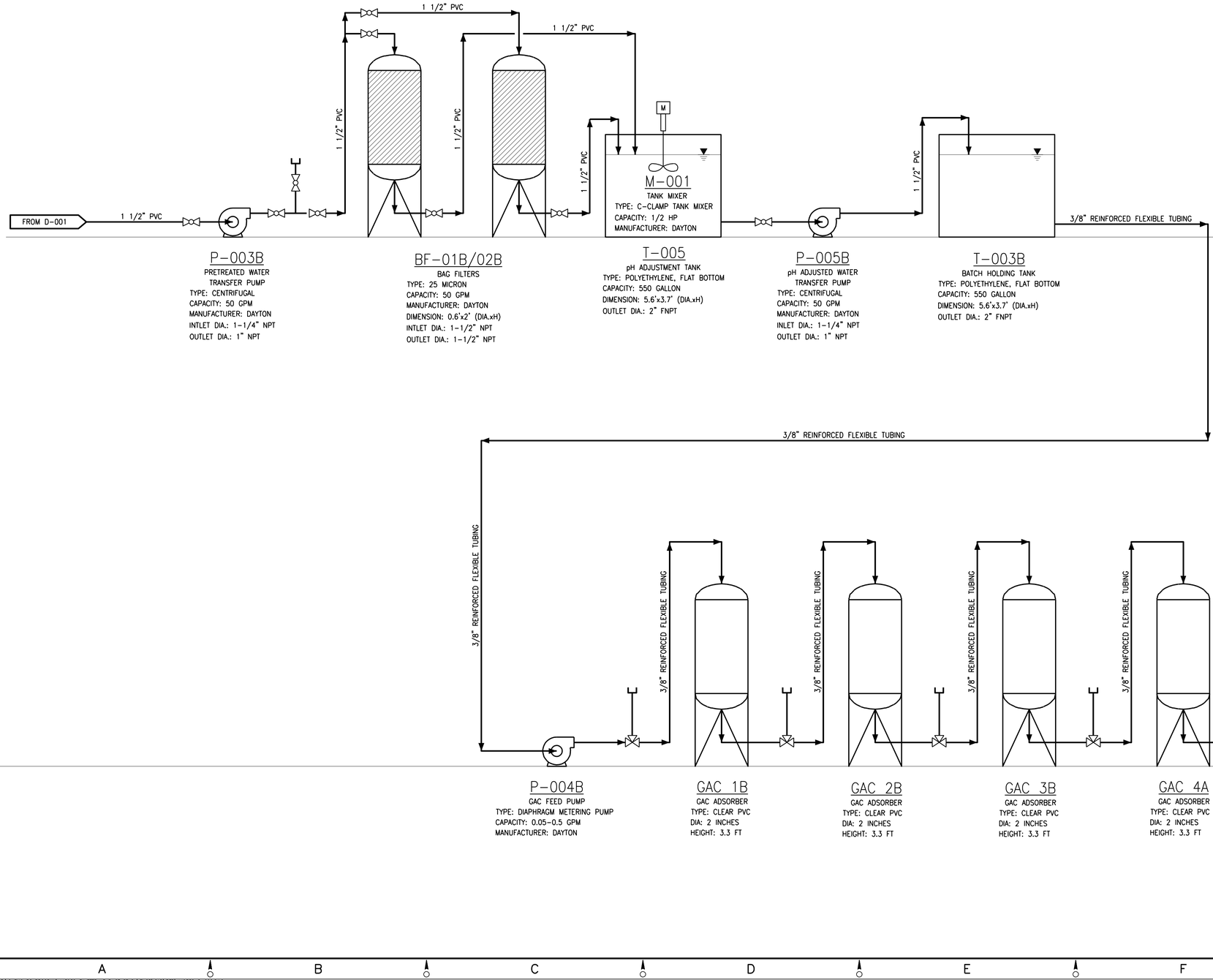
PROJECT TITLE
CHEMOURS
OLD OUTFALL 002 PILOT STUDY
22828 NC-87
FAYETTEVILLE, NC 28306

DRAWING TITLE
PROCESS
PILOT PLANT SCHEMATIC

SCALE NO SCALE

DRAWING NO. 449338-D-001
REV. 1

FILE NAME: P:\CHEMOURS PROGRAM\449338-FAYETTEVILE PILOT STUDY\ENGR\CAD\PFD\449338-D-001.DWG
PLOT DATE: 9/9/2019 4:30 PM PLOTTED BY: GOLDTHWAIT, JAMES



NO.	DESCRIPTION	DATE	DRAWN	CHK'D	APPV'D
1	AS-BUILT	9/13/2019	JHG	KCK	THS

DRAWN BY	JHG	DATE	5/14/19
CHECKED BY	KCK	DATE	5/14/19
APPROVED BY	THS	DATE	5/14/19
PROJECT MGR.	–	DATE	–

SEAL

PARSONS

OFFICE
301 PLAINFIELD ROAD
SYRACUSE, NY 13212
(315) 451-9560

JOB 449338

WBS 01050

PROJECT TITLE
CHEMOURS
OLD OUTFALL 002 PILOT STUDY

22828 NC-87
FAYETTEVILLE, NC 28306

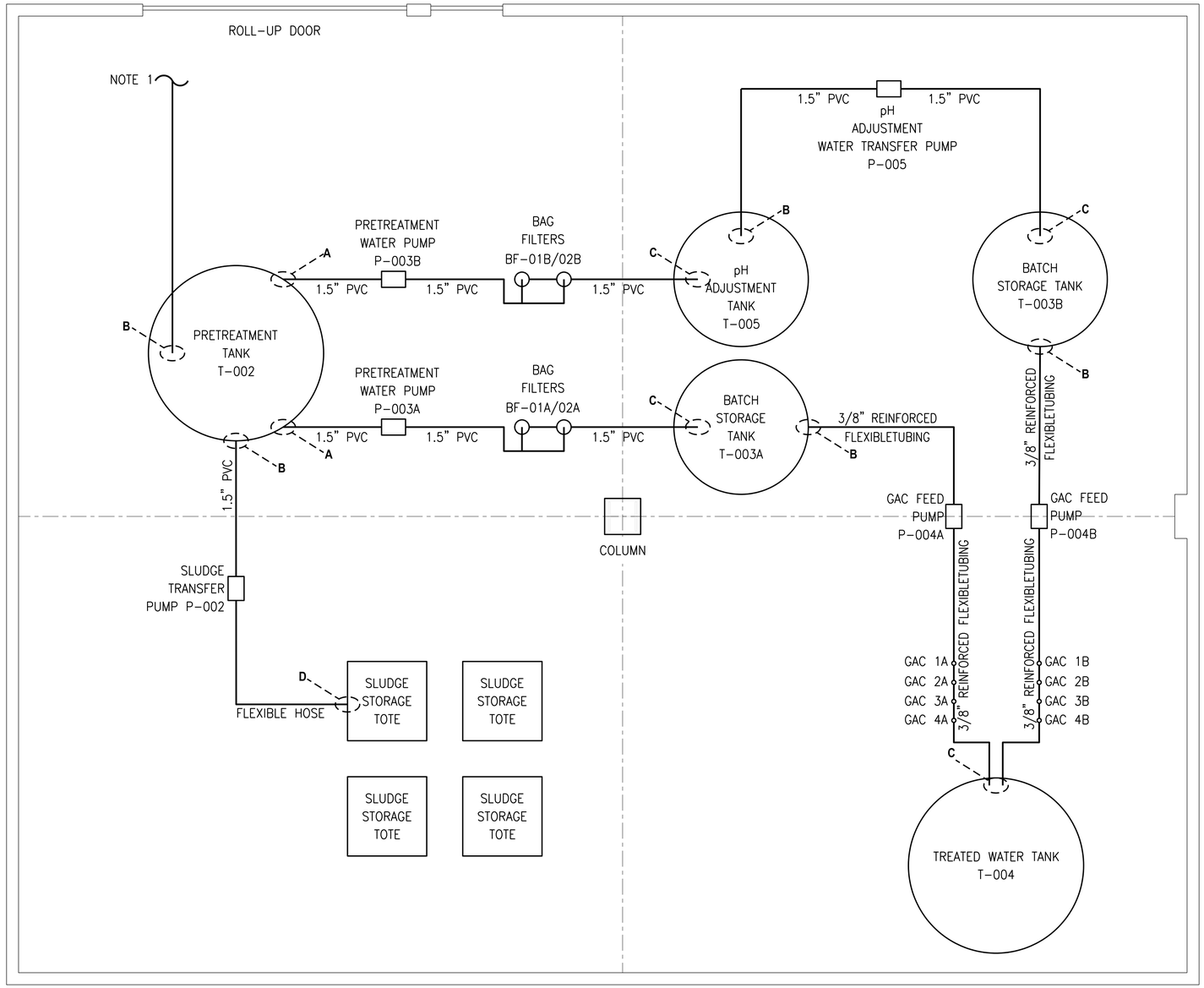
DRAWING TITLE
PROCESS
PILOT PLANT SCHEMATIC

SCALE NO SCALE

DRAWING NO. 449338-D-002

REV. 1

FILE NAME: P:\CHEMOURS PROGRAM\449338-FAYETTEVILE PILOT STUDY\ENGR\CAD\PFD\449338-D-002.DWG
PLOT DATE: 9/9/2019 4:27 PM PLOTTED BY: GOLDTHWAIT, JAMES



CONNECTION LEGEND:

- **A** CONNECTION MADE VIA FIELD-INSTALLED 2" MNPT BULKHEAD FITTING.
- **B** CONNECTION TO EXISTING 2" MNPT DRAIN ON TANK.
- **C** DISCHARGE INTO EXISTING TANK OPENING.
- **D** DISCHARGE INTO EXISTING TOTE OPENING.

NOTES:

1. THIS LINE CONNECTS TO PRETREATMENT FEED PUMP (P-001) LOCATED ADJACENT TO TEST WATER STORAGE TANK (T-001). LOCATION OF TANK TBD.

2 1 0 2 4
APPROXIMATE SCALE IN FEET

NOT FOR CONSTRUCTION

NO.	DESCRIPTION	DATE	DRAWN	CHK'D	APPV'D
0	ISSUED FOR REPORT	9/13/19	JHG	KCK	THS

DRAWN BY	JHG	DATE	5/14/19
CHECKED BY	KCK	DATE	5/14/19
APPROVED BY	THS	DATE	5/14/19
PROJECT MGR.	–	DATE	–

SEAL

PARSONS
OFFICE 301 PLAINFIELD ROAD SYRACUSE, NY 13212 (315) 451-9560

JOB 449338
WBS 01050

PROJECT TITLE
CHEMOURS
OLD OUTFALL 002 PILOT STUDY

22828 NC-87
FAYETTEVILLE, NC 28306

DRAWING TITLE
EQUIPMENT GENERAL ARRANGEMENT

SCALE: AS SHOWN

DRAWING NO. 449338-EA-001 REV. 0

FILE NAME: P:\CHEMOURS PROGRAM\449338-FAYETTEVILE PILOT STUDY\ENGR\CAD\PFD\449338-EA-001.DWG
PLOT DATE: 9/9/2019 4:22 PM PLOTTED BY: GOLDTHWAIT, JAMES

APPENDIX B
CONVENTIONAL PARAMETER FIGURES

APPENDIX C
COMPREHENSIVE PFAS TREATMENT RESULTS

APPENDIX D
BREAKTHROUGH CURVES FOR PFMOAA, HFPO-DA, AND SELECT PARAMETERS

APPENDIX E
COMPARISON OF CONTRACT AND ON-SITE ANALYTICAL LABORATORY RESULTS