STUDY TO ASSESS TREATMENT ALTERNATIVES FOR REDUCING PFAS IN LEACHATE FROM STATE-OWNED LANDFILLS

Prepared for

STATE OF MAINE DEPARTMENT OF ADMINISTRATIVE AND FINANCIAL SERVICES, BUREAU OF GENERAL SERVICES

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ACRONYMS/ABBREVIATIONS/UNITS

AECOM	Architectural Engineering Construction Operations and Management
AFFF	aqueous film forming foam
AOP	advanced oxidation process
AST	above ground storage tank
AWWA	American Water Works Association
BAT	Best Available Technology Economically Achievable
BDD	boron-doped diamond
BGS	Bureau of General Services
BOD5	biochemical oxygen demand
CD&D	construction and demolition debris
CHP	catalyzed hydrogen peroxide
CWA	Clean Water Act
DO	dissolved oxygen
DOC	dissolved organic carbon
EAOP	electrochemical advanced oxidation process
EGLE	Michigan Department of Environment, Great Lakes, and Energy
EMWWTP	East Millinocket Wastewater Treatment Plant
EQ	equalization
FF	foam fractionation
4:2FTS	1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid
6:2FTS	1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid
GAC	granular activated carbon
gpd	gallons per day
HALT	hydrothermal alkaline treatment
HFPO-DA	2,3,3,3-Tetrafluoro-2-[1,1,2,2,3,3,3-Heptafluoropropoxy]-Propanoic Acid
IDWS	Interim Drinking Water Standard
I&C	instrumentation and controls
I/I	Infiltration and Inflow
JRL	Juniper Ridge Landfill
IEX	ion exchange
lbs/d	pounds per day
MBR	membrane biological reactor
MCD	mechanochemical degradation
MCL	maximum contaminant levels
MCLGs	maximum contaminant level goals
MEPDES	Maine Pollutant Discharge Elimination System
MG	million gallons
MGD	million gallons per day
MGY	million gallons per year
MSW	municipal solid waste
NDWWTP	Nine Dragons Wastewater Treatment Plant
NF	nanofiltration
ng/l	nanograms per liter or parts per trillion
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OPEX	annual operation expenditures
ORP	oxidation-reduction potential

PFAS	perfluoroalkyl and polyfluoroalkyl substance
PFBA	perfluorobutanoic Acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFHxA	perfluorohexdecanoic acid
PFHxS	perfluorohexanesulfonic acid
PFHpA	perfluoroheptonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PITT	PFAS Innovative Treatment Team
psi	pounds per square inch
RO	reverse osmosis
SBIR	Small Business Innovative Research
SCADA	supervisory control and data acquisition
SCWO	supercritical water oxidation
SME	Sevee & Maher Engineers, Inc.
SME Team	Sevee & Maher Engineers, Inc. and Crawford Engineers
TBELs	technology-based effluent limitations
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UF	ultrafiltration
U.S.EPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
VTDEC	Vermont Department of Environmental Conservation
WAS	waste activated sludge
WQBELs	water quality-based effluent limitations
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

Resolve 2021, Chapter 172, required the Bureau of General Services (BGS) to conduct a study of methods to treat PFAS in leachate collected from the Juniper Ridge Landfill (JRL) in Old Town and the Dolby Landfill (Dolby) in East Millinocket. Specifically, the study was to identify readily available methods to reduce the concentration of six regulated PFAS (referred to as PFAS(6)) to no more than 20 ng/l, which is the Maine Interim Drinking Water Standard (IDWS) for PFAS in drinking water as per Resolve 2021, Chapter 82.

The ensuing Report contains findings of the study performed by BGS' consultant, Sevee & Maher Engineers, Inc., and their subconsultant, Crawford Engineering.

This Executive Summary reviews the sources and volumes of leachate collected at the Dolby and JRL landfills, provides a summary overview of available treatment technologies, identifies the technologies best suited for the two landfills, and summarizes the estimated costs for developing and implementing the PFAS treatment infrastructure for Dolby and JRL based on current leachate volume and PFAS concentration data from both facilities.

Report Qualifiers

- The is no known PFAS treatment standard for leachate. The report uses the State IDWS as the goal for PFAS treatment. It should be borne in mind that lower PFAS concentration guidance for drinking water is being considered by the State which could affect the conclusions in the Report. It is also possible that a PFAS treatment standard for leachate could be adopted in the future that could affect the conclusions in the Report.
- Funding sources for the PFAS treatment systems are not included in the Report.
- Responsibilities between the state and the JRL operator for leachate treatment and leachate treatment byproducts at JRL are not included in the report.
- The potential for portions of the PFAS treatment equipment to be leased by the state from a private party has not been evaluated for compliance with State of Maine procurement requirements.
- The report uses a five-year timeline for cost-comparisons of the various technologies identified. Based on the research performed, it is likely that some of the identified technologies will be improved while others may be found impractical in a true scale setting.

- The conclusions in the Report draw from PFAS data collected at Dolby and JRL as result of four leachate sampling events conducted between fall 2021 and summer 2022. Changes in the leachate PFAS content are possible and could affect the conclusions.

Sources and Volumes of Leachate - Dolby

Dolby has three separate landfills known as Dolby I, II and III; however, for purposes of the Report, the landfills are referred to collectively as "Dolby" unless specifically indicated otherwise.

The Dolby facility has been closed since 2012 and no longer accepts waste. It does, however, collect leachate from an area comprising 128 acres. To reduce the volume of rain, snow melt, and other infiltration percolating through the landfill and thus producing leachate, the state started capping Dolby with a geomembrane cover in 2016. The capping process is being conducted in stages, with the second phase scheduled to be complete in 2023. As of the date of the report, about 37 acres of Dolby are covered with geomembrane and 91 acres are covered with soil. Funding for the third stage of capping will be requested as part of a Maine Governmental Facilities Authority bond in the FY24 budget.

Leachate flow at Dolby typically averages 110,400 gallons per day (gpd) with peak monthly flows (during the springtime) reaching 227,000 gpd and peak daily flows of over 864,000 gpd. The leachate flow is expected to decline as more geomembrane cover is placed, however the Dolby Landfill also collects contaminated groundwater which will continue after all the geomembrane cap has been placed. Prior to starting the geomembrane cap, the highest springtime daily leachate flows at Dolby reached 864,000 gpd. The leachate from the landfill flows to an on-site storage pond and is then pumped through a pipeline to the East Millinocket Wastewater Treatment Plant (EMWWTP) where it combines with the sanitary wastewater from the Town of East Millinocket for biological treatment before discharge to the Penobscot River. The average daily wastewater flow from the Town is 343,000 gpd (which is over three times greater than the typical average daily leachate flow from Dolby). The combined maximum influent flow to the EMWWTP (i.e., Town wastewater plus Dolby leachate) has exceeded 2 million gallons per day (MGD) in the springtime since the EMWWTP was upgraded in 2019.

Sources and Volumes of Leachate – JRL

The State of Maine owns the land at JRL, but the landfill is operated entirely by NEWSME Landfill Operations, LLC ("NEWSME") under an Operating Services Agreement. Leachate is collected from 122-acres and typically flows at an average rate of 42,000 gpd. The average day leachate flow rate is expected to increase to 69,300 gpd in 2024 when another waste cell is opened and the peak day flow for 2024 is projected at 115,000 gpd. The JRL leachate flow will vary in the coming years as new cells are added and filled cells are permanently covered with geomembrane.

The JRL leachate flows to an on-site storage tank and is then trucked to the Nine Dragons (ND) Wastewater Treatment Plant (NDWWTP) in Old Town. The leachate combines with the wastewater from the ND Mill and undergoes treatment before discharge to the Penobscot River. The average daily wastewater flow from the Mill is over 20 MGD, which is almost 300 times greater than the average daily JRL leachate flow. The large wastewater flows from the ND Mill make treating the JRL leachate, once combined with the ND wastewater, impractical.

PFAS Concentrations in Dolby and JRL Leachate

Four leachate sampling events for PFAS (one in fall 2021 and three in spring 2022) indicated a PFAS(6) range of 351 to 4,426 ng/l (average of 1,725 ng/l and standard deviation of 1,670 ng/l) for Dolby, and a PFAS(6) range of 410 to 2,627 ng/l (average of 1,856 ng/l and standard deviation of 871 ng/l) for JRL. All the measured PFAS concentrations in the Dolby and JRL leachate exceeded the 20 ng/l IDWS for PFAS(6).

Overview of PFAS Treatment Technologies

Four commercially available treatment technologies were identified for removing PFAS(6) from the Dolby and JRL leachates: (1) treatment by "adsorption" media (e.g., granular activated carbon and ion exchange resins); (2) treatment by reverse osmosis (RO), which consists of high-pressure membrane filtration; (3) treatment by foam fractionation (FF), where PFAS molecules attach to air bubbles; and (4) electrochemical advanced oxidation process (EAOP), which destroys PFAS using electrically generated oxidizers. Of these potential treatment technologies, it is considered that EAOP, though attractive due to its potential for PFAS destruction ability, is limited in its capacity to economically handle the volumes of leachate generated at Dolby and JRL. Also, in comparison to the other PFAS treatment technologies, EAOP is promising but still not a maturely developed treatment process. Although effective at PFAS reduction, the EAOP effluent from Dolby and JRL would still require biological treatment before discharge to the environment.

RO, FF, and EAOP are typically used for "upfront bulk" PFAS removal before other forms of water treatment occur whereas adsorption is typically used to remove or polish PFAS from otherwise clean water. It is not uncommon for bulk removal to be paired with adsorption to further lower PFAS concentrations. The Dolby and JRL leachate once treated for PFAS by any of these methods will continue to be conveyed to the wastewater treatment plant(s) for biological treatment and discharge to the river. Use of adsorption media alone for treating the Dolby and JRL leachate after biological treatment is unlikely given that the high-volume wastewater flows would require multiple adsorption treatment units and the non-biological characteristics of the wastewater would rapidly deplete the effectiveness of the adsorption media.

PFAS Treatment Side Streams

Adsorption, FF, and RO technologies all have concentrated PFAS byproducts, or “side streams,” that need to be managed as waste. EAOP does not have a PFAS side stream. Adsorption results in large volumes of granular media containing concentrated PFAS. FF results in 0.5 to 1 percent of the influent flow becoming “foamate” containing concentrated PFAS. RO results in 10 to 12 percent of the influent flow becoming concentrated with PFAS. EAOP is very energy intensive and is not well developed for treatment of large volumes of leachate, however, EAOP could be used to manage the PFAS side streams from FF or RO.

Currently, most concentrated PFAS side streams from FF or RO are either “super-loaded” (i.e., bulk loaded) onto adsorption media or are stabilized/solidified; both side streams can then be disposed by landfilling, or in some situations the stabilized/solidified material can be used as landfill cover. Incineration of PFAS adsorption media is in use, however the end-products of thermal treatment are uncertain and currently incineration of PFAS is being re-examined by the U.S.EPA. At this time, there is no clear regulatory guidance for disposal of PFAS once it has been removed from leachate.

PFAS Treatment Alternatives for Dolby and JRL

PFAS treatment alternatives for the Dolby and JRL leachate include the following:

PFAS Treatment at the Dolby Landfill Site. Upfront treatment at the Dolby landfill site using FF, RO, or EAOP is expected to result in an effluent that meets Maine’s IDWS of 20 ng/l PFAS(6). The PFAS side streams from FF and RO treatment can be either destroyed on-site using EAOP or be super-loaded onto adsorption media for management as solid waste. Leachate treated for PFAS at the Dolby Landfill will continue to be piped to the EMWWTP for biologic treatment.

PFAS Treatment at East Millinocket Wastewater Treatment Plant. Adsorption of PFAS at the EMWWTP (with sufficient leachate pretreatment) should result in an effluent meeting the IDWS for PFAS(6) of 20 ng/l. However, PFAS adsorption at the EMWWTP on a typical day will result in treating three times more daily volume as compared to if treating the Dolby leachate alone. The ratio of wastewater to leachate volume can increase tenfold in the springtime due to the high volume of infiltration and inflow (I&I) associated with the Town’s sewer system. PFAS adsorption at the EMWWTP would require the biological effluent to be pretreated for non-biological parameters before PFAS adsorption to optimize life of the adsorption media.

PFAS Treatment at Juniper Ridge Landfill. The JRL leachate chemistry is very complex and exhibits high concentrations of total suspended solids, total dissolved solids, total organic carbon, ammonia, chloride, iron, manganese, and contaminants that need to be reduced by pretreatment before PFAS removal by adsorption can be efficient.

FF, RO, or EAOP performed at the JRL landfill site is expected to result in an effluent that has PFAS(6) less than 20 ng/l. Pretreating the JRL leachate in advance of FF, RO, or EAOP will only require simple filtration to avoid suspended solids from impacting operations. The concentrated PFAS side streams from FF and RO can be destroyed using EAOP or the foamate can be super-loaded onto an adsorption media for management as solid waste.

An additional JRL leachate alternative was considered but was determined to be cost prohibitive and potentially not technically feasible. This method would use on-site physical-chemical pretreatment of the leachate followed biological treatment using a membrane bioreactor (MBR) with the resulting MBR effluent receiving PFAS treatment by adsorption. Additional investigation of this treatment alternative is necessary to assure sufficient physical-chemical pretreatment of non-PFAS contaminants occurs to achieve MBR efficacy. Due to the complex chemical nature of the JRL leachate, there is a high probability that the leachate cannot be pretreated sufficiently to allow effective follow-up PFAS adsorption. PFAS adsorption of the Nine Dragons Wastewater Treatment Plant effluent (including the JRL leachate) was not considered due the high volume of wastewater from the Mill that would also need to be treated.

Conclusion

Available PFAS treatment technologies were evaluated for removing PFAS(6) from the Dolby and JRL leachates. Four technologies (FF, RO, EAOP, and adsorption) were identified as the most likely to reduce PFAS(6) to less than Maine's IDWS of 20 ng/l.

Best Technology for Treating Leachate Containing PFAS

The report concludes that Foam Fractionation (FF) is the best technology for reducing PFAS concentrations in the leachate from both Dolby and JRL. FF produces foamate as a byproduct that can be destroyed either by using EAOP or by super-loading the PFAS onto adsorption media (granular media) for management as solid waste. Stabilization/solidification of the foamate is also possible, however there are no known facilities in Maine performing that function

As would be expected, any reduction in the volume of leachate produced will also affect the cost of PFAS treatment. At Dolby, reduction of the leachate volume produced is being addressed by way of implement a geomembrane cover upgrade on Dolby III. At JRL the volume of leachate produced is largely a factor of open operating area and covered area. JRL uses temporary and permanent geomembrane to limit infiltration into the waste to minimize leachate production.

Cost Estimates

Cost estimates and notable issues for the Dolby and JRL leachate PFAS treatment alternatives are summarized in Table ES-1. The cost estimates focus on the range of leachate flows expected, overall leachate chemistry, and the range of PFAS(6) measured in the Dolby and JRL leachate for fall 2021 and spring 2022.

Cost for treating Dolby and JRL leachate for PFAS(6) using FF, including foamate treatment, (as of spring 2022) are as follows:

- FF leachate and foamate treatment at Dolby: $1.88 to $3.31 million per year plus $7.6 million infrastructure improvements for startup, which equates to a 5-year present worth range of $15.8 to $22 million.
- FF leachate and foamate treatment at JRL: $1.05 to $1.8 million per year plus $2.6 million for infrastructure improvements for startup, which equates to a 5-year present worth range of $7.2 to $10.4 million.

Next Steps

- Leachate quality monitoring, including testing for PFAS and conventional wastewater pollutants, should be conducted at a monthly frequency during 2023 to identify potential seasonal changes that could affect PFAS treatment selection. Treatment vendors will likely require such data before demonstration of any site-specific PFAS treatment method is considered.
- Pilot testing of the FF treatment technology should be scheduled for both landfills.
- Pilot testing of the EAOP treatment technology on both the leachate and foamate should be considered.
- Super-loading of PFAS in the FF foamate side stream onto adsorption media should also be evaluated.

TABLE ES-1

SUMMARY OF COST, RESIDUALS, AND EFFECTIVENESS OF PFAS TREATMENT ALTERNATIVES AT DOLBY AND JRL

I. DOLBY LANDFILL				
PROJECT ELEMENT	**FF AT DOLBY AND SUPER-LOAD FOAMATE ONTO IEX AND DISPOSAL**	**EAOP AT DOLBY**	**RO AT DOLBY AND EAOP TREATMENT OF CONCENTRATE**	**PFAS TREATMENT OF EMWWTP EFFLUENT AND GAC DISPOSAL**
A. COST SUMMARY				
Site Work/Project Development CAPEX	$4,430,000	$4,600,000	$4,600,000	$2,280,000
Equipment/Process Installation CAPEX	$240,000	Included in Annual Leases	$4,290,000	$5.9 to $9.6 million
Contingency/Engineering/CM	$2,991,040	$2,972,800	$5,680,000	$5.2 to $9.3 million
TOTAL CAPEX	$7,660,000	$7,620,000	$14,500,000	$13.4 to $19.5 million
Annual Leases/Other O&M Costs	$1.88 to $3.31 million per yr	$5.31 million per yr	$2.624 million per yr	$0.84 million per yr
Present Worth Cost of CAPEX	$7.6 million	$7.6 million	$14.6 million	$13.4 to $19.5 million
Present Worth Cost Leases/O&M Costs (1)	$8.1 to $14.3 million	$23.0 million	$11.4 million	$3.6 million
TOTAL 5-YEAR LIFE CYCLE PRESENT WORTH $	$15.8 to $22.0 million	$30.6 million	$25.9 million	$17.0 to $23.1 million
B. OTHER PERFORMANCE CRITERIA				
Ability to Meet PFAS(6) IDWS	Highly Probable: Dolby leachate successfully treated by FF in lab test	Promising: EAOP has treated leachate in bench and pilot studies	Highly Probable: RO has successfully treated leachate full scale	Questionable: Adsorption treatment needs extensive & effective pretreatment
Residuals Requiring Further Management	FF Foamate of 550 gpd to be super-loaded on IEX and LF disposed or treated by EAOP	No residual side streams requiring management	RO concentrate of 11,000 gpd to be treated by EAOP; significant volume and cost for concentrate treatment	Spent GAC requires off-site management; biosolids in lagoons likely tainted with PFAS
Pretreatment Requirements	Process is resilient and effective with simple filtration (if necessary)	Process is resilient and effective with simple filtration (if necessary)	Process is resilient and effective with filtration and pH adjustment	Significant pretreatment of high volume EMWWTP effluent critical

TABLE ES-1 (cont'd)
SUMMARY OF COST, RESIDUALS, AND EFFECTIVENESS OF PFAS TREATMENT ALTERNATIVES AT DOLBY AND JRL

II. JUNIPER RIDGE LANDFILL				
PROJECT ELEMENT	**FF AT JRL AND SUPER-LOAD FOAMATE ONTO IEX AND DISPOSAL**	**EAOP AT JRL**	**RO AT JRL AND EAOP TREATMENT OF CONCENTRATE**	**PRETREATMENT AND PFAS ADSORPTION AT JRL AND GAC DISPOSAL**
A. COST SUMMARY				
Site Work/Project Development CAPEX	$1,470,000	$1,580,000	$1,510,000	$1,420,000
Equipment/Process Installation CAPEX	$130,000	Included in Annual Leases	$3,400,000	$8,940,000
Contingency/Engineering/CM	$1,020,000	$1,010,000	$3,140,000	$6,630,000
TOTAL CAPEX	$2,630,000	$2,590,000	$8,050,000	$17,000,000
Annual Leases/Other O&M Costs	$1.05 to $1.8 million	$2.52 million	$2.04 million	$0.74 million
Present Worth Cost of CAPEX	$2.63 million	$2.59 million	$8.05 million	$17 million
Present Worth Cost Leases/O&M Costs (1)	$4.54 to $7.81 million	$10.9 million	$8.81 million	$3.21 million
TOTAL 5-YEAR LIFE CYCLE PRESENT WORTH $	$7.2 to $10.4 million	$13.5 million	$16.9 million	$20.2 million
B. OTHER PERFORMANCE CRITERIA				
Ability to Meet PFAS(6) IDWS	Highly Probable: JRL leachate successfully treated by FF in 2 lab tests	Promising: EAOP has treated leachate in bench & pilot studies similar to JRL	Highly Probable: RO has successfully treated leachate full scale similar to JRL	Highly Doubtful: Adsorption treatment needs extensive & effective pretreatment
Residuals Requiring Further Management	FF Foamate of 350 gpd to be super-loaded on IEX and LF disposed or treated by EAOP	No residual side streams requiring management	RO concentrate of 6,900 gpd to be treated by EAOP; significant volume and cost for concentrate treatment	Two sludge streams and spent GAC requires management
Pretreatment Requirements	Process is resilient and effective with simple filtration (if necessary)	Process is resilient and effective with simple filtration (if necessary)	Process is resilient and effective with filtration and pH adjustment	Significant pretreatment of complex JRL leachate required

Note:

[1] Present worth cost presented for five-year period with interest rate of 5 percent.

STUDY TO ASSESS TREATMENT ALTERNATIVES FOR REDUCING PFAS IN LEACHATE FROM STATE-OWNED LANDFILLS

1.0 INTRODUCTION

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals manufactured since the 1940s. They were widely used in Teflon and other non-stick household products, stain repellants, waterproof clothing, food paper packaging such as coffee cups and pizza boxes, lubricants, aqueous film forming foam (AFFF), and many other consumer products. The substances have been referenced as "forever chemicals" due to the strength of the PFAS carbon-fluorine bond that comprises each PFAS molecule, which is not susceptible to natural degradation or treatment using typical processes. PFAS have been detected in surface waters, groundwater, drinking water, wastewater treatment plant (WWTP) effluents, and in landfill leachate. Over the past five years, the United States Environmental Protection Agency (U.S.EPA) and other state environmental agencies have identified landfill leachate as a potentially significant source of PFAS to the environment.

Maine passed Resolves 2021, Ch. 172[1] "to address PFAS Pollution at State-Owned Solid Waste Landfills." This law includes language relative to the Bureau of General Services (BGS) completing a study of methods for treating leachate at the State-Owned landfills. Sevee & Maher Engineers, Inc. and Crawford Engineers (i.e., the SME Team) were contracted by BGS to conduct a study (i.e., the Study) to identify and assess treatment alternatives for reducing the concentration of PFAS in the leachate collected from the State-Owned solid waste landfills in East Millinocket (i.e., the Dolby Landfill also known as Dolby) and in Old Town (i.e., the Juniper Ridge Landfill also known as JRL). Figures 1-1 and 1-2 show aerial views of Dolby Landfill and JRL, respectively.

- A copy of Resolves 2021, Ch. 172, which defines the scope of the Study is presented as Appendix A. In 2021, MEDEP adopted an Interim Drinking Water Standard (IDWS) of 20 nanograms per liter (ng/l) for the sum of six specific PFAS in drinking water (see Appendix A for a copy of Resolves 2021, Chapter 82), referred to as PFAS(6) for the Study

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[1] This law stipulates that "BGS and its consultant shall consider treatment technologies other than dilution that are available or under development and that could be designed and installed on-site at the landfills or at an off-site treatment facility to reduce PFAS substances in the leachate to no more than the interim drinking water standards established pursuant to Resolve 2021, Chapter 82. If treatment to that standard is determined by BGS to not be feasible based on available treatment technologies, BGS may, with input from the Maine Department of Environmental Protection (MEDEP), consider options to reduce PFAS substances in the leachate to a different standard".

and this Report. The six PFAS are perfluorooctanoic acid (PFOA), perfluorooctanesulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and perfluorodecanoic acid (PFDA). The Study uses the PFAS(6) IDWS of 20 ng/l as the leachate treatment goal.

This Report presents the findings of the Study authorized by BGS. The Report contains nine sections with associated tables, figures, and appendices. Sections 1.0 through 5.0 provide background information relative to PFAS in general, information specific to the physical characteristics of the Dolby and JRL landfills relative to leachate production, and the quality of the leachate from those facilities relative to PFAS presence and other leachate chemistry that will influence PFAS treatment. Sections 6.0 and 7.0 examine the variety of PFAS treatment alternatives that are potentially available for leachate and describe a group of treatment alternatives considered practical for implementation at Dolby and JRL. Section 8.0 evaluates the costs and feasibility for the various treatment alternatives, and Section 9.0 summarizes the findings of the Study and offers steps to consider for preparation to treat PFAS in the Dolby and JRL leachates.

NOTE:
1. AERIAL IMAGE FROM GOOGLE EARTH, DATED SEPTEMBER 6, 2022.

FIGURE 1-1
EXISTING CONDITIONS DOLBY LANDFILL
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: LMN CTB: SME-STD REV: 11/30/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SITEOVERVIEW.dwg, FIGURE 1-1, 11/30/2022 2:08:07 PM, jrl

NOTE:
1. AERIAL IMAGE LOW ALTITUDE AERIAL PHOTOGRAMMETRIC MAPPING PERFORMED BY SEVEE & MAHER ENGINEERS, INC., DATED NOVEMBER 9, 2022

FIGURE 1-2
EXISTING CONDITIONS JUNIPER RIDGE LANDFILL
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: LMN CTB: SME-STD REV: 11/30/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SITEOVERVIEW.dwg, FIGURE 1-2, 11/30/2022 2:08:09 PM, jrl

2.0 PFAS IN THE ENVIRONMENT

2.1 Physical and Chemical Properties of PFAS

PFAS are a group of approximately 5,000 chemical substances that all consist of carbon chain molecules in which hydrogen atoms have been partly or entirely replaced with fluorine atoms. PFAS are resistant to heat, water, and oil; they have been used in industries such as metal-plating and semiconductor manufacturing, and they are used in producing household items such as nonstick frying pans, waterproof clothing, and wrappings for greasy foods. A widespread use of PFAS has been for the manufacture of aqueous film forming foam (AFFF) that is used for extinguishing fires involving flammable liquids. Perfluoroalkyl substances have a fully fluorinated carbon chain, while polyfluoroalkyl substances have a partially fluorinated carbon chain. The two most prevalent PFAS detected in the environment and the most widely researched are PFOA and PFOS.

PFAS can be harmful to human health, causing cancer, liver damage, thyroid effects, changes in cholesterol, and a depressed immune system, among others (ITRC, 2020). Some of the physical and chemical characteristics of PFAS include:

- PFAS are man-made chemicals that are NOT readily biodegradable. Some PFAS do not degrade at all, while others break down very slowly, often into other PFAS. The non-biodegradable characteristic is the result of the carbon-fluorine bond, which is among the strongest of the molecular bonds for carbon. As a result, PFAS routinely pass through conventional biological water and wastewater treatment systems without changing.
- Recent studies have shown leachate may contain precursors that can be converted into persistent and non-biodegradable perfluoroalkyl acids when released to the environment and/or during treatment (ITRC, 2020). This suggests that traditional water or wastewater treatment processes have the potential to convert PFAS precursors into other PFAS with their own unique characteristics.
- PFAS are chain molecules that have a hydrophilic head (water attracting) connected to a long perfluoroalkyl or polyfluoroalkyl tail that is hydrophobic (water repellent). The dual hydrophilic and hydrophobic properties of PFAS appear to result in the PFAS forming very thin layers between liquids (e.g., water and organic solvents) and solid surfaces (CHEM Trust, 2019).
- In general, longer-chain PFAS molecules are easier to remove from water than short-chain PFAS molecules. Longer-chain PFAS generally have good surfactant (i.e., foaming)

properties and can fractionate onto foam (i.e., bubble) surfaces with little effort helping treatment efficiency. Shorter-chain PFAS have lower surfactant properties and are more soluble, and thus have reduced treatment efficiencies through fractionation compared to longer-chain PFAS.

- Longer-chain PFAS are thought to be more likely to attach to soil or sediment, or to partition to biosolids in a WWTP, as compared to shorter-chain PFAS (ATSDR, 2018; ITRC, 2020).
- PFAS have the ability to resist oil, grease, water, and heat.
- PFAS, for all practical purposes, are resistant to degradation by external factors such as ultraviolet (UV) light, common oxidants, reducing agents, or high temperatures.
- Vapor pressure and Henry's law constant are an indication of the tendency of a substance to partition into the gas phase. Most PFAS, in contrast to volatile chemicals such as ethylbenzene, toluene, or methylene chloride, do not have a strong propensity to volatilize into the gas phase. Moreover, most PFAS will remain dissolved in water rather than volatilize into the vapor phase, making most PFAS not readily amenable to treatment technologies that would take advantage of a substance's volatility such as air stripping or conventional oxidation. It is noted that some short-chain and ultra-short-chain PFAS can volatilize but are typically not in sufficient concentration within water containing PFAS to make vapor phase treatment attractive.
- Many PFAS preferentially form films at the air-water interface, with the hydrophobic carbon-fluorine tail oriented toward the air and the hydrophilic head group dissolved in the surrounding water (Kraft and Reiss, 2015). This unique molecular behavior suggests that PFAS will accumulate at the interface of water-air structures such as foam (i.e., bubbles) so that the PFAS-loaded bubbles can then be transported to the water surface and removed (Ross I, et al., 2018). Leachate with high total organic carbon (TOC) concentrations and high ionic strengths are easier to generate foams with, which improves PFAS sorption to bubbles, which exhibit large air-water interface surfaces.
- The organic carbon to water partition coefficient for PFAS indicates that most PFAS will attach to adsorption media[2] such as granular activated carbon (GAC) and ion exchange (IEX) resin. In general, longer-chain PFAS molecules (i.e., when the chain involves eight or more carbon atoms) are more easily adsorbed by GAC and IEX resin than PFAS with

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[2] For purposes of this Report, the term "adsorption" has been used interchangeably with, and as a replacement for, the term "absorption." The Report writers recognize that the adsorption and absorption processes are separate and different, and that both can play a role in PFAS treatment when using porous media or resin. The term "adsorption" is used in the Report only for simplicity.

shorter-chain molecules. GAC media takes advantage of the hydrophobic tail of the PFAS for adsorption onto the carbon, while IEX resins attract both the hydrophobic tail and hydrophilic head of the PFAS for adsorption. Generally, sulfonic acids (such as PFOS) are more readily retained on the GAC and IEX media as compared to carboxylic acids (such as PFOA). Shorter-chain perfluorinated carboxylic acids (e.g., PFBA and PFPeA) are typically the first PFAS to exceed the adsorptive capacity of a media/resin and exhibit "breakthrough" (i.e., pass through the adsorptive media without being retained).

- PFAS are incorporated within AFFF to enhance the ability to quickly extinguish petroleum-based fires.

2.2 Fate and Transport of PFAS in the Environment

One of the primary routes for human exposure to PFAS is the ingestion of drinking water tainted with PFAS. The difficulty in breaking down PFAS, combined with the fact that many of the substances are highly soluble, mobile in the environment, and bio-accumulative, means there is a risk that drinking water supplies will continue to become contaminated for years to come.

Widespread use of PFAS in consumer products and manufacturing processes, in conjunction with their extreme resistance to degradation, has resulted in PFAS being detected in municipal and industrial wastewaters. While WWTPs are not the source of PFAS, they are a "control collection point." The Interstate Technology Regulatory Council has identified effluents and biosolids from WWTPs as potential PFAS pathways into the environment (ITRC, 2017).

PFAS have been detected with regularity in leachate from solid waste landfills across the nation. The solubility and non-biodegradability of PFAS in leachate is of great concern, since PFAS are readily mobile in the water environment and are extremely resistant to conventional forms of treatment. Due to the strong carbon-fluorine bonds, PFAS are practically indestructible in nature and scientists estimate they could persist in the soil environment for thousands of years (ITRC, 2022). Also, due to the unique chemical makeup of PFAS and their persistent presence in the environment, some PFAS have a propensity to bioaccumulate in living organisms. Health agencies continue to work to understand the health effects of long-term exposure to low concentrations of PFAS.

3.0 DESCRIPTION OF STATE-OWNED LANDFILLS

The State of Maine owns the Dolby Landfill in East Millinocket and the JRL in Old Town, and BGS is responsible for operation of those landfills. The State of Maine has owned the Dolby Landfill since 2011 and JRL since 2004. The Dolby Landfill is a closed facility and no longer accepts waste. The JRL facility is leased to NEWSME Landfill Operations, LLC, who is responsible for operation and management of JRL. A detailed description of each landfill is presented in the Site Reconnaissance Meeting Notes included in Appendix B. In addition, photographs from the Dolby Landfill, JRL, and the EMWWTP are included as Appendix C.

3.1 Dolby Landfill – East Millinocket, Maine

The Dolby Landfill facility consists of three landfill sites (Dolby I, Dolby II, and Dolby III) that have a combined area of approximately 151 acres. Dolby I is the oldest of the three landfills, is not contiguous with Dolby II and III, and does not collect leachate. The Dolby II and Dolby III Landfills are positioned side by side and share the same leachate collection infrastructure. Figure 1-1 shows the general layout of the three Dolby landfill sites. The Dolby Landfill facility is located on the east side of Route 157, approximately 2.5 miles northwest of the town of East Millinocket. Waste was received at Dolby beginning in 1975, and the landfill was closed in 2012.

3.1.1 Dolby Landfill Overview

The Dolby I Landfill occupies about 23 acres southwest of Dolby II and III. The principal waste streams deposited at Dolby I were wastewater treatment sludge, woodroom/woodyard waste, wood ash, and general rubbish from the nearby Millinocket and East Millinocket Mills. Waste was disposed in Dolby I from 1975 to 1979 and a final soil cover was placed over Dolby I in 1980 and 1981. Dolby I is an unlined landfill and leachate is not collected. Rather, Dolby I is an attenuation landfill where leachate is allowed to seep into the underlying soil for natural treatment (similar to treatment by way of a leachfield).

Dolby II is immediately east and upslope of Dolby III and occupies about 63 acres. The principal waste streams delivered to Dolby II were woodroom/woodyard waste, wastewater treatment sludge, wood ash, general rubbish from the Millinocket and East Millinocket Mills, and municipal solid waste (MSW) from the towns of Millinocket and East Millinocket. Waste placement at Dolby II occurred from 1979 to 1986. A final soil cover was placed over Dolby II in 1987. Dolby II is an unlined landfill. Leachate and groundwater from Dolby II are collected by a perimeter cutoff drain, which flows by gravity to the Dolby leachate storage pond.

Dolby III occupies about 65 acres and was operated as contiguous cells. The original waste streams at Dolby III were wastewater treatment sludge, woodroom/woodyard waste, wood ash, rubbish from the Millinocket and East Millinocket Mills, and MSW from the local communities. The disposal of MSW at Dolby was stopped in 1993 due to a change in solid waste regulations. Dolby III was operated as contiguous waste cells and the cells received final soil cover as the cells were filled. Beginning in 2016, the Dolby III cover has been in the process of being upgraded by installation of a geomembrane barrier layer. As of the end of 2022, approximately 37 acres of geomembrane will have been installed. Dolby III is an unlined landfill. Leachate and groundwater from Dolby III are collected by an underdrain layer (below approximately half of the Doby III footprint) and perimeter cutoff drain, which flows by gravity to the leachate storage pond.

The Dolby leachate storage pond is positioned west of Dolby III and has an overall volume of approximately 5 MG; 2 MG of the volume are used for active leachate storage, and the remaining 3 MG are made up of the volume used to keep the inlet and outlet submerged to resist freezing conditions and provide freeboard for overflow protection. Leachate is pumped from the pond by way of a pump station and pipeline that connects to the EMWWTP. Leachate pumping occurs on an automatic basis to maintain availability of the 2-MG storage volume in the pond.

3.1.2 Dolby Leachate Flows

The leachate from Dolby II and Dolby III shares the leachate collection piping that flows to the leachate storage pond. The leachate storage pond provides temporary equalization of the leachate inflow before it is pumped to the EMWWTP for treatment. From 2010 to 2021, the combined volume of leachate inflow from Dolby II and III averaged approximately 46.4 million gallons per year (MGY) or roughly 127,000 gpd. It is estimated that about 25 percent of the leachate is contributed by Dolby II and the other 75 percent is from Dolby III. In the spring, when leachate flows are highest, the leachate storage pond pumps may run 24 hours per day, seven days per week for several weeks; while during drier months the pumps cycle much less frequently. At peak inflows, the pumps remove leachate at a rate of 450 to 650 gpm. For 2020-2021, the average leachate inflow was about 127,000 gpd and the maximum monthly flow during this two-year period was 516,000 gpd (occurred in April 2020). In contrast, during 2021, the maximum monthly leachate flow (i.e., March) was 227,000 gpd. Table 3-1 provides a breakdown of the leachate inflows for the 2020-2021 period. The different maximum monthly flows for 2020 and 2021 show the sensitivity to spring thawing conditions.

The Dolby III Landfill (approximately 65 acres) was closed with a soil final cover and is in the process of having that soil cover upgraded to include a geomembrane layer. The geomembrane is essentially impervious to infiltration, which will help reduce the future volume of leachate coming from Dolby III. As of the end of 2022, approximately 37 acres of the Dolby III cover will have been upgraded with geomembrane. Approximately 18 acres of Dolby III is expected to receive the cover upgrade in 2023 and the remaining portion of Dolby III is anticipated to receive cover upgrade in 2025, or soon thereafter. The average daily leachate flow for Dolby II and III is expected to be reduced to 88,500 gpd (from 127,000 gpd), once the Dolby III cover upgrade is complete. Table 3-1 includes a 20-year leachate flow projection (i.e., 2024 through 2043) that was used for evaluating wastewater treatment flows for the Study. The Dolby II Landfill (approximately 63 acres) was closed with a soil final cover, which is subject to precipitation infiltration. There are currently no plans to upgrade for the Dolby II soil cover.

3.1.3 Dolby Leachate Treatment

Leachate from the Dolby storage pond is pumped roughly 3.7 miles to the EMWWTP, where it combines with sanitary wastewater from the Town of East Millinocket before treatment. The leachate volume on average is roughly 30 percent of the total EMWWTP influent flow; the other 70 percent is the sanitary wastewater. The sanitary wastewater has a high contribution of clean groundwater and stormwater infiltration and inflow (I/I). The combined sanitary wastewater and leachate are treated using an extended aeration process and the treated effluent is discharged to the Penobscot River.

Figure 3-1 presents a flow schematic for how the leachate and sanitary wastewater flows combine and are treated at the EMWWTP. The leachate and sanitary wastewater are combined in EMWWTP's sanitary manhole 106B (SMH-106B). Neither the leachate nor the sanitary wastewater receives any pretreatment before entering the EMWWTP. The combined leachate and sanitary wastewater flow is treated by mechanical screens, a vortex grit removal process, an extended aeration process that uses two lagoons (combined volume of 17.2 MG), disinfection with sodium hypochlorite, and is finally dechlorinated via sodium bisulfite.

The EMWWTP has a design capacity of 2.0 MGD and the MEPDES permit for the plant was issued in October 2015. Over the past two years, the EMWWTP influent flow has averaged about 0.47 MGD, the maximum monthly flow was 1.42 MGD, and peak flows of over 2.0 MGD have been recorded. The EMWWTP includes a supervisory control and data acquisition (SCADA), flow monitoring, automatic flow paced samplers, and continuous monitoring for dissolved oxygen (DO) and chlorine residual. Sludge accumulates within the two lagoons that is projected to require removal and disposal about every 20 to 30 years. The EMWWTP was upgraded in 2019 and has since been in compliance with all parameters of its MEPDES permit. The MEPDES permit currently has no effluent discharge limits for PFAS.

3.2 Juniper Ridge Landfill – Old Town, Maine

The JRL Landfill facility consists of a single footprint of 17 contiguous waste disposal cells that extend over approximately 122 acres, which are located on the west side of Route 16 in (West) Old Town, Maine (approximately 1/2 mile from I-95 Exit 199). JRL is an active operating landfill that started receiving waste in 1996.

3.2.1 JRL Overview

JRL is a lined landfill that was originally permitted for the disposal of pulp and papermaking residuals (primarily wastewater treatment sludge) from the Fort James/GP Old Town mill, ash from Lincoln Pulp and Paper, and burn pile ash from the City of Old Town transfer station. JRL is currently permitted to accept residues from waste-to-energy facilities (i.e., bypass municipal solid waste), construction demolition and debris (CD&D), and other non-hazardous wastes generated within the State of Maine.

JRL includes the original 68-acre landfill footprint (Cells 1 through 10) and an approved 54-acre expansion for Cells 11 through 17. Cells 11, 12, and 13 were constructed in 2018, 2020, and 2021, respectively, Cell 14 in 2022, and Cells 15, 16, and 17 are yet to be constructed. JRL was constructed as a non-hazardous secure waste disposal facility and as such collects all leachate generated by the waste. At the time of this Report, no final geomembrane cover had been placed over the JRL waste deposit; however, several cells had received intermediate final geomembrane cover to help reduce precipitation infiltration.

Leachate from JRL cells is collected in leachate collection systems that flow to several pump stations located around the landfill perimeter. The pump stations are automatically controlled, and pump the leachate to an on-site 0.912-MG above ground leachate storage tank. The leachate storage tank is connected to a leachate tank-truck loading rack. Leachate is trucked to the NDWWTP for treatment. The haul distance from JRL to NDWWTP is approximately 9 miles.

3.2.2 JRL Leachate Flows

During 2020 and 2021, the total quantity of JRL leachate sent to NDWWTP was about 15.2 MGY or roughly 42,000 gpd. As shown in Table 3-2, average leachate flows from JRL (for 2020 and 2021) range from 31,100 to 60,000 gpd. The on-site leachate storage tank provides a buffer that allows consistent volumes of leachate to be trucked daily. The JRL operator estimates that 8 to 10 truckloads of leachate per day are delivered to NDWWTP, five days per week. Tank-trucks with volumes of 6,800 gallons, 7,200 gallons, and 8,300 gallons are typically used to truck the JRL leachate.

For purposes of the Study, a 20-acre landfill expansion at JRL is anticipated for 2028.[3] Preliminary projections are for the expansion to consist of four 5-acre cells. The leachate generation per acre has been calculated and integrated into the future leachate collection volumes. Table 3-2 includes a 20-year leachate flow projection (i.e., 2024 through 2043) that was used for evaluating wastewater treatment flows from JRL for the Study. Although the current average leachate flow is about 42,000 gpd, an increase in leachate volume is expected for 2023 to 2027 due to the addition of the remaining permitted cell areas at JRL (2024 flow is estimated at 69,300 gpd). By the end of 2043 (once final geomembrane cover has been installed over all JRL cells), the leachate flow is expected to decline to approximately 9,000 gpd. Operational leachate flows at JRL are minimized though the use of intermediate geomembrane covers. The intermediate geomembrane covers are applied to areas containing waste, but which have become inactive as waste filling in adjacent areas is occurring.

3.2.3 JRL Leachate Treatment

Leachate collected from JRL is pumped from the waste disposal cells to a 0.912-MG on-site leachate storage tank (see Figure 4-4). The leachate is then trucked to the NDWWTP in Old Town, where it is blended with over 20 MGD of pulp and paper wastewater (see Figure 4-5) before treatment. The NDWWTP provides both primary and secondary treatment before the effluent is discharged to the Penobscot River. Figure 3-2 presents a flow schematic that shows how the JRL leachate and Nine Dragons wastewater flows combine; neither the JRL leachate nor Nine Dragons wastewater receive any pretreatment before entering the NDWWTP. The combined JRL leachate and Nine Dragons wastewater flow is treated using mechanical screens, primary clarifiers, an aeration lagoon system, and secondary clarifiers.

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[3] The 20-acre landfill expansion has not yet been permitted by MEDEP; part of the permitting process will involve submission of a landfill application by NEWSME to MEDEP and a determination by MEDEP that the expansion will result in a public benefit.

TABLE 3-1

FLOW SUMMARY FOR DOLBY LANDFILL LEACHATE AND EMWWTP INFLUENT

Month	2020 EMWWTP Influent[1] (MGD)	2020 Dolby Leachate (MGD)	2021 EMWWTP Influent[1] (MGD)	2021 Dolby Leachate (MGD)	2-Year Avg EMWWTP Influent[1] (MGD)	2-Year Avg Dolby Leachate (MGD)	2-Year Avg EM Sanitary Influent (MGD)	Projected Year	Projected Avg Dolby Leachate[2] (MGD)
January	0.388	0.12	0.424	0.106	0.41	0.113	0.29	2024	110,400
February	0.258	0.068	0.23	0.053	0.24	0.061	0.18	2025	110,400
March	0.67	0.192	0.748	0.227	0.71	0.210	0.50	2026	88,500
April	1.417	0.516	0.78	0.193	1.10	0.355	0.74	2027	88,500
May	0.609	0.165	0.482	0.154	0.55	0.160	0.39	2028	88,500
June	0.263	0.058	0.189	0.004	0.23	0.031	0.20	2029	88,500
								2030	88,500
July	0.227	0.035	0.274	0.081	0.25	0.058	0.19	2031	88,500
August	0.187	0.027	0.169	0.031	0.18	0.029	0.15	2032	88,500
September	0.129	0	0.38	0.094	0.25	0.047	0.21	2033	88,500
October	0.329	0	0.365	0.092	0.35	0.046	0.30	2034	88,500
November	0.527	0.15	0.595	0.162	0.56	0.156	0.41	2035	88,500
December	1.06	0.368	0.463	0.143	0.76	0.256	0.51	2036	88,500
								2037	88,500
Annual Average	0.505	0.142	0.425	0.112	0.47	0.127	0.34	2038	88,500
								2039	88,500
Maximum Month	1.417	0.516	0.78	0.227	1.42	0.516	2.0[3]	2040	88,500
								2041	88,500
Minimum Month	0.129	0.027	0.169	0.004	0.13	0.004	NA	2042	88,500
								2043	88,500

Notes:

[1] EMWWTP influent is combined flows from the Town's sanitary wastewater sewers and from Dolby.

[2] Assumes Dolby III cover upgrade fully complete by 2025.

[3] Maximum day EMWWTP influent flow can exceed 2 MGD, per EMWWTP operations staff.

TABLE 3-2

FLOW SUMMARY FOR JUNIPER RIDGE LANDFILL LEACHATE

Month	2020 JRL Leachate (MGD)	2021 JRL Leachate (MGD)	2-Year Avg JRL Leachate (MGD)	Future Projections	
				Projected Year	Projected Avg JRL Leachate (MGD)
January	45,155	46,234	45,694	2024	69,300
February	41,000	31,651	36,325	2025	60,800
March	42,480	45,554	44,017	2026	53,400
April	55,687	41,185	48,436	2027	46,800
May	38,942	34,286	36,614	2028	42,600
June	31,472	30,866	31,169	2029	37,300
				2030	32,700
July	35,100	42,533	38,816	2031	34,500
August	33,450	32,306	32,878	2032	31,000
September	25,638	52,634	39,136	2033	27,900
October	45,806	47,059	46,433	2034	23,400
November	47,375	45,632	46,503	2035	21,100
December	69,805	50,210	60,007	2036	17,300
				2037	17,300
Annual Average	42,659	41,679	42,169	2038	15,800
				2039	14,500
Maximum Month	69,805	52,634	69,805	2040	12,600
				2041	10.900
Minimum Month	25,638	30,866	25,638	2042	9,400
				2043	9,000

FLOW SCHEMATIC FOR EXISTING DOLBY LEACHATE TREATMENT

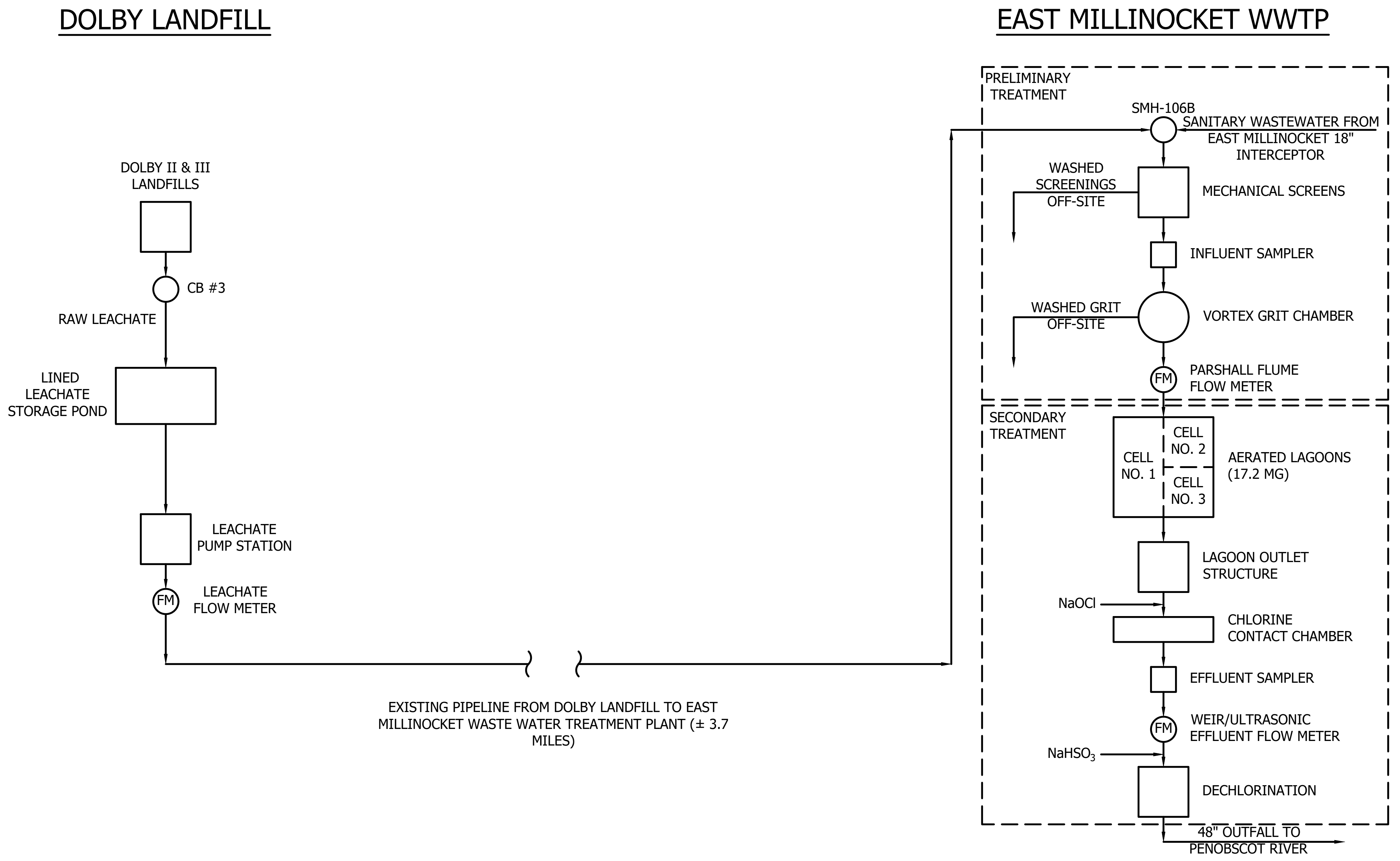

FIGURE 3-1
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 3-1, 12/19/2022 3:03:24 PM, jrl

FLOW SCHEMATIC FOR EXISTING JRL LEACHATE TREATMENT

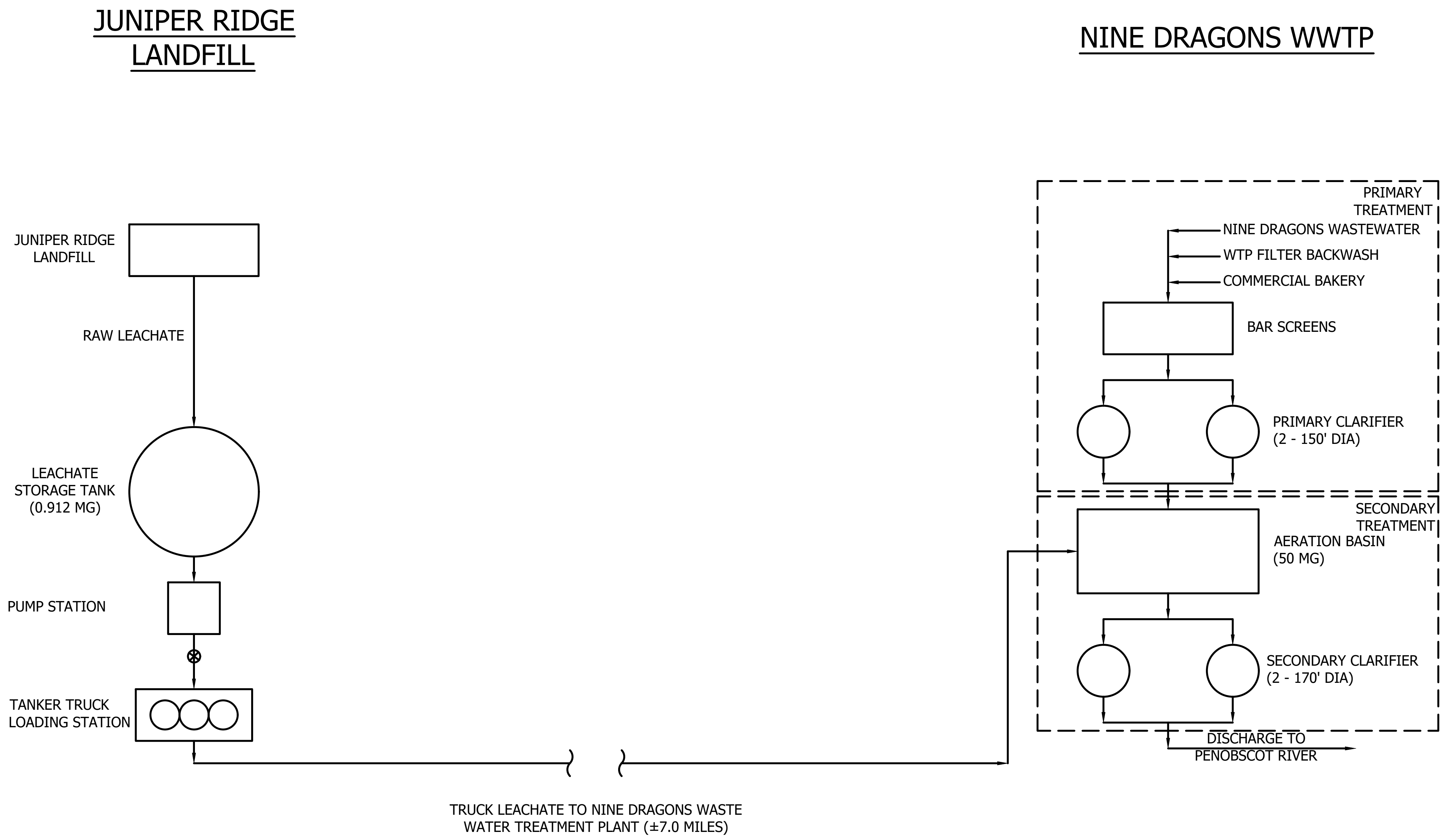

FIGURE 3-2
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 3-2, 12/19/2022 3:03:25 PM, jrl

4.0 LANDFILL LEACHATE CHARACTERIZATION

Four rounds of PFAS sampling and analytical testing (often referred to as sampling, for simplicity) were completed on leachate from the Dolby and JRL landfills. Figure 4-1 presents a photograph of the Dolby and JRL leachates taken as part of a sampling event conducted on May 2, 2022. The Dolby leachate is relatively clear, whereas the JRL leachate is dark and opaque (evidence of considerable presence of suspended solids and decaying organics). Experience with both leachates indicates the color difference is consistent throughout the year. The Dolby leachate sampling occurred in late-September 2021, early-May 2022, mid-June 2022, and late-June 2022, whereas the JRL leachate sampling occurred in December 2021, early-May 2022, late-May 2022, and mid-June 2022.

The analytical testing conducted for the Study included 28 PFAS that are common to U.S.EPA Test Method 537 Version 1.1. The 28 PFAS are listed in Table 4-1 for each of the four sampling events. Table 4-1 also provides the acronym, the formula, and the number of carbon atoms (i.e., short- or long-chain PFAS) for each PFAS listed. The first six PFAS in Table 4-1 are the PFAS associated with the MEDEP IDWS. The summation of those six PFAS (referred to as PFAS(6) throughout this Report), are subject to the IDWS of 20 ng/l. The remaining 22 PFAS listed in Table 4-1 are not covered by the IDWS. On occasion, the sum of all 28 PFAS is used to differentiate between the quality of leachate that discharges from various landfills.

There are currently no U.S.EPA-certified methods for analysis of PFAS in media other than drinking water. Alpha Analytical provided the PFAS testing services for the leachate sampling performed for Dolby and JRL. The PFAS test method used by Alpha Analytical for the leachate was based on U.S.EPA Method 537 Version 1.1, solid-phase extraction and liquid chromatograph/mass spectrographic methods that use isotope dilution for QA/QC adjustments to compensate for matrix interferences (Weston and Sampson, 2019). In general, leachate is a complex matrix of chemical compounds not common to drinking water. The complexity of the leachate can result in analytical detection limits and surrogate recoveries[4] falling outside the practical limits of the testing methods, thus requiring laboratories to sometimes report PFAS results as "estimated."

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[4] Surrogate recoveries represent the extraction efficiency for specific groups of analytes within a sample. If surrogate recoveries are above criteria, a high bias is assumed for that group of analytes; below criteria, a low bias is assumed.

4.1 PFAS Characterization in Landfill Leachate

The significant amount of PFAS observed and/or suspected within landfills nationally has led to increased concern for management of landfill leachate. A number of states have initiated studies to characterize the presence of PFAS within landfill leachate and other associated waste matrices. For example, the Vermont Department of Environmental Conservation (VTDEC) completed work to assess the presence and concentration of PFAS in landfill leachate and effluent from municipal WWTPs that process leachate. VTDEC's findings indicate that PFAS are pervasive and were detected in all landfill leachate tested and in many WWTP influents and effluents, as well as in the associated sludge from the WWTPs (Weston and Sampson, 2019). Another example is that the Michigan Department of Environment, Great Lakes, and Energy (EGLE) formed a Landfills Workgroup to protect human health and the environment by ensuring that PFAS in landfill leachate is effectively managed and is not transferred to other media such as drinking water, groundwater, or surface water at unacceptable concentrations. Initial findings from the EGLE study found that PFAS were frequently detected in sanitary wastewater, WWTP residuals (i.e., sludge [also known as biosolids]), and at land application sites where sludge had been applied (AECOM and EGLE, 2019).

Specific to PFAS in landfill leachate occurring within the State of Maine, the MEDEP is requiring PFAS sampling and testing of leachate collected at 24 landfills in Maine (including the Dolby Landfill and JRL). The MEDEP landfill leachate sampling program includes up to 42 individual leachate sample locations (note, a number of landfills have multiple leachate collection points). MEDEP requires that five rounds of PFAS sampling and testing for the 24 landfills be conducted beginning in the fall-winter of 2021 and extending through fall 2023 (for a total of 5 rounds of spring-fall sampling). Separate from the MEDEP-required leachate PFAS sampling, BGS completed separate rounds of leachate PFAS sampling for the Dolby Landfill and JRL in May and June of 2022. The 28 PFAS listed in Table 4-1 were tested for presence in both the Dolby and JRL leachates collected during the MEDEP and BGS sampling events.

The first round of MEDEP-required PFAS sampling was completed in fall 2021 and the test results are presented in Table 4-2. The average PFAS concentration (for 28 PFAS) for the first round was 4,843 ng/l, the PFAS(6) average was 1,625 ng/l, and the average of PFOS and PFOA (individual PFAS) when added together (i.e., PFOS plus PFOA) was 960 ng/l. It is notable that the PFAS concentrations from one landfill (not state-owned) reported in Table 4-2 were exceptionally high by comparison to all others, thus, making the average PFAS concentrations biased. The leachate PFAS concentrations from the two State-Owned landfills (Dolby and JRL) were comparatively dilute relative to many of the other PFAS concentrations shown in Table 4-2, although the PFAS(6) concentrations in both the Dolby and JRL leachates are approximately 17 and 20 times greater than the Maine IDWS for PFAS(6) in drinking water.

Table 4-3 summarizes the first two rounds of PFAS test results required by MEDEP and compares the relative PFAS concentrations in leachate for all landfills within the State to the concentrations measured in the leachate from Dolby and JRL during the fall-winter of 2021 and the spring-summer of 2022. Examination of Table 4-3 shows the leachate PFAS concentrations from Dolby and JRL were higher during the second round of sampling in comparison to the first round of sampling and each of the six individual PFAS comprising PFAS(6) analyzed during the second round were greater in concentration as compared to the first round of sampling at both Dolby and JRL.

4.2 PFAS in the Dolby and JRL Leachates

As part of the subject Study, two rounds of leachate sampling were conducted at both the Dolby Landfill and JRL (separate of the MEDEP-required sampling). The first round was completed in May 2022 during high-leachate flow conditions (i.e., spring thaw), and the second round was completed in late-June during drier, lower-leachate flow conditions. Leachate sampling for each of the two rounds of sampling (as well as the two rounds required by MEDEP) were conducted by SME personnel following the same sampling protocols, using the same sample collection locations, the same analytical laboratory, and the same analytical methodology. The Dolby leachate samples were collected from manhole No. 3 (i.e., CB#3) and the JRL leachate samples were collected at the tank-truck loading station, which is adjacent to the leachate storage tank at JRL. Both leachate sample locations provided raw (i.e., untreated) leachate.

Table 4-4 presents the results for the four rounds (first two MEDEP rounds and two BGS rounds) of PFAS sampling completed at Dolby and JRL to characterize raw leachate quality. During the two BGS sampling rounds, one additional Dolby location and three locations at the EMWWTP were sampled. The additional sampling locations included: 1) the effluent from the Dolby leachate storage pond; 2) a manhole at the EMWWTP where only municipal sanitary wastewater flows from the Town of East Millinocket occur, before being combined with the Dolby leachate; 3) the point at which the Dolby leachate and the East Millinocket sanitary wastewater flows are combined (i.e., EMWWTP influent); and 4) the treated effluent from the EMWWTP (i.e., EMWWTP effluent). The additional Dolby leachate-related sample locations were chosen to better understand the change in PFAS concentration starting at the landfill raw leachate sample point (i.e., manhole CB#3) and ending with the EMWWTP effluent, before it is discharged to the Penobscot River. Table 4-5 summarizes the PFAS concentrations measured at the Dolby site and the EMWWTP. Figures 4-2, 4-3 and 4-4 show the sample location points for the Dolby leachate, the EMWWTP, and JRL leachate, respectively. No PFAS sampling of influent or effluent was completed at the NDWWTP for the Study. Figure 4-5 shows the location where the JRL leachate enters the NDWWTP facility. The PFAS testing results shown in Table 4-5 have undergone SME's standard quality control review for analytical data and are considered acceptable for use with respect to the project objectives. Laboratory data deliverables are on file at SME and are available for review upon request.

Examination of the PFAS results (Tables 4-2, 4-3, 4-4, and 4-5) indicate the following:

- Dolby raw leachate PFAS concentrations were low for the sampling events conducted in September 2021 and May 2022 (see Table 4-4), and more concentrated for the June 2022 sampling events. The PFAS(6) in raw leachate from Dolby for the four events ranged from 325 to 4,426 ng/l with an average value of 1,725 ng/l and a standard deviation of 1670 ng/l. The sum of all 28 PFAS in the Dolby raw leachate for the four sampling rounds ranged from 434 to 4,734 ng/l with an average value of 1,948 ng/l. The sum of PFOS plus PFOA for the four Dolby sampling rounds ranged from 244 to 3,622 ng/l with an average value of 1,396 ng/l. In comparison to other Maine landfill leachates, the Dolby raw leachate PFAS concentrations were quite low for the September 2021 and May 2022 sampling rounds. The PFAS(6) concentrations for the Dolby raw leachate was 351 ng/l and 325 ng/l, respectively, in comparison to an average PFAS(6) of about 1,583 ng/l for the other 22 Maine landfill locations. The Dolby PFAS(6) concentrations for the two June 2022 sampling events were greater in value than the previous two sampling rounds at Dolby and were also greater than the PFAS(6) averages for the other 22 landfills where MEDEP required sampling is conducted.
- On average, 17 of the 28 PFAS for the four rounds of Dolby leachate samples were below the respective detection limits for the PFAS analytical test method. PFOA (114 to 3,080 ng/l) and PFOS (84.7 to 912 ng/l) were the two PFAS detected with the highest average concentrations.

The sanitary wastewater flow (0.34 MGD) from the Town of East Millinocket represents about 72 percent of the EMWWTP influent flow and was essentially free of PFAS. As shown in Table 4-5, only four PFAS were detected in the sanitary wastewater above the laboratory method's analytical detection limit (i.e., about 2 ng/l) and consisted of PFOS (2.6 to 3.7 ng/l), PFBA (2.7 ng/l), PFHxA (2 to 2.1 ng/l), and 6:2FTS (non-detect [ND] to 3.3 ng/l).

- Although Dolby contributes about 28 percent of the flow to the EMWWTP, the Dolby leachate essentially contributes 100 percent of the PFAS load to the EMWWTP influent.
- Of the 28 PFAS analyzed for the EMWWTP influent and effluent, 20 of the 28 PFAS were reported at concentrations less than the analytical detection limit associated with the analytical test method. There was roughly a 54 percent reduction between the EMWWTP influent and effluent samples for PFAS(6); and similar reductions for three other PFAS (i.e., PFBA, PFHxA, and PFPeA). It is speculated that the PFAS reduction is primarily associated with PFAS partitioning (i.e., adsorption) onto the biosolids associated with biological treatment, and to a lesser extent due to biodegradation, which are both components of the EMWWTP processes. It is notable that other PFAS studies (Ross Helmer, 2021 and Zachary Harvell, 2020) have observed increases in PFAS concentrations in wastewater treatment effluent, theorized as being due to transformation of precursors in the wastewater into other PFAS. No such increases in PFAS concentration between the influent and effluent sample locations were observed at the EMWWTP.
- Based on current conditions (the EMWWTP effluent flow of 0.47 MGD and the average effluent PFAS concentration of 113 ng/l), it is estimated that approximately 0.0004 pounds per day (lbs/d) of PFAS are discharged to the Penobscot River. By contrast, about 25 lbs/d of total suspended solids (TSS) are present in the EMWWTP effluent and are discharged to the river, which is roughly 60,000 times greater in quantity than the amount of PFAS discharged to the river.
- JRL PFAS concentrations were quite varied between the four sampling events. The PFAS(6) concentration in the JRL raw leachate ranged from 410 to 2,627 ng/l with an average value of 1,856 ng/l and a standard deviation of 871 ng/l. Likewise, the sum of all 28 PFAS ranged from 1,723 to 11,007 ng/l with an average value of 7,853 ng/l. The sum of PFOS plus PFOA for JRL was quite erratic, ranging from 211 to 1,558 ng/l with an average value of 1,013 ng/l. Currently, there is no treatment of the JRL leachate prior to it being introduced to the NDWWTP.
- On average, 14 of 28 PFAS analyzed for in the JRL leachate for the four sampling rounds were below the respective analytical detection limits. PFOA (average = 924 ng/l) and PFHpA (average = 504 ng/l) were the PFAS(6) detected at the highest average concentrations. PFHxA (average = 1,683 ng/l), PFBS (average = 1,668 ng/l), PFBA (average = 1,312 ng/l) and PFPeA (average = 967 ng/l) were the non-PFAS(6) detected on average at the highest concentrations.
- The Dolby leachate discharges to the EMWWTP, and the effluent from EMWWTP's secondary treatment (i.e., biological) process is considered a potential candidate for PFAS

removal by GAC, IEX, or alternative adsorbents recognizing that the EMWWTP effluent is generally clean with relatively low concentrations of co-pollutants (e.g., BOD5, TSS, total dissolved solids (TDS), and cations and anions). Further analysis of the viability of the EMWWTP effluent to serve as feed water to a PFAS polishing process will need to address the variability of effluent quality from an aerated lagoon process and any other specific pretreatment requirements, the need for iron and manganese pretreatment, and whether pretreatment can be provided to reduce the TOC and ammonia levels to below about 1 mg/l. Of the 28 PFAS analyzed by U.S.EPA Method 537.1, version 1.1, eight of those PFAS are short-chain carbon-fluorine based molecules that are more difficult to remove with sorption media (i.e., GAC) and ion exchange (i.e., IEX) processes. The only short-chain PFAS of the PFAS(6) detected in the Dolby leachate was PFHxS, and it was detected at an average concentration of 27 ng/l for the four rounds of Dolby leachate samples collected from CB#3. The three non-PFAS(6) short-chain PFAS with positive occurrences in the leachate from CB#3 were PFBA, PFHxA, and PFPeA.

- In comparison to the Dolby leachate, the JRL leachate is much darker in color and opaque in clarity; the JRL leachate contains higher concentrations of PFAS. Dolby (as in Dolby II and III) is an unlined landfill subject to groundwater inflow, has final covers constructed of soil (90 acres, currently) and geomembrane (37 acres, currently), and has not received wastes since 2012. In contrast, JRL is a lined landfill that actively receives a wide variety of waste materials including wastewater treatment sludge. Much of JRL includes temporary geomembrane covers over the waste that influences the volume and quality of the leachate generated at JRL.

4.3 Leachate Quality from the Dolby and Juniper Ridge Landfills

In addition to testing for PFAS in the Dolby and JRL leachates, BGS routinely monitors for a number of conventional pollutants (BOD5, TOC, TSS, pH, and ammonia), toxic metals (zinc), toxic organics, anions and cations, and a number of non-conventional parameters as shown in Table 4-6. In general, these data were collected from June 2018 through January 2022. Table 4-7 summarizes the same analytes tested during the recent BGS funded sampling that occurred in May and June 2022 and compares the recent leachate quality data to the historical leachate data in Table 4-6.

4.3.1 Dolby Leachate Quality

Historically, the Dolby leachate quality has exhibited relatively low concentrations of TSS, TDS, conductivity, and turbidity. General observations for the Dolby leachate (see Tables 4-6 and 4-7) include:

- The historical Dolby leachate quality and concentrations are comparable to the recent MEDEP and BGS leachate quality data as summarized in Table 4-7.
- The Dolby leachate is aerobic throughout the year with no noxious odors such as from sulfide or ammonia that often are associated with landfill leachates.
- The pH of the Dolby leachate has historically ranged from 6.6 to 7.5, and during the recent sampling in May and June 2022 the pH was 7.5 to 7.7. The Dolby leachate pH appears fairly stable, although it is possible that minor pH adjustment may be adopted by one or two treatment technologies in order to optimize reaction kinetics.
- The Dolby leachate is not typically tested for BOD5, although recent BOD5 testing conducted in May and June 2022 showed very low concentrations. The Dolby leachate historical TOC (average of 25 mg/l) and recent leachate sampling for TOC showed similar concentrations. The concentrations of TOC in the Dolby leachate may warrant pretreatment to less than 1 mg/l if GAC media or IEX resin are proposed for removing PFAS directly from the leachate.
- The TSS concentrations in the Dolby leachate have been relatively low (10 mg/l on average) and the recent TSS concentrations in May and June 2022 were 42 mg/l and < 5 mg/l, respectively.
- Historical ammonia concentrations in the Dolby leachate (CB#3) have ranged from 0.46 to 7.2 mg/l with an average concentration of 5.4 mg/l and recent ammonia concentrations were 7.3 to 9.9 mg/l. Although the ammonia concentrations are relatively low and there are no ammonia discharge standards for the EMWWTP effluent, it is generally desirable to reduce the ammonia concentration to less than 1 mg/l prior to using adsorption technologies for reducing PFAS. In this situation, it may be necessary to oxidize the ammonia to below 1 mg/l if PFAS treatment of the EMWWTP effluent is performed.
- The Dolby leachate did not test positive for four toxic organic compounds (i.e., alpha terpineol, benzoic acid, p-cresol, and phenol) and zinc, which would be regulated if the Dolby leachate was treated by a new facility and then discharged to the Penobscot River. In addition, the Dolby leachate was sampled and tested for volatile organic compounds

(VOCs). None of the 75 VOCs analyzed for were detected above the respective analytical detection limits.

- The iron and manganese concentrations in the EMWWTP effluent (1.05 mg/l for iron and 0.9 mg/l for manganese) would likely need to be reduced to below 0.3 mg/l for iron and 0.05 mg/l for manganese by pretreatment if the effluent is to be considered for subsequent removal of PFAS using adsorption technologies.
- The anion/cation concentrations in the Dolby leachate are low and do not appear to represent a concern for implementing adsorption technologies for PFAS reduction.
- If an "upfront gross PFAS removal" technology is implemented at the Dolby site and effectively removes PFAS without requiring pretreatment, the resulting PFAS-treated leachate can then be discharged to the EMWWTP for biological treatment.

4.3.2 JRL Leachate Quality

In contrast to the Dolby leachate, the JRL leachate is dark in color and opaque in clarity. The JRL leachate conductivity readings and TDS concentrations are an order-of-magnitude greater than for the Dolby leachate, and the JRL leachate is too dark in color to allow accurate turbidity readings. General observations for the JRL leachate (see Tables 4-6 and 4-7) include:

- The JRL leachate is trending anaerobic and exhibits noticeable sulfide and ammonia odors.
- The pH of the JRL leachate has historically ranged from 5.9 to 7.6 and during the recent sampling in May and June 2022, the pH was 7.5 to 7.7. The pH appears fairly stable although depending on the PFAS treatment process selected, it may be necessary to pretreat the leachate for maintaining the pH in a desirable range.
- The JRL leachate historically has been high in BOD5 (about 400 mg/l on average), and the TOC has averaged about 500 mg/l. Both the BOD5 and TOC concentrations are significant and variable and both parameters may warrant biological treatment if a conventional liquid treatment process with tertiary treatment for PFAS is considered. If an "upfront gross PFAS removal" technology is implemented that selectively removes PFAS without requiring pretreatment, the JRL leachate could continue to be discharged to the NDWWTP for biological treatment once the PFAS removal has occurred.
- The TSS of the JRL leachate has been 37 mg/l on average and the recent TSS concentrations in May and June 2022 were 53 mg/l and 40 mg/l, respectively. Although

these TSS concentrations are not excessive, leachate pretreatment by filtration may be warranted depending on the PFAS treatment technology selected.

- The ammonia concentration in the JRL leachate is extremely high for both the historical and recent sampling events and is consistently in excess of 600 mg/l. Depending on the PFAS treatment technology selected, a form of ammonia removal may need to be implemented.
- The JRL leachate was analyzed for presence of alpha terpineol, benzoic acid, p-cresol, and phenol. All four of these organic compounds would exceed direct discharge permit limit(s) if the JRL leachate did not first flow through the NDWWTP before being discharged. The JRL leachate was also tested for 75 VOCs. The composite VOC concentration was 740 μg/l with 22 VOCs showing concentrations above the respective analytical detection limits.
- The iron and manganese concentrations in the JRL leachate are high (8.8 to 9.2 mg/l for iron and 2.4 to 4.9 mg/l for manganese) and may need to be reduced by pretreatment, depending on the PFAS treatment technology implemented.
- The anion and cation concentrations in the JRL leachate are extremely high and will need significant pretreatment if a conventional tertiary PFAS adsorption treatment system is implemented. If an “upfront gross PFAS removal” technology is implemented that selectively removes PFAS without requiring pretreatment, the JRL leachate can then continue to be discharged to the NDWWTP without pretreatment for anion removal.
- Historical JRL leachate concentrations for BOD5, chloride, nitrate, and sulfate were significantly greater than the recent MEDEP and BGS results in May and June of 2022.
- The high calcium and hardness of the leachate could result in scaling within the treatment operations.
- The JRL leachate chloride concentration (5,450 mg/l or roughly 25% the chloride level of seawater) and TDS concentration (> 10,000 mg/l) are extremely high and could result in reduced biomass activity and ineffective treatment if biological treatment of JRL is considered.

TABLE 4-1

LEACHATE CHARACTERIZATION FOR PFAS IN MAINE LANDFILLS[1]

Parameter	Acronym Name	CAS Number	Formula	# Carbon Atoms[3]	Analytical Detection Limit Range (ng/l)[4]	Comments
A. Six State of Maine Regulated PFAS[2]						
Perfluorooctanesulfonic Acid	PFOS	1763-23-1	C8F17SO3H	8	2.02 - 20	Non-polymeric, perfluorosulfonic acid (PFSA); One of the most prevalent PFAS in the environment; PFOS is no longer manufactured in the US since 2015
Perfluorooctanic Acid	PFOA	335-67-1	C7F15COOH	8	2.02 - 20	Non-polymeric, perfluorocarboxylic acid (PFCA); One of the most prevalent PFAS in the environment; PFOA is no longer manufactured in the US since 2015
Perfluoroheptanoic Acid	PFHpA	375-85-9	C6F13COOH	7	2.02 - 20	Six perfluorinated carbons terminated with a carboxylate group
Perfluorononanoic Acid	PFNA	375-95-1	C8F17COOH	9	2.02 - 20	Non-polymeric, perfluorocarboxylic acid (PFCA)
Perfluorohexanesulfonic Acid	PFHxS	355-46-4	C6F13SO3H	6	2.02 - 20	Non-polymeric, perfluorosulfonic acid (PFSA)
Perfluorodecanoic Acid	PFDA	335-76-2	C9F19C00H	10	2.02 - 20	Non-polymeric, perfluorocarboxylic acid (PFCA)
Sum of Six Regulated Compounds[2]						
B. Other Unregulated PFAS[2]						
Perfluorobutanesulfonic Acid	PFBS	375-73-5	C4F9SO3H	4	2.02 - 20	Non-polymeric, perfluorosulfonic acid (PFSA); PFBS is being used as a replacement for PFOS
Perfluorobutanoic Acid	PFBA	375-22-4	C3F7COOH	4	2.02 - 20	Non-polymeric, perfluorocarboxylic acid (PFCA); low affinity to GAC
Perfluorodecanesulfonic Acid	PFDS	335-77-3	C10F21SO3H	10	2.02 - 20	
Perfluorododecanoic Acid	PFDoDA	307-55-1	C11F23COOH	12	2.02 - 20	
Perfluoroheptanesulfonic Acid	PFHpS	375-92-8	C7F15SO3H	7	2.02 - 20	
Perfluorohexdecanoic Acid	PFHxDA	67905-19-5	C16HF3102	16	4.04 - 40	
Perfluorohexanoic Acid	PFHxA	307-24-4	C5F11COOH	6	2.02 - 20	Non-polymeric, perfluorocarboxylic acid (PFCA)
Perfluoronanesulfonic Acid	PFNS	68259-12-1	C9F19SO3H	9	2.02 - 20	
Perfluorooctadecanoic Acid	PFODA	16517-11-6	C18HF35O2	18	50.5 - 500	
Perfluorooctanesulfonamide	PFOSA	754-91-6	C8H2F17NO2S	8	2.02 - 20	
Perfluoropentanesulfonic Acid	PFPeS	2706-91-4	C5F11SO3H	5	2.02 - 20	
Perfluoropentanoic Acid	PFPeA	2706-90-3	C4F9COOH	5	2.02 - 20	Low affinity to GAC
Perfluorotetradecanoic Acid	PFTA	376-06-7	C14HF27O2	14	2.02 - 20	
Perfluorotridecanoic Acid	PFTrDA	72629-94-8	C12F25COOH	13	2.02 - 20	
Perfluoroundecanoic Acid	PFUnDA	2058-94-8	C10F21COOH	11	2.02 - 20	Non-polymeric, perfluorocarboxylic acid (PFCA)
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	39108-34-4	C10H4F17O3S	10	2.02 - 20	Non-polymeric, polyfluorinated PFAS
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	757124-72-4	C6H5F9O3S	6	2.02 - 20	
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	27619-97-2	C8H5F13O3S	8	2.02 - 20	Non-polymeric, perfluorinated PFAS
2,3,3,3-Tetraflluoro-2-[1,1,2,2,3,3,3-Heptaflluoropropoxy]-Propanoic Acid	HFPO-DA	13252-13-6	C6HF11O3	6	2.02 - 20	Referenced as Gen-X; compound is being used as a replacement for PFOA; Perfluoroether
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	9119005-14-4	C10H11N4NaO5S	10	2.02 - 20	Perfluoroether
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	2355-31-9	C11H6F17NO4S	11	2.02 - 20	
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	2991-50-6	C12H8F17NO4S	12	2.02 - 20	

Notes:

[1] Analytes tested by both MEDEP Solid Waste Division in December 2021 and October 2022 and samples collected by SME for State-Owned landfill leachates in May 2022 and July 2022.

[2] PFAS values are State of Maine IDWS established June 21, 2021 for six PFAS analytes combined in drinking water. IDWS = 20 ng/l.

[3] General nomenclature is short-chain refers to PFCA molecules with seven or less carbon atoms and PFAS molecules with five or less carbon atoms. Long-chain refers to PFCA molecules with eight or more carbon.

[4] Detection limits as determined by U.S.EPA Method 537 Version 1.1.

TABLE 4-2

PFAS CONCENTRATION IN MAINE LANDFILLS – FOURTH QUARTER 2021[1]

Town City	Site Name		IDWS Regulated PFAS (6 total)						Sum of 6 PFAS Compounds[2]	PFAS with no IDWS (22 total)								
		Sample Date	PFOS	PFOA	PFHpA	PFNA	PFHxS	PFDA		PFBS	PFBA	PFDS	PFDoDA	PFHpS	PFHxDA	PFHxA	PFNS	PFODA
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	143	163	49.3	7.45	6.29	4.88	374	0.834	26.3	ND	ND	3.07	1.15	61.7	ND	ND
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	172	162	48.6	7.53	6.06	6.76	403	1.04	28	ND	ND	2.99	1.08	59.8	ND	ND
HAMPDEN	PINETREE LANDFILL AND TRANSFER STATION	12/07/2021	ND	1,020	515	112	182	51	1,880	747	762	ND	ND	6.87	ND	923	ND	ND
SCARBOROUGH	ECO-MAINE LANDFILL	02/03/2022	98.7	246	107	9.75	36.7	ND	498	10	166	ND	ND	1.86	ND	208	ND	ND
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	66.6	102	11.5	ND	4.12	184	ND	1,890	ND	ND	ND	ND	1,020	ND	ND
BATH	BATH LANDFILL	01/27/2022	137	293	127	27.8	145	13.3	743	46.9	199	ND	ND	3.51	ND	382	ND	ND
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	11.6	211	236	40.2	2.6	11.2	513	2.18	1,490	ND	ND	ND	ND	1,880	ND	ND
ROCKLAND	ROCKLAND QUARRY LANDFILL	11/02/2021	238	546	236	34.5	286	19.6	1,360	248	203	ND	ND	8.41	ND	498	ND	ND
BAILEYVILLE	WOODLAND PULP LLC NO 3 LANDFILL	07/07/2021	100	75.4	7.89	2.2	16.1	ND	202	10.2	ND	ND	ND	2.31	ND	7.49	ND	ND
BAILEYVILLE	WOODLAND PULP LLC NO 3 LANDFILL	11/10/2021	24.6	67.9	8.54	ND	49	ND	150	10.9	34.4	ND	ND	ND	ND	7.28	ND	ND
BAILEYVILLE	WOODLAND PULP LLC NO 3 LANDFILL	05/02/2022	16.9	46	3.56	ND	2.24	ND	69	3.68	61.6	ND	ND	ND	ND	3.42	ND	ND
OLD TOWN	JUNIPER RIDGE LANDFILL	12/07/2021	29.4	182	110	10.9	72.8	4.77	410	333	299	ND	ND	ND	ND	392	ND	ND
EAST MILLINOCKET	KATAHDIN PAPER CO DOLBY LANDFILLS	09/23/2021	84.7	159	79.2	26	ND	2.52	351	2.41	72.2	ND	ND	2.7	ND	89.8	ND	ND
SCARBOROUGH	ECO-MAINE LANDFILL	02/03/2022	45.3	125	73.9	9.44	49.3	2.26	305	115	192	ND	ND	ND	ND	574	ND	ND
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	281	113	26.9	12.3	6.27	5.9	445	ND	12.7	ND	ND	3.37	ND	34.8	ND	ND
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	1,410	1,150	310	42.2	113	27.6	3,053	17.2	438	ND	ND	35.4	ND	679	ND	ND
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	11/03/2021	472	138	35.6	6.42	27.7	ND	680	77.9	72.5	ND	ND	5.42	ND	120	ND	ND
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	04/05/2022	114	84.3	31.2	3.75	23.3	ND	257	65.5	72.2	ND	ND	2.01	ND	108	ND	ND
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	11/03/2021	36.2	99.3	50.7	2.77	40.3	ND	229	170	154	ND	ND	ND	ND	210	ND	ND
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	04/05/2022	36.2	84.1	42.2	4.19	31.2	ND	198	161	129	ND	ND	ND	ND	188	ND	ND
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	11/03/2021	11.4	8.85	3.29	ND	2.35	ND	26	1.84	4.33	ND	ND	ND	ND	5.7	ND	ND
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	04/05/2022	4.76	5.45	2.58	ND	ND	ND	13	ND	4.16	ND	ND	ND	ND	4.78	ND	ND
HARTLAND	HARTLAND SLUDGE LANDFILL PHASES I AND II	10/28/2021	1,950	381	102	8.19	747	3.03	3,191	3,610	362	ND	ND	90.9	ND	345	ND	ND
HARTLAND	HARTLAND SLUDGE LANDFILL PHASES I AND II	04/27/2022	2,030	409	124	10.1	621	4.58	3,199	2,290	266	3.83	ND	90.4	ND	423	ND	ND
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	1,280	1,430	313	ND	118	3,141	ND	1,780	ND	ND	ND	ND	3,360	ND	ND
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	28.5	43.2	19.2	14.4	2.2	4	112	ND	303	ND	ND	ND	ND	51.7	ND	ND
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	3.09	136	101	34.2	ND	11.1	285	ND	510	ND	ND	ND	ND	474	ND	ND
ROCKLAND	ROCKLAND QUARRY LANDFILL	11/02/2021	89.1	116	46.7	9.75	39.5	ND	301	12.8	32.9	ND	ND	2.42	ND	78.9	ND	ND
BUCKSPORT	AIM LANDFILL BUCKSPORT RT 15	11/17/2021	ND	13.6	10.4	ND	ND	ND	24	ND	ND	ND	ND	ND	ND	17.1	ND	ND
FORT FAIRFIELD	AROOSTOOK WASTE SOLUTIONS	10/14/2021	186	835	313	35.4	223	26.9	1,619	683	1,110	ND	ND	ND	ND	3,140	ND	ND
BRUNSWICK	BRUNSWICK LANDFILL	10/27/2021	260	2,800	560	89	330	100	4,139	190	1,100	ND	ND	ND	ND	2,400	ND	ND
NORRIDGEWOCK	WMDSM LANDFILLS	12/29/2021	240	1,400	530	110	340	60	2,680	4,100	2,200	ND	ND	ND	ND	4,400	ND	ND
FRENCHVILLE	FRENCHVILLE TWIN RIVERS SLUDGE LANDFILL	11/22/2021	130	11,800	8,470	3,430	5.5	456	24,292	ND	2,440	ND	ND	3.33	ND	8,970	ND	ND
LEWISTON	LAWPCA SLUDGE LANDFILL	11/22/2021	283	143	28.4	7.89	55.2	3.82	521	10.8	23.6	ND	ND	6.81	ND	93	ND	ND
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	1,050	1,210	158	ND	47.4	2,465	ND	2,950	ND	ND	ND	ND	4,890	ND	ND
AUGUSTA	AUGUSTA TISSUE LLC SLUDGE LANDFILL	11/16/2021	309	149	120	8.42	13.2	3.67	603	6.86	923	ND	ND	3.15	ND	1,750	ND	ND
ROCKPORT	MID-COAST SOLID WASTE TRANSFER STATION	11/04/2021	ND	424	173	20.8	166	8.64	792	83.5	95.5	ND	ND	7.3	ND	299	ND	ND
PRESQUE ISLE	PRESQUE ISLE LANDFILL AND SPRAY IRRIGATION	11/09/2021	274	763	366	41.1	558	32.4	2,035	626	1,930	ND	ND	ND	ND	3,260	ND	ND
	AVERAGE CONCENTRATION		243	705	416	123	110	27	1,625	359	588	ND		7.4	ND	1,090	ND	ND
	STATE OF MAINE IDWS FOR DRINKING WATER		20 (2)	20 (2)	20 (2)	20 (2)	20 (2)	20 (2)	20 (2)									

Notes:

[1] All units are ng/l (parts per quintrillion).

[2] State of Maine IDWS = 20 ng/l for sum of 6 PFAS regulated compounds.

TABLE 4-2 (cont'd)

PFAS CONCENTRATION IN MAINE LANDFILLS – FOURTH QUARTER 2021[1]

Town/City	Site Name	Sample Date	PFAS with No IDWS													Sum of 22 PFAS Without IDWS	Sum of 28 PFAS	Sum of PFOA + PFOS
			PFOSA	PFPeS	PFPeA	PFTA	PFTrDA	PFUnA	8:2 FTS	4:2 FTS	6:2 FTS	HFPO-DA	ADONA	N-MeFOSAA_	NEtFOSAA			
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	3.94	ND	37.3	0.579	ND	0.262	1.42	ND	3.26	ND	ND	3.65	195	338	712	306
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	7.1	ND	35.4	0.593	ND	0.448	2.42	ND	3.29	ND	ND	5.91	260	408	811	334
HAMPDEN	PINETREE LANDFILL AND TRANSFER STATION	12/07/2021	6	26.4	628	2.58	ND	11.6	65.8	3.14	66	ND	ND	51.5	47.4	3,347	5,227	1,250
SCARBOROUGH	ECO-MAINE LANDFILL	02/03/2022	ND	5.14	84.8	ND	ND	ND	5.06	ND	4.64	ND	ND	6.02	64.6	556	1,054	344.7
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	ND	2,380	ND	ND	ND	ND	ND	4.25	ND	ND	ND	12.5	5,307	5,491	66.6
BATH	BATH LANDFILL	01/27/2022	ND	19.2	210	ND	ND	ND	46.1	ND	39.4	ND	ND	13.4	9.22	969	1,712	430
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	ND	3,190	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.72	6,566	7,079	222.6
ROCKLAND	ROCKLAND QUARRY LANDFILL	11/02/2021	2.81	33	306	ND	ND	ND	13.2	2.67	126	ND	ND	187	49.2	1,677	3,037	784
BAILEYVILLE	WOODLAND PULP LLC NO 3 LANDFILL	07/07/2021	ND	2.78	11.8	ND	ND	ND	ND	ND	ND	ND	ND	59.2	20.1	114	315	175.4
BAILEYVILLE	WOODLAND PULP LLC NO 3 LANDFILL	11/10/2021	ND	3.83	10.5	ND	ND	ND	ND	ND	ND	ND	ND	7.97	2.52	77	227	92.5
BAILEYVILLE	WOODLAND PULP LLC NO 3 LANDFILL	05/02/2022	ND	ND	5.68	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	74	143	62.9
OLD TOWN	JUNIPER RIDGE LANDFILL	12/07/2021	ND	10.4	189	ND	ND	ND	3.48	ND	62.2	ND	ND	20.7	3.82	1,314	1,723	211.4
EAST MILLINOCKET	KATAHDIN PAPER CO DOLBY LANDFILLS	09/23/2021	ND	ND	74.1	ND	ND	ND	ND	ND	2.44	ND	ND	ND	5.8	249	601	243.7
SCARBOROUGH	ECO-MAINE LANDFILL	02/03/2022	ND	3.91	287	ND	ND	ND	6.11	ND	72.1	ND	ND	5.51	7.45	1,263	1,568	170.3
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	ND	ND	32.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.89	86	532	394
JAY	PIXELLE ANDROSCOGGIN JAY LANDFILL	12/30/2021	23.1	17.7	428	ND	ND	0.953	14.4	0.745	34	ND	ND	8.36	395	2,092	5,145	2,560
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	11/03/2021	ND	6.88	82.2	ND	ND	ND	ND	ND	6.32	ND	ND	ND	2.45	374	1,053	610
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	04/05/2022	ND	5.19	71.7	ND	ND	ND	ND	ND	6.43	ND	ND	ND	5.65	337	593	198.3
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	11/03/2021	ND	12	149	ND	ND	ND	ND	ND	11	ND	ND	ND	5.8	712	941	135.5
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	04/05/2022	ND	6.04	146	ND	ND	ND	ND	ND	8.73	ND	ND	ND	2.32	641	839	120.3
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	11/03/2021	ND	ND	7.21	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	19	45	20.25
LEWISTON	LEWISTON LANDFILL AND TRANSFER STATION	04/05/2022	ND	ND	5.46	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14	27	10.21
HARTLAND	HARTLAND SLUDGE LANDFILL PHASES I AND II	10/28/2021	27.2	400	210	ND	ND	ND	ND	ND	36.7	ND	ND	366	60.8	5,509	8,700	2,331
HARTLAND	HARTLAND SLUDGE LANDFILL PHASES I AND II	04/27/2022	34.6	254	274	ND	ND	ND	ND	0.652	20.7	ND	ND	341	59.3	4,057	7,256	2,439
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	ND	4,210	ND	ND	9.09	ND	ND	3.79	ND	ND	ND	ND	9,363	12,504	1,280
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	ND	108	ND	ND	ND	ND	ND	ND	ND	ND	43.1	224	730	841	71.7
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	ND	680	ND	ND	ND	ND	ND	2.92	ND	ND	ND	ND	1667	1,952	139.09
ROCKLAND	ROCKLAND QUARRY LANDFILL	11/02/2021	ND	5.03	90.5	ND	ND	ND	5.16	ND	49.2	ND	ND	8.85	90.3	376	677	205.1
BUCKSPORT	AIM LANDFILL BUCKSPORT RT 15	11/17/2021	ND	ND	46.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	64	88	13.6
FORT FAIRFIELD	AROOSTOOK WASTE SOLUTIONS	10/14/2021	ND	26.6	1,370	ND	ND	ND	12.9	ND	144	ND	ND	51.5	19.6	6,558	8,177	1,021
BRUNSWICK	BRUNSWICK LANDFILL	10/27/2021	6.6	35	920	ND	ND	ND	50	5.3	160	75	ND	36	61	5,039	9,178	3,060
NORRIDGEWOCK	WMDSM LANDFILLS	12/29/2021	ND	51	1,200	ND	ND	ND	150	ND	530	610	ND	250	71	13,562	16,242	1,640
FRENCHVILLE	FRENCHVILLE TWIN RIVERS SLUDGE LANDFILL	11/22/2021	2.41	ND	7,290	ND	ND	79	1.9	ND	6.67	ND	ND	8.87	33.8	18,836	43,128	11,930
LEWISTON	LAWPCA SLUDGE LANDFILL	11/22/2021	ND	6.85	42.1	ND	ND	ND	ND	ND	ND	ND	ND	11.1	8.4	203	724	426
FAIRFIELD	SAPPI - SD WARREN SLUDGE LANDFILL	11/04/2021	ND	ND	7,660	ND	ND	3.36	ND	ND	3.39	ND	ND	ND	ND	15,507	17,972	1,050
AUGUSTA	AUGUSTA TISSUE LLC SLUDGE LANDFILL	11/16/2021	4.02	2.37	2,620	0.393	0.404	0.605	1.22	ND	4.82	ND	ND	11	24.6	5,352	5,956	458
ROCKPORT	MID-COAST SOLID WASTE TRANSFER STATION	11/04/2021	ND	20.8	235	ND	ND	ND	3.55	ND	45.4	ND	ND	84	55.7	930	1,722	633
PRESQUE ISLE	PRESQUE ISLE LANDFILL AND SPRAY IRRIGATION	11/09/2021	ND	80.7	1,440	ND	ND	ND	41.1	ND	335	ND	ND	192	89.4	7,994	10,029	1,037
	AVERAGE CONCENTRATION		3.1	27	968	ND	ND	2.8	11	0.3	47	ND	ND	47	50	3,218	4,843	960
	STATE OF MAINE IDWS FOR DRINKING WATER																	

Notes:

[1] All units are ng/l (parts per quintrillion).

TABLE 4-3

SUMMARY OF PFAS CONCENTRATIONS IN MAINE LANDFILL LEACHATES COMPARED TO DOLBY AND JRL LEACHATE[1,4]

PFAS Parameter	Acronym	Range[2]	MEDEP Round 1			MEDEP Round 2		
			Leachate from 24 Landfills Sample Locations Fall-Winter 2021	**Leachate from Dolby Sep-21**	**Leachate from JRL Dec-21**	**Leachate from 24 Landfills Sample Locations Spring-Summer 2022**	**Leachate from Dolby Jun-22**	**Leachate from JRL Jun-22**
Total Number of Sample Locations	-		41	1	1	42	1	1
Total PFAS (28 Compounds)	See Table 4-1 for Listing	Average	4,843	601	1,723	-	4,734	11,007
		Maximum	43,127	-	-	-	-	-
		Minimum	27	-	-	-	-	-
Sum of 6 PFAS with Maine IDWS	PFOA, PFHpA, PFOS, PFNA, PFHxS, PFDA	Average	1,625	266	380	1,541	4,426	2,443
		Maximum	24,292	-	-	-	-	-
		Minimum	13.6	-	-	-	-	-
Perfluorooctanic Acid and Perfluorooctanesulfonic Acid	PFOA + PFOS	Average	960	244	211	898	3,622	1,298
		Maximum	11,930	-	-	-	-	-
		Minimum	13.6	-	-	-	-	-
Regulated PFAS								
Perfluorooctanic Acid	PFOA		705[5]	159	182	696[5]	3,080	1,190
Perfluoroheptanoic Acid	PFHpA		416[5]	79	110	419[5]	286	677
Perfluorooctanesulfonic	PFOS		243[5]	85	29	202[5]	542	108
Perfluorononanoic Acid	PFNA		123[5]	26	11	104[5]	411	55
Perfluorohexanesulfonic	PFHxS		110[5]	ND	73	94[5]	80	390
Perfluorodecanoic Acid	PFDA		28[5]	2	5	26[5]	27	23
	Sum of 6 PFAS with IDWS		1,625[5]	351	410	1,541[5]	4,426	2,443
Non-Regulated PFAS[3]								
Perfluorohexanoic Acid	PFHxA		1,090[5]	90	392	-	65	2,250
Perfluoropentanoic Acid	PFPeA		968[5]	74	189	-	40	1,260
Perfluorobutanoic Acid	PFBA		589[5]	72	299	-	43	1,470
Perfluorobutanesulfonic Acid	PFBS		359[5]	2.4	333	-	2.2	2,560
N-Ethyl Perfluorooctane Sulfonamidoacetic Acid	NetFOSAA		50[5]	5.8	3.8	-	49	23
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2 FTS		47[5]	2.4	62	-	73	384
N-Methyl Perfluorooctane Sulfonamidoacetic Acid	N-MeFOSAA		47[5]	ND	21	-	6	88
Perfluoropentanesulfonic Acid	PFPeS		27[5]	ND	10	-	ND	52
	Sum of Non-Regulated PFAS		3,177	247	1,310	-	278	8,087

<u>Notes</u>:

[1] Samples collected during fourth quarter 2021 and second quarter 2022 as part of MEDEP Solid Waste Division Testing Program.

[2] All units are ng/l (parts per trillion).

[3] Only non-regulated PFAS reported to be above laboratory detection limit shown in table.

[4] Leachate samples taken from CB#3 at Dolby and from truck loading station at JRL.

[5] Reported as average of 24 landfills.

TABLE 4-4

PFAS ANALYTICAL RESULTS – DOLBY AND JUNIPER RIDGE LANDFILLS LEACHATE[1]

Parameter/Pollutant	Acronym Name	Dolby MEDEP #1 9/23/2021	Dolby BGS #1 2-May-22	Dolby BGS #2 15-Jun-22	Dolby MEDEP #2 29-Jun-22	Dolby Average PFAS Concentration	JRL MEDEP #1 12/7/2021	JRL BGS #1 2-May-22	JRL BGS #2 15-Jun-22	JRL MEDEP #2 26-May-22	JRL Average PFAS Concentration
A. Six State of Maine Regulated PFAS[2]											
Perfluorooctanesulfonic Acid	PFOS	84.7	129	912	542	417	29.4	148	108	71.5	89.2
Perfluorooctanic Acid	PFOA	159	114	562	3,080	979	182	1,410	1,190	914	924
Perfluoroheptanoic Acid	PFHpA	79.2	43	89	286	124	110	652	677	578	504
Perfluorononanoic Acid	PFNA	26	22.2	190	411	162	10.9	68.7	54.8	37	42.9
Perfluorohexanesulfonic	PFHxS	<2.1	16.7	12.2	80.2	27	72.8	316	390	343	280
Perfluorodecanoic Acid	PFDA	2.52	<2.02	31	27.2	15	4.77	32.1	23.4	<20	15.1
Sum of 6 Regulated Compounds[3]		351	325	1,796	4,426	1,725	410	2,627	2,443	1,944	1,856
B. Other Unregulated PFAS[2]											
Perfluorobutanesulfonic Acid	PFBS	2.41	<2.02	<1.96	2.15	1.1	333	1,770	2,560	2,010	1,668
Perfluorobutanoic Acid	PFBA	72.2	28.2	39.4	42.6	45.6	299	1,340	1,970	1,640	1,312
Perfluorodecanesulfonic Acid	PFDS	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluorododeanoic Acid	PFDoDA	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluoroheptanesulfonic Acid	PFHpS	2.7	<2.02	6.4	16.7	6.5	<1.95	<20	<20	<20	<20
Perfluorohexadecanoic Acid	PFHxDA	<2.1	<4.05	<3.91	<3.7	<2	<3.9	<40	<40	<40	<40
Perfluorohexanoic Acid	PFHxA	89.8	43.3	58	65.4	64.1	392	2,050	2,250	2,040	1,683
Perfluorononanesulfonic Acid	PFNS	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluorooctadecanoic Acid	PFODA	<2.1	<4.05	<3.91	<3.7	<2	<3.9	<40	<40	<40	<40
Perfluorooctanesulfonamide Acid	PFOSA	<2.1	<2.02	2.56	<1.85	1	<1.95	<20	<20	<20	<20
Perfluoropentanesulfonic Acid	PFPeS	<2.1	<2.02	<1.96	<1.85	<2	10.4	35	51.7	61.1	39.6
Perfluoropentanoic Acid	PFPeA	74.1	34.6	43	40	48	189	1,150	1,260	1,270	967
Perfluorotetradecanoic Acid	PFTA	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluorotridecanoic Acid	PFTrDA	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluoroundecanoic Acid	PFUnA	<2.1	<2.02	4.18	2.46	2	<1.95	<20	<20	<20	<20
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	<2.1	<2.02	17.4	11.3	7	3.48	<20	<20	<20	<20
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	2.44	<2.02	10.8	72.9	22	62.2	345	384	272	266
2,3,3,3-Tetraflluoro-2-[1,1,2,2,3,3,3-Heptaflluoropropoxy]-Propanoic Acid	HFPO-DA	<2.1	<50.6	<48.9	<46.2	<2	<48.8	<500	<500	<500	<500
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	<2.1	<2.02	4.9	5.66	2.6	20.7	83	88.1	46.8	59.7
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	5.8	3.18	39.8	48.5	24.3	3.82	<20	23.4	<20	<20
Sum of All PFAS Compounds[4]		601	434	2,023	4,734	1,948	1,723	9,400	11,007	9,283	7,853

Notes:

[1] Database includes sampling funded by MEDEP SWD in 4th quarter 2021 and 2nd quarter 2022 and sampling funded by BGS for State-Owned landfill leachates on May 2, 2022 and June 15, 2022.

[2] All units are ng/l (parts per trillion, ppt).

[3] PFAS values are State of Maine IDWS established June 21, 2021 for six PFAS analytes combined in drinking water. IDWS = 20 ng/l.

[4] Values less than the analytical detection limit are assumed as zero when calculating the sum and averages.

[5] Dolby leachate samples collected as grab from CB-3 manhole location.

[6] JRL leachate samples collected from tank truck loading station.

TABLE 4-5

DOLBY LEACHATE AND EMWWTP INFLUENT/EFFLUENT PFAS SUMMARY[1]

Parameter/Pollutant	Acronym	Units	Dolby[4] CB#3 May-22	Dolby Leachate Pond Effluent May-22	Town of E. Millinocket[5] May-22	EMWWTP[6] Influent May-22	EMWWTP Effluent May-22	Dolby[4] CB#3 Jun-22	Dolby Leachate Pond Effluent Jun-22	Town of E. Millinocket[5] Jun-22	EMWWTP[6] Influent Jun-22	EMWWTP Effluent Jun-22	Dolby Leachate Pond Effluent Average	EMWWTP Effluent Average
Per- and Polyfluoralkyl Substances														
a. Six State of Maine Regulated PFAS[2]														
Perfluorooctanesulfonic Acid	PFOS	ng/l	129	119	3.69	68.8	31.5	912	52.6	2.61	34.6	30.2	85.8	30.9
Perfluorooctanic Acid	PFOA	ng/l	114	122	<1.97	69.8	34.4	562	90.4	<1.89	63.2	24.6	106	29.5
Perfluoroheptanoic Acid	PFHpA	ng/l	43	44.7	<1.97	29.6	13.4	89	41.5	<1.89	32.4	11.2	43.1	12.3
Perfluorononanoic Acid	PFNA	ng/l	22.2	23	<1.97	12.1	6.42	190	16	<1.89	10	4.9	19.5	5.66
Perfluorohexanesulfonic	PFHxS	ng/l	16.7	5.83	<1.97	4.77	<2.04	12.2	2.5	<1.89	2.12	<1.88	4.17	ND
Perfluorodecanoic Acid	PFDA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	31	<1.86	<1.89	<1.91	<1.88	ND	ND
Sum of 6 Regulated Compounds[2]	Sum of Six	ng/l	325	315	3.69	185	85.7	1,796	203	2.61	142	70.9	259	78.3
b. Other Unregulated PFAS														
Perfluorobutanesulfonic Acid	PFBS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorobutanoic Acid	PFBA	ng/l	28.2	26.2	2.74	17.3	7.78	39.4	27.8	2.67	26	6.86	27	7.32
Perfluorodecanesulfonic Acid	PFDS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorododeanoic Acid	PFDoA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoroheptanesulfonic Acid	PFHpS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	6.4	<1.86	<1.89	<1.91	<3.76	ND	ND
Perfluorohexadecanoic Acid	PFHxDA	ng/l	<4.05	<4.04	<3.95	<3.91	<4.06	<3.91	<3.71	<3.76	<3.82	<1.88	ND	ND
Perfluorohexanoic Acid	PFHxA	ng/l	43.3	41.9	2.04	29	15.3	58	42.5	2.12	36.4	15.8	42.2	15.6
Perfluoronanesulfonic Acid	PFNS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorooctadecanoic Acid	PFODA	ng/l	<4.05	<4.04	<3.95	<3.91	<4.08	<3.91	<3.71	<3.78	<3.8	<3.76	ND	ND
Perfluorooctanesulfonamide Acid	PFOSA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	2.56	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoropentanesulfonic Acid	PFPeS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoropentanoic Acid	PFPeA	ng/l	34.6	35.3	<1.97	23.9	12.3	43	38.3	<1.89	32.3	11.3	36.8	11.8
Perfluorotetradecanoic Acid	PFTA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorotridecanoic Acid	PFTrDA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoroundecanoic Acid	PFUnA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	4.18	<1.86	<1.89	<1.91	<1.88	ND	ND
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	17.9	<1.86	<1.89	<1.91	<1.88	ND	ND
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	ng/l	<2.02	<2.02	3.34	<1.95	<2.04	10.8	<1.86	<1.89	<1.91	<1.88	ND	ND
2,3,3,3-Tetraflluoro-2-[1,1,2,2,3,3,3-Heptaflluoropropoxy]-Propanoic Acid	HFPO-DA	ng/l	<50.6	<50.5	<49.4	<48.8	<51.1	<48.9	<46.4	<47.2	<47.7	<46.9	ND	ND
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	4.9	<1.86	<1.89	<1.91	<1.88	ND	ND
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	ng/l	3.18	3.06	<1.97	<1.95	<2.04	39.8	<1.86	<1.89	<1.91	<1.88	ND	ND
Sum of All PFAS Compounds[3]	Total PFAS	ng/l	434	421	11.81	255	121	2,023	312	7.4	237	105	366	113

Notes:

[1] Database includes two rounds of sampling in May and June 2022 funded by BGS.

[2] PFAS State of Maine IDWS for drinking water for six PFAS analytes established June 21, 2021 at 20 ng/l.

[3] Values less than analytical detection limit assumed as zero in calculating average concentration.

[4] Leachate from CB#3 is raw leachate; CB#3 flows to the Dolby leachate pond.

[5] Town sanitary wastewater only.

[6] Combined Dolby leachate and Town sanitary wastewater.

TABLE 4-6

HISTORICAL LEACHATE QUALITY – DOLBY AND JUNIPER RIDGE LANDFILLS – 2018 TO 2022[1]

Parameter/Pollutant	Units	NPDES Limit[2]		Dolby # Leachate Samples	Dolby Minimum Concentration	Dolby Maximum Concentration	Dolby Historical Average Concentration	JRL # Leachate Samples	JRL Minimum Concentration	JRL Maximum Concentration	JRL Historical Average Concentration
		Avg. Mo.	Max. Day								
A. Conventional/Nutrients											
Biochemical Oxygen Demand (BOD5)	mg/l	37	140	0	NS	NS	NS	16	150	1,200	417
Total Organic Carbon (TOC)	mg/l	NA	NA	12	7.2	62.5	24.6	14	110	1,100	508
Total Suspended Solids (TSS)	mg/l	27	88	12	ND	14.9	9.7	16	ND	140	37.2
Ammonia as Nitrogen	mg/l	4.9	10	12	0.46	7.2	5.4	16	320	890	648
pH	s.u.	6 to 9	6 to 9	12	6.6	7.5	7.3	16	5.9	7.6	7.1
B. Toxic Metals											
Zinc	ug/l	110	200	3	ND	ND	ND	16	ND	1.0	0.09
C. Toxic Organics											
Alpha Terpineol	ug/l	16	33	0	NS	NS	NS	5	ND	330	156
Benzoic Acid	ug/l	71	120	0	NS	NS	NS	5	ND	ND	ND
p-Cresol	ug/l	14	25	0	NS	NS	NS	0	NS	NS	NS
Phenol	ug/l	15	26	0	NS	NS	NS	12	24	200	101
D. Anions/Cations											
Barium	mg/l	NA	NA	4	0.044	0.11	0.09	16	0.6	1.7	1.12
Calcium	mg/l	NA	NA	12	105	138	121	16	205	530	325
Magnesium	mg/l	NA	NA	12	43.4	111	76.2	16	160	335	243
Potassium	mg/l	NA	NA	12	16.8	116	76.4	16	460	1350	923
Sodium	mg/l	NA	NA	12	23.9	84.1	46.5	16	1000	2,850	2,044
Strontium	mg/l	NA	NA	0	NS	NS	NS	0	NS	NS	NS
Bicarbonate (HCO3)	mg/l	NA	NA	12	490	930	695	16	2200	3,600	2,716
Chloride	mg/l	NA	NA	12	21	94.5	48.5	16	5150	15,000	9,581
Fluoride	mg/l	NA	NA	0	NS	NS	NS	0	NS	NS	NS
Nitrate	mg/l	NA	NA	12	ND	2.2	0.38	9	ND	310	142
Sulfate	mg/l	NA	NA	12	3.6	55	27.2	16	ND	6,300	1,426
E. Other Non-Conventional Parameters											
Alkalinity as CaCO3	mg/l	NA	NA	12	490	930	695	16	2,200	3,600	2,716
Hardness as CaCO3	mg/l	NA	NA	0	NS	NS	NS	0	NS	NS	NS
Iron	mg/l	NA	NA	12	2.6	5.8	4.2	16	3.7	26	9.2
Manganese	mg/l	NA	NA	12	2.03	5.05	2.95	16	1.35	17	4.9
Total Dissolved Solids (TDS)	mg/l	NA	NA	12	545	1,040	827	16	6,399	15,375	10,678
Conductivity	µmhos/cm	NA	NA	12	916	1,711	1,333	16	11,310	26,966	19,460
Temperature	degree C	NA	NA	12	4.4	25.5	19	16	3.5	29	14.9
F. Per- and Polyfluoroalkyl Substances[3]											
PFAS (6 Analytes: PFOS, PFOA, PFHpA, PFNA, PFHxS, PFDA)	ng/l	20 (4)	NA	4	325	4,426	1,725	4	410	2637	1,856
See Table 3-4 for PFAS Results for 28 Analytes	ng/l	NA	NA	4	434	4,734	1,948	4	1723	11007	7,853

Notes:

[1] Database is from quarterly sampling for the period June 2018 through January 2022 with exception of PFAS results.

[2] NPDES values taken from Landfill Point Source Development document for non-hazardous landfills.

[3] PFAS Sampling Conducted for MEDEP in Oct 2021 and May 2022 and BGS in May 2022 and June 2022.

[4] PFAS values are State of Maine IDWS established June 21, 2021 for sum of 6 PFAS analytes combined in drinking water.

NA – Not Applicable
NS – Not Samples
ND – Not Detected

TABLE 4-7

RECENT AND HISTORICAL LEACHATE QUALITY – DOLBY AND JUNIPER RIDGE LANDFILLS[1]

Parameter/Pollutant	Units	NPDES Limit[2]		Dolby Leachate 2-May-22	Dolby Leachate 15-Jun-22	Dolby Recent Average	Dolby Historical Average[4]	JRL Leachate 2-May-22	JRL Leachate 15-Jun-22	JRL Recent Average	JRL Historical Average[4]
		Avg. Mo.	Max. Day								
A. Conventional/Nutrients											
Biochemical Oxygen Demand (BOD5)	mg/l	37	140	6.1	<2.0	4.0	NS	140	110	125	417
Total Organic Carbon (TOC)	mg/l	NA	NA	16.3	22.5	19.4	24.6	443	482	463	508
Total Suspended Solids (TSS)	mg/l	27	88	42	<5.0	24.5	9.7	53	40	47	37.2
Ammonia as Nitrogen	mg/l	4.9	10	7.27	9.85	8.56	5.4	685	678	682	648
pH	s.u.	6 to 9	6 to 9	7.5	7.7	7.6	7.3	7.4	7.5	7.45	7.1
B. Toxic Metals											
Arsenic	µg/l	NA	NA	NS	<0.005	<0.005	<0.005	NS	0.406	0.406	NS
Zinc	µg/l	110	200	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1	0.09
C. Toxic Organics											
Alpha Terpineol	µg/l	16	33	<5	<5	<5	NS	49.2	23.5	36	156
Benzoic Acid	µg/l	71	120	<50	<50	<50	NS	234	<200	117	<50
p-Cresol	µg/l	14	25	<5	<5	<5	NS	108	63	86	NS
Phenol	µg/l	15	26	<5	<5	<5	NS	53.5	<20	27	101
Volatile Organic Compounds (VOCs)	µg/l	NA	NA	NS	ND	ND	NS	NS	740	740	NS
D. Anions/Cations											
Barium	mg/l	NA	NA	0.077	0.063	0.07	0.09	0.853	1.16	1.01	1.12
Bromide	mg/l	NA	NA	NS	0.15	0.15	NS	NS	81.2	81.2	NS
Calcium	mg/l	NA	NA	104	111	108	121	239	244	242	325
Magnesium	mg/l	NA	NA	40.6	77.6	59.1	76.2	160	201	181	243
Potassium	mg/l	NA	NA	44.2	77.4	60.8	74.4	894	1,130	1,012	923
Sodium	mg/l	NA	NA	15.1	28.9	22	46.5	2,130	2,570	2,350	2,044
Strontium	mg/l	NA	NA	0.414	0.639	0.527	NS	2.37	2.93	2.65	NS
Bicarbonate (HCO3)	mg/l	NA	NA	509	760	635	695	2,810	3,570	3,190	2,716
Chloride	mg/l	NA	NA	14	28	21	48.5	5,100	5,800	5,450	9,581
Fluoride	mg/l	NA	NA	<0.2	<0.2	<0.2	NS	0.22	0.26	0.24	NS
Nitrite/Nitrate	mg/l	NA	NA	0.3	0.27	0.285	0.38	<0.1	1.9	0.95	142
Sulfate	mg/l	NA	NA	27	28	27.5	27.2	150	120	135	1,426
E. Other Non-Conventional Parameters											
Alkalinity as CaCO3	mg/l	NA	NA	509	760	635	695	2,810	3,570	3,190	2,716
Hardness as CaCO3	mg/l	NA	NA	427	597	512	NS	1,260	1,440	1,350	NS
Iron	mg/l	NA	NA	12.8	1.27	7.04	4.2	9.24	8.34	8.79	9.2
Manganese	mg/l	NA	NA	4.68	1.03	2.86	2.95	2.51	2.25	2.38	4.9
Total Dissolved Solids (TDS)	mg/l	NA	NA	550	910	730	827	9,900	12,000	10,950	10,678
Conductivity	µmhos/cm	NA	NA	1,100	1,412	1,256	1,333	19,000	24,000	21,500	19,460
Surfactants	mg/l	NA	NA	NS	0.151	0.151	NS	NS	1.6	1.6	NS
F. Per- and Polyfluoroalkyl Substances											
PFAS (6 Analytes: PFOS, PFOA, PFHpA, PFNA, PFHxS, PFDA)	ng/l	20[3]	NA	325	1,796	1061	-	2,627	2,443	2,535	-
See Table 4 for PFAS Results for 28 Analytes	ng/l	NA	NA	434	2,023	1229	-	9,400	11,007	10,204	-

Notes:

[1] Samples Collected by SME for State of Maine in May 2022 and June 2022.

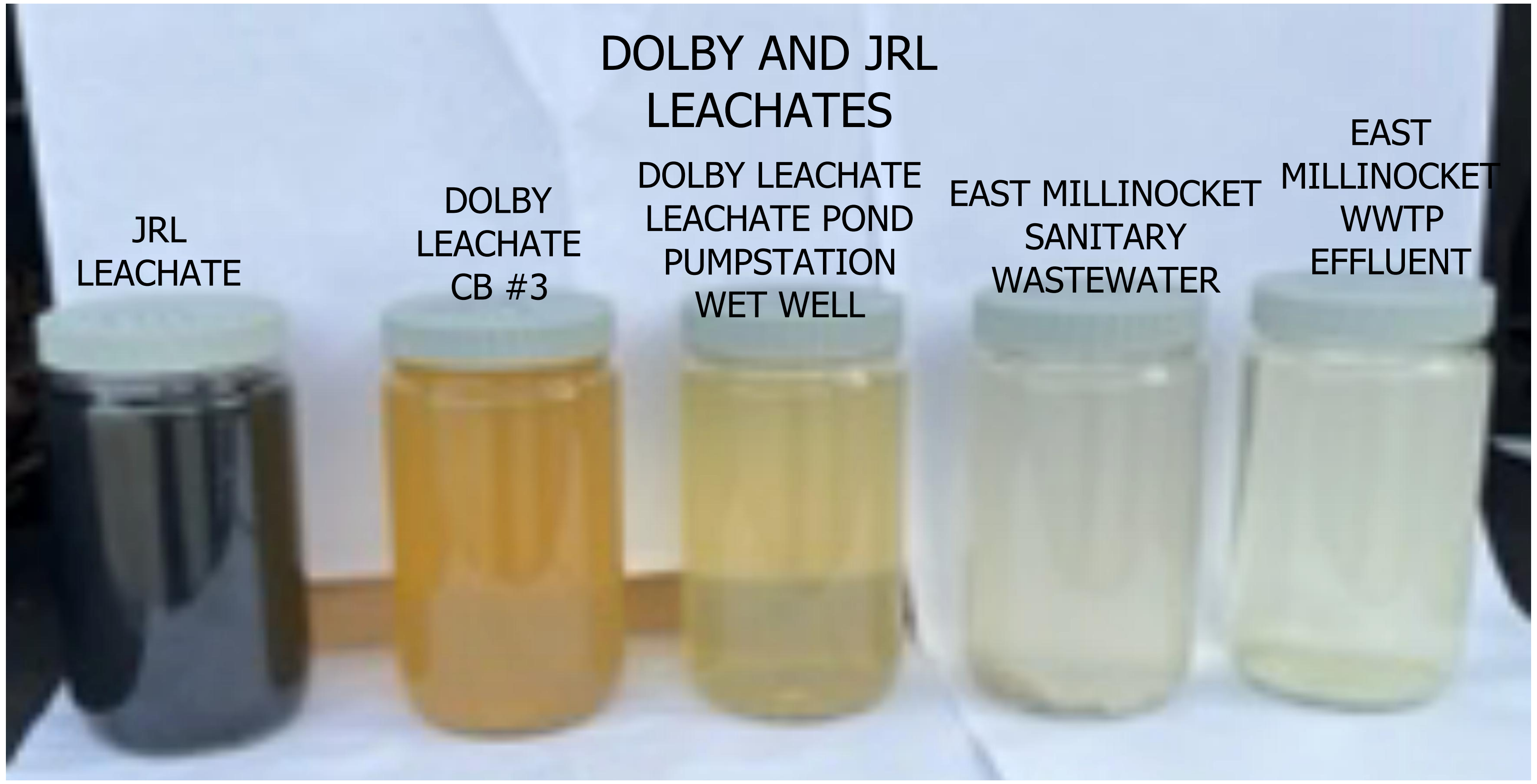
[2] NPDES values taken from Landfill Point Source Development document for non-hazardous landfills.

[3] PFAS values are State of Maine IDWS established June 21, 2021 for six PFAS analytes combined in drinking water.

[4] See Table 3-6 for Historical Leachate Quality Summary.

NA – Not Applicable
NS – Not Sampled
ND – Not Detected

DOLBY AND JRL LEACHATE SAMPLES COLLECTED JUNE 15, 2022



NOTE:
1. SAMPLES COLLECTED ON JUNE 15, 2022 BY SEVEE & MAHER ENGINEERS, INC.

FIGURE 4-1
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 4-1, 12/19/2022 3:03:25 PM, jrl

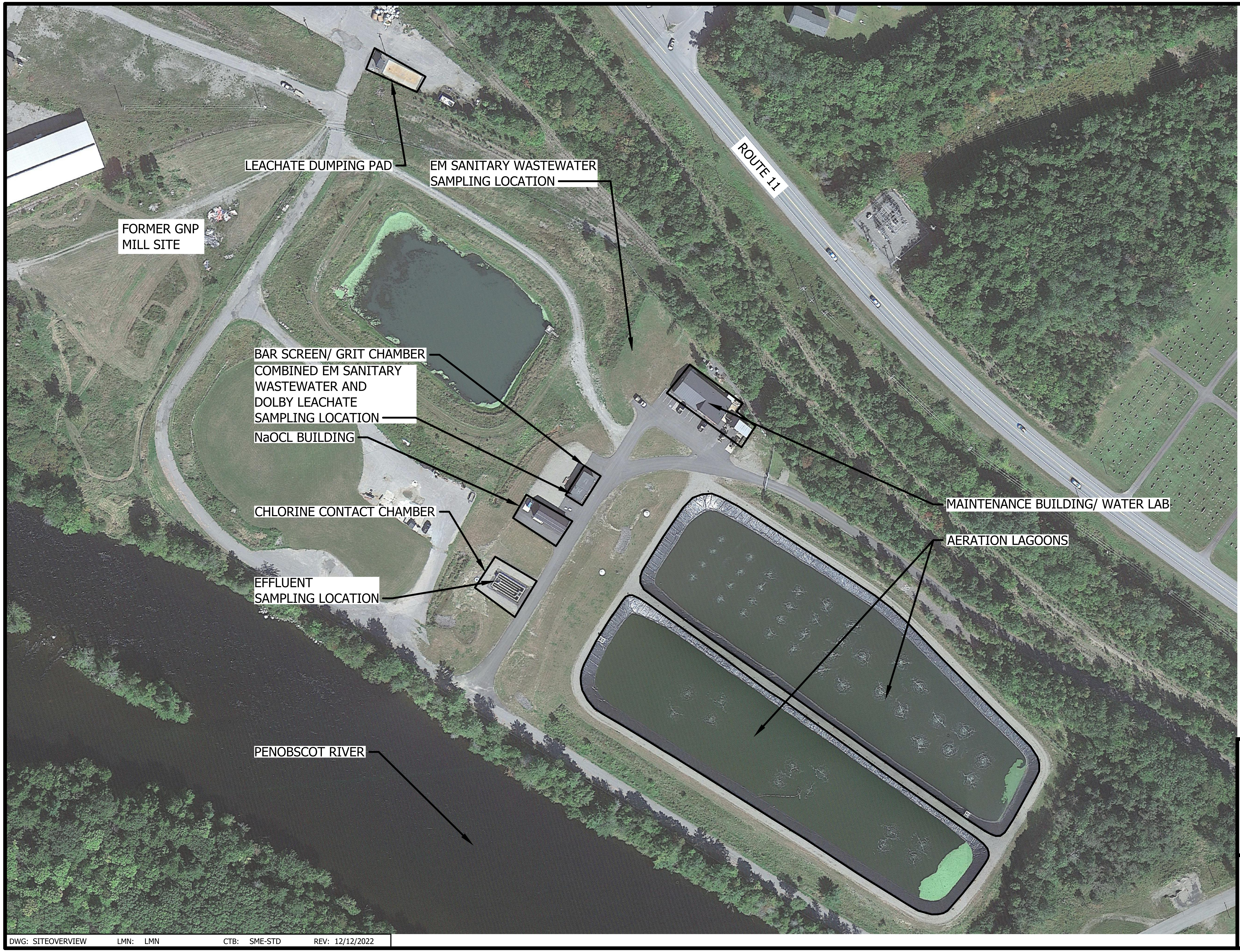
NOTE:
1. AERIAL IMAGE FROM GOOGLE EARTH, DATED SEPTEMBER 6, 2022.

75 0 150 FEET

FIGURE 4-2
LEACHATE SAMPLING POINTS AT DOLBY
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: LMN CTB: SME-STD REV: 12/12/2022



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NOTE:
1. AERIAL IMAGE FROM GOOGLE EARTH, DATED SEPTEMBER 6, 2022.

75 0 150 FEET

FIGURE 4-3
LEACHATE SAMPLING POINTS EMWWTP
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: LMN CTB: SME-STD REV: 12/12/2022

NOTE:

1. AERIAL IMAGE LOW ALTITUDE AERIAL PHOTOGRAMMETRIC MAPPING PERFORMED BY SEVEE & MAHER ENGINEERS, INC., DATED NOVEMBER 9, 2022

100 0 200 FEET

FIGURE 4-4
LEACHATE SAMPLING POINTS AT JUNIPER RIDGE LANDFILL
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: LMN CTB: SME-STD REV: 12/12/2022

NOTE:
1. AERIAL IMAGE FROM GOOGLE EARTH, DATED MAY 10, 2018.

100 0 200 FEET

FIGURE 4-5
LEACHATE ENTRY POINT AT NDWWTP
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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5.0 PFAS AND LANDFILL LEACHATE REGULATORY DISCUSSION

Congress enacted the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act, or CWA) in 1972 "to restore and maintain the chemical, physical, and biological integrity of the Nation's water." The CWA makes it unlawful for any person to discharge pollutants into waters of the United States from any point source, except as authorized by the National Pollutant Discharge Elimination System (NPDES) permit program. NPDES permits contain discharge limitations and establish related monitoring and reporting requirements. The State of Maine is an NPDES-delegated state and, as such, the MEDEP is the authority that issues discharge permits in Maine (referred to as Maine Pollutant Discharge Elimination System or MEPDES permit). Both the EMWWTP and NDWWTP are subject to water quality limits set forth in their respective MEPDES permits; although there are currently no PFAS regulations for either WWTP, if MEDEP or U.S.EPA were to promulgate PFAS water quality limits within those permits then the WWTPs would be obligated to comply.

NPDES and MEPDES permits provide for two types of effluent limitations to be addressed in each permit: "technology-based" effluent limitations (TBELs) and "water quality-based" effluent limitations (WQBELs).

5.1 Landfill Leachate Technology-Based Effluent Limitations (TBELs) Overview

Landfill leachate effluent limitation guidelines, pretreatment standards, and new source performance standards for facilities within the Landfill Industry were established by the U.S.EPA in January 2000. The TBELs depend on (1) if a landfill accepts hazardous or non-hazardous material, (2) if the leachate from a landfill is discharged directly to a receiving stream (referenced as Direct Discharge), or to an off-site treatment facility such as a local municipal or industrial WWTP (referenced as Indirect Discharge), and (3) the availability and effectiveness of wastewater technologies used to treat pollutants within leachate. The two discharge alternatives available for both the Dolby leachate and JRL leachate are to construct dedicated treatment facilities at each landfill site that are capable of attaining the U.S.EPA promulgated effluent standards for direct discharge to surface water (i.e., the Penobscot River), or to continue with indirect discharges to the EMWWTP (Dolby) and the NDWWTP (JRL). For non-hazardous landfills (such as Dolby and JRL), the effluent discharge requirements for leachate are outlined in the Development Document for Final Effluent Limitations Guidelines and Standards for the Landfills Point Source Category (U.S.EPA, 2000) and are summarized in Table 5-1.

Currently, there are no PFAS TBELs established for landfill leachate. If U.S.EPA considers promulgation of updated TBELs specific to PFAS in landfill leachate, U.S.EPA would need to develop effluent limitations on an industry-by-industry basis (in this case the Landfill Industry), take into account the cost of achieving the established effluent limitations (i.e., the cost reasonableness), and conduct a cost-benefit analysis for implementing such TBELs. MEDEP personnel have indicated that they do not anticipate promulgation of any PFAS discharge limitations for leachate, but rather will wait for U.S.EPA to assess and implement leachate PFAS regulations for landfills in the future. At this time, it is not clear if or when, PFAS concentrations will be regulated in landfill leachate.

5.1.1 Direct Discharge TBELs for Non-Hazardous Landfills

The direct discharge TBELs for non-hazardous landfills include: the conventional pollutants (i.e., BOD5, TSS, and pH); and pollutants subject to Best Available Technology Economically Achievable (BAT) including ammonia, zinc, alpha terpineol, benzoic acid, p-cresol, and phenol. Although there are no federal or state TBELs for PFAS in leachate, any dedicated leachate treatment facilities that utilize direct discharge of effluent must be capable of meeting the discharge concentration limits outlined in Table 5-1 for non-hazardous landfills, plus, for the Study, the PFAS effluent concentrations should be less than the State of Maine IDWS for PFAS in drinking water. If it is determined that PFAS removal from leachate to below 20 ng/l (i.e., the interim drinking water standard) is not technically practical, then less stringent effluent PFAS concentration limits will need to be identified that can be reliably attained.

The current process for treating landfill leachate with respect to the established U.S.EPA direct discharge TBELs is biological treatment for controlling BOD5, TSS, and removing ammonia; pH adjustment; and biological treatment and/or filtration for controlling zinc, alpha terpineol, benzoic acid, p-cresol, and phenol. As discussed in subsequent sections of this Report, leachate containing PFAS will need to be treated by conventional biological treatment to control BOD5, TSS, ammonia, pH, toxic organics and zinc, before receiving tertiary PFAS treatment at a WWTP, or the in the case of Dolby and JRL, the leachate will need to be pretreated at the landfill sites to remove the majority of the PFAS before the leachate is released to the EMWWTP or NDWWTP.

5.1.2 Indirect Discharge TBELs for Non-Hazardous Landfills

U.S.EPA has not established any treatment standards for indirect discharge of leachate from new or existing landfills, although landfill leachate must comply with 40 CFR Part 403 relative to pollutants that pass through, interfere with, or are otherwise incompatible with the operation of municipal or industrial wastewater treatment facilities. The current indirect discharge of leachate from Dolby and JRL to the EMWWTP and NDWWTP, respectively, do not require any leachate pretreatment for TBELs at either landfill site because the follow-up biological treatment facilities at the EMWWTP (Dolby) and the NDWWTP (JRL) already provide treatment to comply with the present effluent discharge limits for each respective WWTP. Similar to the direct discharge TBELs for landfill leachate, there are currently no federal or state indirect discharge standards for PFAS discharged to municipal or industrial WWTPs. It should also be noted that for the Dolby and JRL leachate, there are no specific Industrial Discharge permits, pretreatment requirements, or other agreements between BGS and East Millinocket or between JRL and Nine Dragons, relative to the quality of leachate received from Dolby or JRL.

There are no PFAS TBELs for indirect discharge of landfill leachate. Therefore, for both Dolby and JRL, a PFAS removal unit operation would need to either precede the biological treatment operations at EMWWTP and NDWWTP, or a tertiary PFAS removal process would need to be installed to treat the biological treatment effluent from the treatment plants before the effluent could be discharged to the river. While the concept of tertiary PFAS removal from the biological treatment effluent for the combined flow of Dolby leachate and East Millinocket sanitary wastewater seems technically reasonable, it may not be practical due to the periodic high effluent flows experienced. Similarly, the overall daily flows at NDWWTP make tertiary PFAS treatment impractical. For this reason, the options of installing an “upfront bulk PFAS removal technology” followed by the existing biological treatment at the EMWWTP and NDWWTP with discharge to the river, are considered and evaluated in Sections 7.0 and 8.0.

5.2 Water Quality-Based Effluent Limitations (WQBEL) Overview

The CWA requires that permit effluent limitations based on water quality considerations be established for point source discharges when such limitations are necessary to protect state or federal water quality standards that are applicable to the designated receiving water. In this regard, Water Quality-Based Effluent Limitations (WQBELs) are used when less stringent TBELs do not achieve attainment with, or maintenance of, the water quality criteria in the receiving water.

The establishment of water quality-based standards for WWTP effluent generally consists of three parts: 1) designation of uses assigned to a water body or a segment of a water body; 2) development of numeric or narrative water quality criteria sufficient to protect the assigned designated use(s); and 3) ensuring that once a designated use is attained, the water body and water quality will not be degraded.

If new direct discharge options are considered for treating either the Dolby or JRL leachate, a new MEPDES permit(s) will be required. The permitting process would require the applicant to demonstrate that the new discharge, in combination with other existing discharges, will not lower the quality of the receiving body of water. Further, the provisions of the State's water anti-degradation policy (38 MRSA Section 464(4)-F) must also be met. Personnel from the MEDEP have expressed concern that a new direct discharge from either Dolby or JRL could lower the quality of the Penobscot River to below its current water quality classification. Further, MEDEP has expressed concern that direct discharge of any concentration of PFAS may not protect existing uses and the provisions of the State's anti-degradation policy may not be met.

In general, it is anticipated that the permitting process for allowing a new direct discharge from either Dolby or JRL to the Penobscot River could be more complex and challenging in addressing WQBELs related to PFAS as compared to continuing with indirect discharge by way of the EMWWTP and NDWWTP.

5.3 Drinking Water Regulations Specific to PFAS

In the United States, there is a lack of federal policies to deal with PFAS, in general. Since 2009, U.S.EPA has announced short-term drinking water advisories, but the federal government has still not introduced an enforceable limit. In summary, currently there is no federal maximum contaminant level (MCL) for PFAS related to drinking water. On June 15, 2022, U.S.EPA released four lifetime health advisories for PFAS: PFOA, 0.004 ng/l; PFOS, 0.02 ng/l; HFPO-DA (also referenced as GenX chemicals), 10 ng/l; and PFBS, 2,000 ng/l. These new lifetime health advisories replace the previous advisory value of 70 ng/l for PFOA plus PFOS combined that was established in 2016. Lifetime health advisories are intended, with a margin of safety, to represent chemical concentrations at which adverse health effects are not expected to occur over a lifetime of exposure. U.S.EPA's drinking water health advisories are non-enforceable, non-regulatory, and are meant to provide technical information to state agencies and other public health officials. Of particular note for the recent U.S.EPA drinking water health advisories, is that the proposed concentrations for PFOA plus PFOS are significantly less than the current analytical detection limit of about 2 to 4 ng/l.

The U.S.EPA has stated they propose to issue new enforceable maximum contaminant level goals (MCLGs) for PFOS and PFOA in drinking water in November 2022, with implementation by the fall 2023. U.S.EPA has indicated they will consider other PFAS (including Gen-X and PFBS) in this rulemaking effort. To complete the development of new standards, U.S.EPA will need to assess the affordability of the new regulations and prepare a cost-benefit analysis.

Many states have regulated, are in the process of regulating, or have published guidelines and notification concentrations for a number of PFAS in drinking water. Currently, there are six states with enforceable PFAS MCLs, three states with proposed standards, and 12 states with guidelines or notification levels. Table 5-2 provides an overview on PFAS regulations, including standards for drinking water.

The State of Maine established an interim drinking water standard (IDWS) for the combined concentration of PFOA, PFOS, PFNA, PFHxS, PFHpA, and PFDA (i.e., PFAS(6)) in drinking water in June 2021. The Maine IDWS for PFAS(6) is 20 ng/l and is among the most restrictive PFAS concentration standards in the United States. The U.S.EPA and state water quality agencies are evaluating potential changes to the PFAS drinking water regulatory limits based on emerging science and available treatment technologies, both of which continue to evolve.

5.4 PFAS Regulations for Other Media

PFAS regulations or guidance are extremely sporadic for most environmental media with the exception of drinking water in 21 states as mentioned above. There are no federal or state PFAS limits for municipal WWTP effluents, industrial effluents, or landfill leachate and there are sporadic state guidelines for wastewater sludge and residuals.

In addition to drinking water standards, the State of Maine has been relatively proactive in establishing PFAS limits for other matrices including the beneficial reuse of biosolids from WWTPs, soil remediation, groundwater and surface water cleanup levels, and concentrations within fish tissue and foodstuffs (such as beef and milk). These PFAS limits are likewise summarized in Table 5-2.

It is notable that there are no federal or State of Maine guidelines or limits on disposal of PFAS in landfills. Most of the treatment alternatives considered for the Study generate a residual side stream that is concentrated with PFAS. Promulgation of PFAS disposal limitations for landfills could have a direct bearing on how to effectively manage these side streams.

TABLE 5-1

CONCENTRATION LIMITS FOR LANDFILL LEACHATE DISCHARGES TO RECEIVING STREAMS AND/OR LOCAL TREATMENT FACILITIES[1]

Pollutant	Hazardous Waste LF Direct Discharge Maximum Day (mg/L)	Hazardous Waste LF Direct Discharge Monthly Average (mg/l)	Non-Hazardous Waste LF Direct Discharge Maximum Day (mg/L)	Non-Hazardous Waste LF Direct Discharge Monthly Average (mg/L)	Hazardous Waste LF Indirect Discharge Pretreatment (mg/L)	Non-Hazardous Waste LF Indirect Discharge Pretreatment (mg/L)
Biochemical Oxygen Demand (BOD5)	220	56	140	37	Note 2	Note 2
Total Suspended Solids (TSS)	88	27	88	27	Note 2	Note 2
Ammonia	10	4.9	10	4.9	Note 2	Note 2
Arsenic	1.1	0.54	Not Regulated	Not Regulated	Note 2	Note 2
Chromium	1.1	0.46	Not Regulated	Not Regulated	Note 2	Note 2
Zinc	0.535	0.296	0.2	0.11	Note 2	Note 2
Alpha Terpineol	0.042	0.019	0.033	0.016	Note 2	Note 2
Aniline	0.024	0.015	Not Regulated	Not Regulated	Note 2	Note 2
Benzoic Acid	0.119	0.073	0.12	0.071	Note 2	Note 2
Naphthalene	0.059	0.022	Not Regulated	Not Regulated	Note 2	Note 2
p-cresol	0.024	0.015	0.025	0.014	Note 2	Note 2
Phenol	0.048	0.029	0.026	0.015	Note 2	Note 2
Pyridine	0.072	0.025	Not Regulated	Not Regulated	Note 2	Note 2
pH	6 to 9 s.u.	6 to 9 s.u.	6 to 9 s.u.	6 to 9 s.u.	Note 2	Note 2
PFAS Compounds	No Current Limits[3]	No Current Limits[3]	No Current Limits[3]	No Current Limits[3]	No Current Limits[3]	No Current Limits[3]

Notes:

[1] Permit Limits taken from Development Document for Final Effluent Limitation Guidelines and Standards for the Landfills Point Source Category, USEPA, EPA-821-R-99-019, January 2000.

[2] U.S.EPA did not establish Pretreatment Standards for either the Hazardous Waste or Non-Hazardous Waste Landfill Subcategories.

[3] There are currently no discharge standards for PFAS compounds in leachates; for the subject study the discharge goal is the current State of Maine IDWS in drinking water which is the sum of PFOA, PFOS, PFNA, PFHxS, PFHpA and PFDA combined is less than 20 ng/l.

TABLE 5-2

OVERVIEW OF PFAS REGULATIONS FOR DRINKING WATER, WASTEWATER, LEACHATE, INDUSTRIAL DISCHARGES, SLUDGE, AND OTHER MEDIA

State/Agency	PFAS Regulations	Comments
1. POTABLE WATER		
U.S.EPA	Final Health Advisory (HA): GenX 10 ng/l; PFBS 2,000 ng/l; Interim HA: PFOA 0.004 ng/l; PFOS 0.02 ng/l	EPA non-enforceable HA Level issued June 15, 2022; Agency to propose IDWS for PFOA, PFOS and other PFAS in Nov 2022 after assessing affordability and benefit-cost analysis
Maine	PFOA, PFOS, PFNA, PFHxS, PFHpA, and PFDA combined 20 ng/l	PFAS enforceable limits are State of Maine IDWS established June 2021 for drinking water
New Hampshire	PFHxS 18 ng/l; PFOA 12 ng/l; PFOS 15 ng/l; PFNA 11 ng/l	PFAS enforceable limits are State of New Hampshire IDWS for drinking water effective Feb 2019
Massachusetts	PFOA,PFOS, PFNA, PFHxS and PFHpA combined 70 ng/l	PFAS enforceable limits are State of MA IDWS established October 2020 for drinking water
Connecticut	PFOA 16 ng/l; PFOS 10 ng/l; PFNA 12 ng/l; PFHxS 49 ng/l l	PFAS drinking water action levels issued June 15, 2022; action levels are non-enforceable guidelines
Vermont	PFOA, PFOS, PFNA, PFHxS and PFHpA combined 20 ng/l	PFAS enforceable limits are State of Vermont IDWS for drinking water effective March 2020
Rhode Island	PFOA and PFOS combined 70 ng/l	PFAS non-enforceable limits are guidelines for using water for drinking water purposes
New York	PFOA and PFOS combined 10 ng/l	PFAS enforceable limits are State of New York IDWS for drinking water effective July 2020
New Jersey	PFOA 14 ng/l; PFOS 13 ng/l and PFNA 13 ng/l	PFAS enforceable limits are State of New Jersey IDWS for drinking water
Michigan	PFOA 8 ng/l; PFOS 16 ng/l; PFNA 6 ng/l; PFHxS 51 ng/l; PFHxA 400,000 ng/l; PFBS 420 ng/l; and HFPO-DA 370 ng/l	PFAS enforceable limits are State of Michigan IDWS for drinking water effective August 2020
Other	Agencies/States with Proposed Standards	Arizona, Iowa, Kentucky
Other	Agencies/States with Guidelines or Notification Levels	Arkansas, California, Colorado, Delaware, Illinois, Minnesota, North Carolina, New Mexico, Oklahoma
2. POTW TREATED EFFLUENT		
U.S.EPA/State Agencies	No current regulations or guidelines	EPA/Miscellaneous States monitoring and evaluating; No proposed regulations to date
3. LANDFILL LEACHATES		
U.S.EPA/State Agencies	No current regulations or guidelines	EPA/Miscellaneous States monitoring and evaluating; No proposed regulations to date
4. INDUSTRIAL DISCHARGE EFFLUENTS		
U.S.EPA/State Agencies	No current regulations or guidelines	EPA/Miscellaneous States monitoring and evaluating; No proposed regulations to date
5. RESIDUALS (SLUDGE) FROM TREATMENT PROCESSES		
U.S.EPA/State Agencies	No current regulations or guidelines	EPA/Miscellaneous States monitoring and evaluating; No proposed regulations to date
6. OTHER GUIDELINES OR LIMITS		
Michigan	Groundwater Standards	PFOA 8 ng/l; PFOS 16 ng/l
New York	Raw Water Sources	PFOA 6.7 ng/l for Human Health; PFOS 2.7 ng/l for Human Health; 160 ug/l for freshwater chronic aquatic life and 160 ug/l for saltwater chronic aquatic life
Maine	Beneficial Use of Solid Wastes	PFBS 1,900,000 ng/kg; PFOA 2,500 ng/kg; PFOS 5,200 ng/kg
	Soil Remedial Actions:	
	a.) Leaching to Groundwater	PFBS 7,100,000 ng/kg; PFOS 3,600 ng/kg; PFOA 1,700 ng/kg
	b.) Residential Area Cleanup	PFBS 1,700,000,000 ng/kg; PFOS 1,700,000 ng/kg; PFOA 1,700,000 ng/kg
	c.) Commercial Area Cleanup	PFBS 22,000,000,000 ng/kg; PFOS 22,000,000 ng/kg; PFOA 22,000,000 ng/kg
	d.) Park Area Cleanup	PFBS 4,900,000,000 ng/kg; 4,900,000 ng/kg; PFOA 4,900,000 ng/kg
	e.) Recreational (sediment) Cleanup	PFBS 5,700,000,000 ng/kg; PFOS 5,700,000 ng/kg; PFOA 5,700,000 ng/kg
	f.) Construction Area Cleanup	PFBS 51,000,000,000 ng/kg; PFOS 5,100,000 ng/kg; PFOA 5,100,000 ng/kg
	Water Remedial Aclion Levels	
	a.) Residential	PFBS 400,000 ng/l; PFOS 400 ng/l; PFOA 400 ng/l
	b.) Construction	PFBS 100,000,000 ng/l; PFOS 750,000 ng/l; PFOA 750,000 ng/l
	Fish Tissue Remedial Action	PFBS 52,000,000 ng/kg; PFOS 52,000 ng/kg; PFOA 520,000 ng/kg
	Foodstuff Action Levels	
	a.) Milk	PFOS 210 ng/l
	b.) Beef	PFOS 3,400 ng/kg

6.0 POTENTIAL PFAS TREATMENT OPTIONS

This section provides information about treatment technologies for reducing PFAS concentrations in liquids (e.g., drinking water, municipal wastewater effluents, industrial wastewater effluents, and landfill leachate) and solid waste (e.g., sludge, contaminated soils, and treatment residues). The treatment technologies described in this section are organized by degree of development and implementation. Similar to the PFAS treatability template used by the Interstate Technology and Regulatory Council (ITRC), levels of treatment development are organized as: Commercially Demonstrated or Field Implemented; Evolving or Limited Application Technologies; and Developing Technologies (ITRC, 2020).

Only a limited number of PFAS treatment technologies are commercially available that have been demonstrated to reduce PFAS, while there are numerous technologies being developed, advertised, and yet to be proven in a field-scale setting. Some of these developing technologies have shown promising results in laboratory bench-scale trials but reports and discussions indicate there is only limited data available on the applicability and scalability of those technologies relative to the potential for large-scale reduction of PFAS concentrations in wastewater and leachate like that needed for Dolby and JRL.

Treating landfill leachates containing PFAS is a challenging proposition. In contrast to groundwater drinking water supplies that have little to no other co-pollutants that require pretreatment, leachates are typically a complex matrix of organic, inorganic, and other constituents that may require pretreatment before PFAS can be efficiently removed by tertiary treatment processes (i.e., such as adsorption technologies). PFAS treatment for leachate does not have a single solution. Rather, the selected PFAS treatment process for leachate will likely vary from landfill to landfill and be very different as compared to treating PFAS in groundwater to be used for drinking water purposes.

In evaluating the potential applicability of technologies for reducing PFAS(6) concentrations to below 20 ng/l (i.e., the IDWS), a number of recently completed reports and PFAS treatment demonstrations were reviewed and closely examined. Table 6-1 provides a partial listing of these reports. Of particular interest are the first five documents listed on Table 6-1, which are summarized as follows.

> <u>PFAS Technical and Regulatory Guidance Document</u>, prepared by Interstate Technology & Regulatory Council, in 2020. This is an exhaustive analysis of PFAS, including a detailed assessment of technologies for treating PFAS in various environmental matrices.

Technologies are organized by degree of development and implementation as well as current confidence in the technology based on peer-reviewed literature and the professional judgment of the authors (ITRC, 2020). The guidance document is updated on an annual basis and technology development is highlighted.

Review of Water Treatment System for PFAS Removal, prepared by Concawe Environmental Science for European Refining, 2020. This review evaluates technologies for removing PFAS from contaminated groundwater and from AFFF-contaminated waters. This analysis is particularly valuable since the AFFF-contaminated water matrix is similar to leachate in that the concentration of PFAS is elevated and the waste matrices are more complex due to the high concentrations of co-contaminants that are related to fire suppression sites in comparison to PFAS-tainted groundwater.

PFAS Innovative Treatment Team (PITT), prepared by U.S.EPA, 2020-2022. U.S.EPA initiated the PITT program for funding innovative technologies that are not fully developed commercially but show promise for treating PFAS. Each year, U.S.EPA funds a series of technologies for technical demonstration and the technology summaries are published annually.

Drinking Water Treatment for PFAS Selection Guide, prepared for American Water Works Association (AWWA) by HDR, 2021. The purpose of the Selection Guide is to assist water systems with drinking water treatment decisions for PFAS. This guide reviews treatment technologies with demonstrated ability to remove PFAS, provides technical answers important to the technology selection process, and identifies potential unintended consequences of the technologies.

PFAS Management and Treatment for Landfill Leachate, report prepared by the Solid Waste Association of North America Applied Research Foundation, November 2021. The report provides solid waste managers with information and guidance on leachate management and treatment options to manage PFAS in leachate.

In addition to the documents listed in Table 6-1, numerous vendors were contacted for the Study to update any recent progress in development of those technologies. Table 6-2 provides a list of full-scale PFAS treatment systems currently used to reduce PFAS from various liquid and solid matrices (drinking water, wastewater treatment effluents, leachate, soil and groundwater from AFFF sites, and other comparable cleanups). Table 6-2 is dominated by full-scale PFAS treatment systems for drinking water and highlights that the demonstrated technologies for PFAS removal are mainly adsorption by GAC and IEX. For leachate treatment, there has been some success using reverse osmosis (RO) and foam fractionation (FF), although the treatment goals have varied widely from site to site. A few other technologies have been successful in reducing PFAS in leachate using bench-scale testing and field pilot trials.

6.1 Liquid Treatment Technologies

6.1.1 Commercially Demonstrated and Field Implemented Technologies

There are technologies that have been commercially demonstrated and implemented at a wide array of sites and the effectiveness to reduce PFAS is certain. The three liquid treatment technologies that have been successfully field-implemented include adsorption to activated carbon, ion exchange, and reverse osmosis. Each of these processes transfer the PFAS molecules to a separate media or to a reduced volume waste stream that must be further managed or treated.

Granular Activated Carbon (GAC). Removal of PFAS by GAC is a physical mass transfer process (adsorption) from the aqueous phase (i.e., leachate) onto a solid media (i.e., activated carbon) that does not involve or trigger any form of chemical degradation or transformation (ITRC, 2020). GAC is a proven technology for the removal of PFAS (particularly long-chain carbon molecules such as PFOA and PFOS) from relatively clean or otherwise pretreated liquids. GAC is not considered to be suitable for direct treatment of raw landfill leachate due to the high concentration of other pollutants present in leachate that would reduce PFAS adsorption efficiency. PFAS are typically present at extremely low concentrations (ng/l range) in leachate by comparison to the organic pollutants that are typically present at mg/l concentrations. Additionally, the high concentrations of other organic compounds in leachate will quickly exhaust available adsorption capacity of carbon, thus resulting in frequent carbon replacement. GAC is less effective at removing short-chain PFAS as compared to long-chain PFAS and, as a consequence, quicker breakthrough of the short-chain PFAS occurs, thereby, requiring more carbon usage and higher operating costs than would be expected for treating long-chain PFAS. The more effective removal of long-chain PFAS is attributed to the hydrophobic effects of GAC. In addition, the effectiveness of GAC to remove short-chain PFAS is diminished when dissolved organic carbon (DOC) is present due to the competition and displacement of shorter-chain PFAS by the DOC, as well as by longer-chain PFAS and other contaminants (HDR, 2021).

GAC usage is extremely site-specific and dependent on the PFAS molecule(s) of interest, the concentration of PFAS, the PFAS cleanup goals, and the overall quality of the matrix being treated. GAC must be replaced when the available carbon adsorption sites are exhausted. The spent (or exhausted) GAC can be disposed of at properly licensed landfills or be regenerated by exposing the GAC to steam or hot gas at a specialized PFAS treatment facility. It has been reported that thermal regeneration can destroy PFAS attached to GAC if conducted at 1,000°C or higher (Brown and Caldwell, 2019). Although incineration and thermal reactivation/ regeneration offer the possibility of destroying PFAS attached to GAC, others have reported that incineration may yield incomplete combustion byproducts (ITRC, 2020). The regulatory framework for disposal of spent GAC and the respective disposal/destruction technologies are not clear at this time relative to PFAS treatment. It is possible that spent GAC could become subject to hazardous waste disposal requirements in the future.

GAC treatment is an effective PFAS treatment technology to consider for Dolby and JRL. For the Dolby leachate, GAC could be particularly useful for removing PFAS from the EMWWTP effluent before final discharge if sufficient pretreatment is provided to protect the GAC from fouling. For example, the pretreatment would likely need to include reduction of iron and manganese to below 0.3 mg/l and 0.005 mg/l, respectively, and TOC and ammonia concentrations to below 1 mg/l and 0.5 mg/l, respectively, to optimize GAC usage. In contrast, for the JRL leachate, GAC is not considered as suitable for treating leachate due to even greater and more involved pretreatment requirements for non-PFAS contaminants. It should also be understood that it is not practical to remove PFAS from the NDWWTP effluent due to the large flows from that facility (by comparison to EMWWTP flows); rather, any PFAS treatment of the JRL leachate will need to be conducted at the JRL site. GAC vendors contacted for the Study included Calgon Carbon, ECT2, AdEdge, and NEWTERRA (formerly TIGG Environmental).

Ion Exchange (IEX). Removal of PFAS using IEX media (also called IEX resin) involves synthetic and polymeric materials designed to take advantage of exchanging purposely charged ions in a solid (i.e., the resin) with charged ions in a solution (the liquid). Ion exchange resin also treats PFAS by adsorption. At normal pH values, dissolved PFAS exist as negatively charged molecules (i.e., anions), which are attracted to specially designed and positively charged molecules (i.e., cations) in the resin (Concawe, 2020). Most early IEX resins contained chloride or sodium, and some also included hydroxide or hydrogen ions (HDR, 2021). As the PFAS issue has become more complex and pervasive, manufacturers have been developing and fine-tuning resins for treating specific PFAS molecules, which allows preferential removal of PFAS with less competition from other pollutants in leachate (HDR, 2021). IEX resin, like GAC adsorption media, becomes exhausted with time and must be regenerated, replaced, or disposed.

As with GAC, IEX resins are intended for treatment of comparatively clean wastewaters to avoid fouling and premature replacement and, therefore, are primarily used for final polishing of effluents after significant pretreatment has occurred to remove other pollutants that interfere with resin functions (Brown and Caldwell, 2019). As such, the same description relative to GAC pretreatment also applies to IEX. Most resins used for PFAS treatment in drinking water applications are single-use resins although regenerable resins are available. During the regeneration procedure, a regenerate solution (such as an organic solvent, alcohol, and acidic or alkaline solutions) containing PFAS is produced that must be treated or disposed.

An enhanced IEX method for removing PFAS from water is being investigated that uses alternative resins and/or adsorption media that can be heavily loaded with other pollutants while remaining effective for PFAS treatment. These specially designed IEX media could significantly reduce the volume of IEX residuals requiring regeneration or disposal.

Reverse Osmosis (RO). RO is a separation technology used to remove a broad array of pollutants (including PFAS) from water by applying differential pressure across a semi-permeable membrane. Water passing through the membrane (i.e., the permeate) is treated, whereas the water not passing the membrane (i.e., the concentrate) contains concentrated PFAS that is collected for further treatment or disposal. RO has been shown to remove PFAS to below analytical detection limits (typically less than 2 ng/l); however, concentrations of pollutants in permeate vary depending on the specific compound for treatment and the overall liquid matrix characteristics (Brown and Caldwell, 2019).

Most conventional RO applications require a relatively clean influent to minimize membrane fouling (i.e., flux loss across the membrane due to the accumulation of organic and colloidal matter, precipitation of inorganic salts, suspended solids, and microbial growth) and may have a concentrate volume as high as 20 percent of the leachate feed volume. The JRL leachate TSS concentration (in the range of 30 to 40 mg/l) is a greater concern than the Dolby leachate TSS concentration (about 10 mg/l) relative to potential RO fouling. Adequate pretreatment and appropriate membrane selection can minimize the fouling rate, but membrane cleaning is an essential step in maintaining the performance of the RO process (ITRC, 2022).

A different RO configuration is offered by Rochem Americas, Inc that has been demonstrated to operate effectively on raw leachate with simple preliminary filtration at 10 microns and pH adjustment. The Rochem RO uses an alternative membrane element construction using an open channel flow path with high crossflow velocity to reduce fouling. Coupled with higher available operating pressures than conventional membranes (up to about 1,800 pounds per square inch [psi]), this system is designed to maximize PFAS recovery and minimize concentrate volume to about 10 to 12 percent of the feed volume (SWANA, 2021).

An issue inherent to PFAS removal by membrane processes is the disposal of the PFAS-enriched concentrate, which depending on the membrane design and characteristics of the feed water, the concentrate may consist of about 10 to 20 percent of the feed water volume. Developing an effective means to further concentrate and remove PFAS from RO concentrate needs to be addressed for cost efficiency. Although RO is a commercially available technology to effectively reduce PFAS, the volume of Dolby leachate and associated concentrate makes RO potentially impractical for the Dolby leachate. Conversely, the JRL leachate volume may be more suitable but, however, contains a greater variety of non-PFAS pollutants at much greater concentration. Additionally, a major challenge to using RO technology for either the Dolby or JRL leachate is identification and implementation of an effective concentrate management plan. RO vendors contacted for the Study included Koch Industries, Dow Water and Process Solutions, and Rochem Americas, Inc. RO appears to be a viable PFAS treatment methodology for either Dolby or JRL, provided adequate PFAS concentrate management can be implemented.

6.1.2 Evolving and Limited Application Liquid Treatment Technologies

As defined by ITRC, only a few liquid treatment technologies have been implemented for PFAS removal and only at a limited number of sites. These treatment technologies have involved few waste matrices, and typically have been demonstrated as field pilot test applications (ITRC, 2022). Liquid treatment technologies that are expected to remove PFAS from the Dolby and JRL leachates include Adsorption with Alternative Media, Foam Fractionation, Electrochemical Advanced Oxidation, and Supercritical Water Oxidation.

Adsorption with Alternative Media. One area of development for removing PFAS from complex liquids such as leachate is the use of alternative adsorption media or resin that has an affinity for attaching and holding PFAS molecules. Examples of such alternative media include:

Coated Sands – Sand beds are commonly used for filtration of drinking water before distribution to users. Researchers are developing coatings for filtration sands that would be attractive to PFAS while remaining effective for filtration. Sand filtration for wastewater will likely be subject to premature clogging due to high volumes of particulates typically carried in wastewater. For Dolby and JRL, the coated sand filtration would occur as a final treatment step at the EMWWTP and NDWWTP before effluent discharge to the river. Large area sand beds would be needed due to the large flows treated at both treatment facilities as well as the coating's effectiveness. The sand beds would also need to be operated in heated enclosures. Sand bed change-outs would likely result in creation of large volumes of PFAS containing solid waste needing disposal.

Zeolites and Clay Minerals – Zeolites and certain clay minerals are large surface area particles receptive to adsorption of PFAS and other organic compounds. Practical experience has shown liquid leaching through clay and particles of similar structure can be very slow and likely prohibitive to treating large volumes of water. Like sand beds for wastewater treatment, use of zeolites and clay minerals for leachate treatment would be a slow process and bed change-outs would likely result in creation of large volumes of PFAS containing solid waste needing disposal.

Fluoro-Sorb – Fluoro-sorb is a proprietary designed, surface-modified, bentonite clay media that attracts a wide range of PFAS. Unlike other adsorption products that can be non-selective and unpredictable for PFAS adsorption, fluoro-sorb adsorbent binds the entire spectrum of PFAS using a wide variety of removal and retention processes. With a specialty-modified surface, fluoro-sorb adsorbent resists competitive adsorption from other co-pollutants within leachate, making it an effective and efficient media. The kinetics of fluoro-sorb to adsorb PFAS in comparison to GAC is much quicker and results in bed contact times (the time necessary for the leachate to remain in an adsorption reactor with viable media to achieve adequate adsorption) of 2 to 3 minutes in comparison to 10 minutes for GAC, thus requiring only about a third of the treatment capacity compared to GAC. Fluoro-sorb has been demonstrated to effectively remove PFAS and should be considered as a candidate for PFAS treatment of the Dolby and JRL leachates.

Cyclodextrine – Cyclodextrine are cage-shaped molecules used for design of polymers that have an inner hydrophobic pocket that is the right size to trap micropollutants such as PFAS. While shown to be effective in small applications, the ability of designed polymers is not expected to be an effective treatment method of large wastewater or leachate flows. Cyclodextrine also results in a PFAS concentrate that presents final disposal difficulty.

Foam Fractionation (FF). Foam fractionation is a relatively new PFAS removal technology and has been used successfully for treating drinking water, wastewater, and leachate contaminated with PFAS. FF takes advantage of the high surface activity imparted by the chain of fluorocarbon molecules that comprise various PFAS and the affinity of those molecule(s) to attach to the surface of air bubbles. PFAS species consisting of long-chain molecules benefit from higher adsorption coefficients compared to short-chain molecules and are easier to remove using FF, nonetheless FF has been shown to be effective for removing both short-, and long-chain PFAS.

The FF process is similar to a counter-current air stripper or dissolved air flotation (DAF) technology. A vessel (i.e., fractionator) consisting mainly of a water column equipped with a bubbler at its base releases air bubbles into the water which flow upward through the water column. PFAS molecules contained in the water attach themselves to the air/water interface forming the bubbles. As the bubbles float to the top of the water column, a layer of foam (i.e., foamate) accumulates at the top of the fractionator. The foamate is vacuumed off the top of the fractionator for further treatment, destruction, or concentration. The hydrophobic (i.e., water resistant) nature of PFAS makes many PFAS prone to accumulation on the surface of liquid-gas bubble interfaces.

As FF bubbling progresses, treated water (i.e., raffinate) flows to the bottom of the fractionator and is relatively free of PFAS. The raffinate can be diverted to a subsequent fractionator for further PFAS removal (for the shorter-chain PFAS), be directly discharged, or be further treated using adsorption technologies such as GAC or IEX, depending on the PFAS cleanup goals. In general, FF results in about 95 percent clean raffinate with respect to the total volume treated and about 5 percent foamate that requires further concentration and/or treatment. The foamate can further be concentrated from about 5 percent of the total volume to about 0.5 to 1 percent of the total volume through other concentration technologies.

In contrast to treating potable water containing PFAS using GAC or IEX adsorption technologies (i.e., as a polishing treatment step), FF is viewed as a potentially effective “upfront bulk” PFAS removal method. FF is well suited for treating complex wastewaters such as landfill leachates that are not conducive to adsorption treatment due to the abundance of other non-PFAS pollutants in the leachate that compete for transfer onto the adsorptive media.

Two experienced technology vendors (Sanexen and ECT2) that provide FF for PFAS treatment agreed to demonstrate the viability of FF by conducting bench-scale laboratory treatability testing using leachate from Dolby and JRL. The results of the laboratory FF simulations are included as Appendix D and further discussed in Section 7.0. The bench-scale treatability results from both Sanexen and ECT2 demonstrate that FF is effective at reducing PFAS concentrations in the Dolby and JRL leachate to near or below the 20 ng/l PFAS IDWS. The application of FF, if used as an “upfront bulk” PFAS removal process, should allow both the Dolby and JRL leachates to be pretreated to reduce PFAS below the Maine IDWS in advance of treating the leachate for conventional pollutants (e.g., BOD5, TSS, and ammonia) at the EMWWTP and the NDWWTP, respectively. FF vendors contacted for the Study included Allonia, ECT2, and Sanexen.

Electrochemical Advanced Oxidation. Electrochemical advanced oxidation process (EAOP) is a water treatment technology that uses electrical currents passed through a solution to oxidize pollutants. EAOP treatment of persistent pollutants such as PFAS has been demonstrated effective in bench-scale and field pilot treatability applications (Nzeribe et al., 2019). Advantages of EAOP include operation at ambient conditions, ability to be in a mobile unit, and no requirements for chemical oxidants as additives (Garcia-Segura et al. 2018). Limitations of this technology include the potential generation of toxic byproducts, incomplete destruction of some PFAS, efficiency losses due to mineral buildup (especially calcium carbonate) on the cathode, high cost of electrodes and energy, and potential volatilization of contaminants (Schafer et al., 2019; Nzeribe et al., 2019). Despite these potential limitations, EAOP may be a promising technology for PFAS destruction in certain instances because of its demonstrated ability to destroy PFAS with lower energy demands than thermal incineration (U.S.EPA PFAS Innovative Treatment Team (PITT), 2021).

The degradation of pollutants by EAOP is based on an electron transfer process, leading to the degradation (i.e., oxidation) of the PFAS and other pollutants present in the leachate (such as BOD5, ammonia and organics). The electrons are generated from an electrical anode that requires a power supply. EAOP degradation of PFAS can be achieved effectively with boron-doped diamond (BDD) electrodes and Magnéli-phase titanium suboxides (Ti_nO_{2n-1}). The total energy consumption is between 50 kWh/m^3 for groundwater containing limited concentrations of PFAS and 250 kWh/m^3 for industrial wastes containing PFAS similar to AFFF or leachate (Concawe, 2020).

Recently, a number of EAOP equipment suppliers have reported promising reductions of PFAS in landfill leachate. Aclarity, Inc. demonstrated that their patent pending EAOP process significantly reduces the concentration of PFAS, organic pollutants, ammonia, and other pollutants in leachate as a stand-alone process. Aclarity's EAOP system is based on using Magnéli-phase Ti_4O_7 anodes with titanium-mesh cathodes to generate an over-potential where water is capable of splitting to hydrogen and oxygen. Their system is able to operate at higher voltages to produce strong oxidants to free electrons before generating excess hydrogen and oxygen, leading to reduced efficiency. Two separate leachate bench-scale tests have been completed by Aclarity and were determined capable of reducing a combined PFOA and PFOS concentration from about 800 ng/l to below 80 ng/l and a combined PFOA and PFOS concentration from about 2,000 ng/l to below 30 ng/l combined (Aclarity, 2022). Recent field pilot testing using landfill leachate has shown degradation of PFOS from 450 to < 10 ng/l using less than 50 W-hr/gal of applied power and degradation of PFOA from approximately 1,600 to 100 ng/L using the same applied power (Aclarity, 2022). It should be noted that these field pilot tests were performed in Michigan, where the permit for disposal of the leachate at a local POTW only required PFOA to be below 2,300 ng/l and PFOS to be below 60 ng/l. Figure 6-1 shows the change in color of the Michigan leachate from raw to treated using EAOP. Another potential advantage of the EAOP is the incidental oxidation of other pollutants such as BOD5, organic pollutants, and ammonia in the leachate, thus reducing the pollutant loading on subsequent treatment processes necessary for processing leachate prior to discharging to receiving waters.

Treatment of leachate using EAOP appears promising although EAOP is a non-selective treatment method, and it is possible that incomplete PFAS reduction could occur and other toxic byproducts from the oxidation process could be created. Field pilot testing to confirm EAOP as an effective stand-alone treatment process should be considered for each specific leachate prior to progressing to a full-scale design. The field pilot testing should document no adverse impacts on treated leachate quality (complete PFAS removal and no toxic byproduct formation) and the potential synergy of EAOP to reduce other conventional and non-conventional pollutants related to leachate. It also should be noted that there is interest from a number of other technology vendors to incorporate EAOP to destroy concentrated PFAS waste streams generated from other technologies such as ion exchange, foam fractionation and RO (ITRC, 2022). U.S.EPA PITT continues to evaluate PFAS destruction by EAOP under a variety of conditions (PITT Research Brief, 2021). Vendors contacted to discuss EAOP include Aclarity, AECOM (De-FLUORO process), and Xogen.

Supercritical Water Oxidation (SCWO). Water above a temperature of 705°F and a pressure of 3,210 psi is considered "supercritical," which is a special state of water where certain chemical oxidation processes are accelerated. Organic compounds, usually insoluble in liquid water, are highly soluble in supercritical water. In the presence of an oxidizing agent (such as oxygen), supercritical water dissolves and oxidizes a broad array of hazardous organic pollutants (U.S.EPA, 2001). SCWO has been used to destroy halogenated hazardous waste compounds including polychlorinated biphenyls (PCBs) since the 1980s (Abeln et al., 2001, Kim et al., 2010). PFAS destruction of greater than 99 percent of 12 PFAS in landfill leachate (from 3,600 ng/l to less than 30 ng/l) using SCWO has been reported (Jama et al., 2020). In addition, the chemical oxygen demand (COD) and ammonia concentrations in the leachate treated by SWCO were reduced by 99.8 percent.

Implementation of SCWO at full-scale has been limited by several technical challenges, including buildup of corrosive gases during the oxidation reaction, precipitation of salts, and high-energy requirements (U.S.EPA, 2001). Technical challenges to implementing SCWO are presented by the high pressures and temperatures required, causing potential system degradation and maintenance issues (Vadillo et al., 2013). In addition, the requirement for elevated and stable temperatures for SCWO demand a large and expensive energy input. The breakdown of PFAS produces fluoride salts, and although not considered toxic, the salts can create reactor-plugging issues and reduce system performance (Voisin et al., 2017). Lastly, the transformation of fluorine to corrosive hydrofluoric acid may require protections for worker health, emission controls and reactor care (U.S.EPA, 2021). The capability to decompose an array of complex molecular structures simultaneously with PFAS makes SCWO a promising technology for PFAS destruction that warrants further research and investigation. Vendors contacted that offer SCWO include Battelle and 374 Water.

6.1.3 Developing Liquid Treatment Alternatives

Developing technologies have been researched at the laboratory or bench-scale level but have not been field demonstrated. Only those technologies that have a publicly available documentation demonstrating effectiveness are included in this section (ITRC, 2022). The majority of these developing technologies are advanced oxidation processes (AOP) that are in different phases of technology development. Ozone (an oxidizer) has often been used in drinking water applications for disinfection and organic oxidation purposes. However, research shows that ozone by itself is unable to break down or oxidize PFAS. Ozone can be coupled with other oxidants such as hydrogen peroxide, persulfate, or UV light to promote generation of a suite of aggressive free radicals capable of breaking down or degrading PFAS, however these combined technologies remain untried or unproven. So far, AOPs have been demonstrated to reduce PFAS concentrations, particularly for medium-sized PFAS molecules with C6 to C11 carbon chains. It is not clear, however, if PFAS concentrations can be reduced to the ng/l range using AOP. A critical concern for this developing technology is the production of unwanted byproducts (such as bromates) and the transformation of PFAS precursors into short-chain PFAS as a side reaction to the advanced oxidation treatment process (Lenntech, 2022). Although work is being done on advanced oxidation techniques, these technologies are not yet commercially available and are expected to be energy intensive (Saltworks, 2019). Several promising advanced oxidation processes are discussed below:

UV Oxidation with Iodine and Sulfite Addition. A recent study by the University of California – Riverside identified that adding iodine to a water treatment reactor that uses ultraviolet (UV) light, and sulfite destroys up to 90 percent of carbon-fluorine atoms in PFAS chemicals in just a few hours (University of California – Riverside, May 2020). The addition of iodine reportedly accelerates the speed of the reaction by a factor of four. The UV/iodine/sulfite system was able to destroy perfluorobutane sulfonate (i.e., PFBS) that is a particularly strong four-carbon PFAS molecule. The research also showed that the frequently detected PFOA and PFOS molecules could be treated. This technology has not been demonstrated beyond laboratory-scale testing and the potential for formation of PFAS or PFAS precursors during UV oxidation treatment needs to be further investigated as part of that technology’s development.

Activated Persulfate. Within the last five years, activated persulfate degradation reactions have grown to include various means of activating persulfate for enhanced removal of organic species including PFAS. Persulfate, a strong and relatively stable oxidant, can be activated to generate free radicals to achieve a higher oxidative potential under conditions of heat, light or chemical activation (by a base or metal). For example, heat-activated (i.e., above 85°C) persulfate oxidation has been reported to transform PFOA in water to fluoride and carbon dioxide (Yin, et al., 2016). However, these extreme activation processes are energy-intensive and expensive to implement in full-scale applications. Little research has been reported on the degradation of PFAS under low concentration conditions. Optimal conditions for PFAS degradation by persulfate under low concentration conditions along with PFAS degradation mechanisms need to be further investigated before this technology can be scaled to commercial application.

Catalyzed Hydrogen Peroxide (CHP). CHP is one of the strongest oxidant systems used in environmental remediation. It involves reaction of hydrogen peroxide with a catalyst to predominately generate hydroxyl radicals that have been demonstrated to degrade specific PFAS. Some CHP systems produce nucleophiles and reductants, including superoxide and hydroperoxide (Mitchell et al., 2014). Common catalysts for CHP include transition metals such as iron (Fenton-like reaction), manganese, chelated metals, and naturally occurring minerals (Watts et al., 2005). CHP technology is still being tested in the laboratory and is not fully developed for commercialization at this time.

Sonichemical Oxidation. Sonichemical oxidation is a physio-chemical treatment that splits molecules by applying ultrasonic wave energy. The sonochemical process relies on the propagation of acoustic waves in liquids at frequencies ranging from 20 to 1,000 kHz that results in cavitation (Furuta, et al., 2004). Sonochemical degradation occurs via two mechanisms: localized thermal treatment and free radical destruction. During cavitation, cyclic formation, growth, and collapse of microbubbles result in an intense increase in temperature and pressure along with the generation of free radicals (Furuta, et al., 2004). Cavitating bubbles release considerable energy in the form of heat, which is theorized to pyrolyze PFAS. Sonichemical oxidation has been reported to successfully degrade PFAS to fluoride, sulfate, and carbon dioxide in a number of laboratory trials, although defluorination was limited to 90 percent for PFOA and PFOS (Gole et al., 2018). PFOS and PFOA in groundwater beneath a landfill was defluorinated to 90 percent by sonication (Vecitis et al., 2008).

Electrocoagulation. The electrocoagulation (EC) process involves destabilization and aggregation of contaminant particles in solution to create a floc of pollutant(s) that can be collected for further treatment and/or disposal. Studies using EC to remove PFAS are limited, although several researchers are exploring use of EC in tandem with EAOP for treating PFAS.

6.1.4 Conventional Liquid Pretreatment Technologies

There are numerous conventional water and wastewater unit operations that are capable of providing pretreatment of co-contaminants in leachate, but that are not effective for removing or treating PFAS. Although these technologies are ineffective for actively treating PFAS in leachate, these unit operations can provide significant benefit in pretreating landfill leachate to a condition suitable for efficient follow-up PFAS reduction in subsequent unit operations designed specifically for PFAS reduction.

Biological Treatment. There are a wide variety of biological treatment processes that are designed to oxidize organic contaminants and nutrients, such as nitrogen compounds and phosphorus, as well as remove suspended solids from the leachate. Biological treatment will have little impact on the removal of PFAS since the carbon-fluoride bond is essentially non-biodegradable.

In order to optimize the removal of organic pollution and other constituents in leachate (such as ammonia) in advance of PFAS reduction, reliable and effective biological pretreatment needs to be implemented using a membrane biological reactor (MBR) or similar apparatus. The MBR process differs from numerous other conventional biological treatment systems in that an MBR incorporates an ultrafiltration (UF) membrane to accomplish solids/liquid separation rather than gravity separation using clarifiers (Brown and Caldwell, 2019). As a result, the effluent quality from a MBR is significantly better and more reliable than from other biological treatment processes. The MBR essentially provides biological oxidation and tertiary filtration in one step. The MBR effluent will be pretreated and allow PFAS removal in a downstream treatment process such as GAC, IEX, or alternative adsorbents. The MBR process is capable of operating at a higher biosolid concentration than other biological processes and has been successfully used to treat landfill leachate.

One potential concern for use of an MBR to treat leachate is the biodegradability of leachate that can often include excessive concentrations of chloride, TDS, iron and manganese, and refractory organics not amenable to biological treatment. Another concern is the degree to which PFAS may partition to the biosolids (created by the MBR) that will need to be thickened and disposed off-site. Currently, there are no limits on the concentration of PFAS in biosolids but depending on the concentration of PFAS and the specific PFAS of interest, the biosolids may also require treatment in the future.

Conventional Oxidation. Conventional oxidation processes involve the exchange of electrons between chemical species to change the oxidation state (valence) of the species involved (AWWA, 1990). Oxidation processes should be referred to as reduction-oxidation (redox) processes because one species of compound loses electrons (i.e., is oxidized) while another species gains electrons (i.e., is reduced). Oxidants are added to water treatment processes for a number of reasons, including control of biological growth; color removal; control of taste and odor; reduction of specific organic pollutants; precipitation of metals; and as a coagulant aid. Chlorine is by far the most widely used oxidant and is primarily used to provide disinfection of drinking water and wastewater effluents. Other conventional oxidants used in the water industry include potassium permanganate, chlorine dioxide, chloramines, ozone, and hydrogen peroxide. Depending on the waste characteristics and the treatment process necessary to pretreat the Dolby and JRL leachate, it is possible that conventional oxidation may be implemented even though oxidation will have no impact on PFAS removal.

Coagulation/Flocculation/Precipitation. The process of applying coagulation, flocculation, and precipitation is a common approach used in water and wastewater treatment to remove particulates, dissolved constituents, anions, and cations that may otherwise inhibit or compete against the reaction kinetics used for PFAS removal. These three separate physical-chemical processes typically are conducted in series. Coagulants, either obtained as commodity chemicals or proprietary chemicals, assist in the formation of solids. Flocculation is conducted by adding a soluble polymer, and slowly mixing to allow the solids to agglomerate. The agglomerated solids are then removed from solution by sedimentation (i.e., precipitation). A concern with this type of pretreatment step in dealing with influent containing PFAS is that a portion of the PFAS may partition to the precipitated solids and require separate management and treatment.

Filtration, Ultrafiltration and Nanofiltration. Filtration processes are used primarily to remove suspended particulates from solution and are often one of the unit operations used as pretreatment for sorption processes such as GAC and IEX. There is an array of filters capable of providing pretreatment prior to GAC or IEX. Ultrafiltration (UF) membranes have pore openings in the range of 0.1 micron. UF membranes operate as a low pressure-driven sieving mechanism and are capable of removing high weights of dissolved organics, bacteria, and some viruses. Nanofiltration (NF) is a form of membrane filtration technology that is pressure-driven (higher pressures than UF) and provides a high-water flux across the membrane at moderate operating pressures. Pores in NF membranes are usually around 0.001 micron and are capable of removing most organic molecules, nearly all viruses, a range of salts, and divalent ions (i.e., Ca+2 and Mg+2 are removed and, therefore, NF is often used to soften hard water). There have been some reports of NF, and to a lesser extent UF, being able to remove some PFAS. However, the success and reliability of any of these filtration processes to remove PFAS is not as effective as RO membranes that have an effective pore size of 0.0001 micron.

6.2 Solids Treatment Technologies

Solids treatment technologies may be applied to a variety of PFAS-contaminated solid media including soils, sediments, sludge, exhausted sorption media such as GAC or IX resins, and other technologies that concentrate PFAS-contaminated wastes by driving off excess water. Currently, there are a number of evolving and developing technologies that are focused on destroying PFAS in solids in lieu of merely transferring PFAS from one media to another. These technologies for destroying PFAS are based on high-energy incineration or advanced oxidation processes and include electrochemical oxidation, microwave thermal treatment, photolytic degradation, pyrolysis, and sonochemistry. These extreme PFAS destruction pathways are projected to be very costly and are still in the technology development phase.

6.2.1 Commercially Demonstrated and Field Implemented Solids Treatment Technologies

Solids treatment technologies focus mainly on Thermal destruction, Solidification, and Evaporation.

Thermal Treatment. Incineration is defined as destruction (mineralization) of chemicals using heat in the presence of oxygen. High temperature incineration (> 1,000°C) can destroy PFAS but have a high energy and carbon dioxide footprint and the actual fate of PFAS after incineration is questionable. Incineration offers the possibility of destruction of multiple PFAS waste streams, although incineration is currently being critiqued by U.S.EPA due to the possibility of incomplete PFAS combustion and possible PFAS byproduct generation. Similarly, the Department of Defense recently placed a moratorium on the incineration of PFAS laden wastes until further research is conducted into the potential formation of toxic byproducts. A number of thermal treatment aspects that continue to be researched include the effective destruction temperatures and treatment times, the potential to generate PFAS byproducts of incomplete combustion, deposition of PFAS onto land, stack gas analyses, and other risk factors (ITRC, 2021).

Incineration is a mature technology and one of only a few technologies that can potentially destroy PFAS. Incineration of spent GAC, IEX, alternative sorbents, side streams, sludge, biosolids, and solid wastes tainted with PFAS will continue to be considered a viable treatment technology, recognizing that the process continues to be evaluated and critiqued as noted above. Other developing thermal treatment processes such as Thermolysis and Pyrolysis that use heat in oxygen-limited environments are discussed in the next Section.

Solidification/Stabilization. Solidification and stabilization are recognized immobilization or chemical fixation technologies. In solidification, contaminants of concern (i.e., PFAS) are physically bound or encapsulated within a stabilized mass; whereas stabilization involves chemical reactions that are induced between the stabilizing agent and contaminants to reduce their mobility. PFAS-sorbing materials (i.e., admixtures) are mixed with the PFAS-laden solid wastes to reduce the leachability of PFAS from the waste through physical and/or chemical bonding. Primary processes include pozzolanic-based materials (similar to Portland cement), modified sulfur cement, bituminization, emulsified asphalt, soluble phosphates, and vitrification or molten glass (FRTR, 2020). These processes are relatively quick, simple, and low-cost (relative to PFAS destruction technologies). Stabilization and solidification techniques vary in their effectiveness depending on the waste characteristics (particularly the organic content of the waste matrix), PFAS types and concentrations, mixing approaches, and the admixtures. The PFAS characteristic that has the most profound impact on sorption is the length of the carbon-fluorine molecule, with longer chains/molecules having increased sorption qualities (ITRC, 2022). A disadvantage of this technology is that the PFAS are not destroyed, but instead are bound or immobilized and ultimately disposed in a landfill. This technology may be effective for concentrated PFAS waste that has been consolidated to a small volume such as IEX regeneration wastes.

Evaporation/Concentration Technology. The last solids treatment processes to be discussed are the processes that can reduce the volume of PFAS wastes and concentrate PFAS into its highest allowable concentration together with co-contaminants. The more concentrated PFAS wastes can then be transported to either an off-site incinerator or a regional PFAS treatment facility.

Other developing technologies to continue tracking are desalination technologies that are being developed for desalination and treatment of fracking wastewaters via evaporators and crystallizers.

6.2.2 Developing Solids Treatment Technologies

Six developing treatment alternatives for solids containing PFAS are: Mechanical Degradation, Thermolysis, Pyrolysis, Plasma Technology, Hydrothermal Alkaline Treatment, and Electron Beam Treatment.

Mechanochemical Degradation (MCD). MCD describes the mechanism of destroying persistent organic substances using a high-energy ball-milling (i.e., pulverizing) device. Co-milling reagents such as silica, potassium hydroxide, or calcium oxide are added to solids containing PFAS to help react with fluorine and to produce highly reactive conditions. The crystalline structures used in the co-milling reagents are crushed and sheared by high-energy impacts from stainless steel milling balls in a rotating vessel. Research has shown that these conditions produce radicals, electrons, heat, and even plasmas that react with PFAS to produce inorganic fluoride compounds and graphite (Wang, et al., 2019).

The U.S.EPA funded a MCD demonstration pilot test performed by Cyclopure as part of a Small Business Innovative Research (SBIR) grant in 2021. U.S.EPA identified the need for PFAS treatment technologies that remove PFAS from contaminated solid matrices and completely mineralize PFAS. In particular, the MCD process is focused on solid (soils) or semi-solid (sludge) waste matrices. Further research into the destruction of PFAS by means of MCD is needed to understand the effects of various matrices, the function of different milling reagents, the potential for loss of volatile PFAS, and the performance of MCD for field-scale applications (U.S.EPA Research Brief, Shields and Whitehill, Jan 2021). The MCD process is considered to have an in-development status, and there are concerns the MCD process may generate a gas phase waste stream requiring treatment. MCD technology is not commercially available for full-scale field use.

Thermolysis. Thermal decomposition, or thermolysis, is the chemical decomposition of a waste caused by heat between 650° and 1,100°C in the absence of oxygen (Landfill Solutions, 2022). Because of the lack of oxygen, thermolysis has minimum air emissions as the waste is heated and transformed into energy, thus avoiding the release of toxins to the atmosphere. The reaction is usually endothermic as heat is required to break the chemical bonds in the waste undergoing treatment. Thermolysis has been identified as a potential thermal regeneration process of PFAS-laden GAC. In contrast to current incineration processes for treating GAC, thermolysis is accomplished at lower temperatures than incineration (i.e., higher temperatures) that may result in less GAC pore structure deterioration. Additionally, the air pollution control process for thermolysis is much simpler and the potential for incomplete byproducts of combustion is much lower. To date, thermolysis studies have focused on select PFAS and fluoropolymers and are not representative of the wide range of PFAS precursors found at contaminated sites (U.S.EPA, 2022). However, the thermal treatment of PFAS-laden GAC by thermolysis is promising and, as incineration is suspect relative to combustion byproducts and the destruction of PFAS, future regulations may encourage thermolysis to become commercialized.

Pyrolysis. Pyrolysis is a process that decomposes solid and semi-solid materials at elevated temperatures (300° to 1,000°C) in an oxygen-free environment. Pyrolysis forms both a useful char and a hydrogen-rich synthetic gas (syngas). The oxygen-free environment in pyrolysis distinguishes this technology from incineration. Pyrolysis requires much lower air flow than incineration, which reduces the size and capital expenses of air pollution control equipment. The high temperatures and residence times achieved by pyrolysis followed directly by combustion of the hydrogen-rich syngas in a thermal oxidizer or afterburner could potentially destroy PFAS by breaking apart the PFAS into inert or less recalcitrant constituents. However, pyrolysis, as well as evaluation of potential products of incomplete destruction during pyrolysis, remains a subject for further investigation and research (U.S.EPA Research Brief, 2021). In the United States, there is only one biosolids pyrolysis company (i.e., Bioforce Technology) that is known to operate on a full-scale basis (PYREG, 2019).

Plasma Technology. Plasma technology incorporates a plasma water reactor with air, water, and electricity to purify contaminated matrices. Plasma (i.e., ionized gas), interacting with water results in a cascade of molecular collisions, or reactions, which mineralize contaminants into harmless byproducts including carbon dioxide, fluoride, and water (U.S.EPA, 2021). The technology has been demonstrated to destroy emerging contaminants such as PFAS and 1,4-dioxane. Although plasma technology could potentially evolve as a stand-alone technology to destroy PFAS in leachate, plasma use is currently not considered scalable to treat large volumes of wastewater (U.S.EPA, 2021). Improved designs will be necessary to upscale plasma technology to commercial development.

Plasma technology vendors believe a market opportunity may exist for treating low volume, highly concentrated PFAS wastes such as AFFF cleanups, biosolids, and side streams such as RO reject water, spent GAC and IEX, foamate from FF, and others. Purafide has submitted a grant application to the SBIR to treat various biosolids, and foamate from FF process similar to that which could be used at Dolby and JRL. While the application of plasma technology is promising, it has not yet evolved into a commercially viable technology.

Hydrothermal Alkaline Treatment (HALT). Aquagga Inc. has developed a PFAS treatment unit that uses pressurized water to convert PFAS to benign salts within their HALT process. In a number of case studies, Aquagga has demonstrated greater than 99 percent destruction of PFAS in a variety of feedstocks (from AFFF to leachate to contaminated groundwater). The HALT process is reported to not produce short-chain PFAS or hydrofluoric acid (HF) as a byproduct. Aquagga is confident the technology can be adapted to treat RO concentrate, foamate from FF, leachate, AFFF waste, and sorbent regeneration byproducts.

Electron Beam Treatment. Electron beam (eBeam) technology utilizes compact electron accelerators to generate large numbers of highly energetic electrons from electricity (U.S.EPA SBIR, 2022). High-energy eBeam accelerators have been used for water treatment to degrade a wide range of recalcitrant contaminants, including PFAS, since the 1960s. However, large-scale applications of eBeam for water treatment are restricted due to its high-energy consumption and inability to treat large flow rates (Londhe, K., 2021). To date, very limited studies have been conducted to investigate the success of this technology to treat PFAS, although U.S.EPA has funded research to demonstrate that PFOA and PFOS can be completely degraded in a few seconds in aqueous and solid media with eBeam technology (U.S.EPA SBIR, 2022).

6.3 Side Stream Management Technologies

A number of recognized PFAS treatment processes transfer and concentrate PFAS from one media to another. The side streams generated from PFAS treatment must be properly managed, although there are few commercially available technologies for destroying the low-volume, highly concentrated PFAS associated with spent GAC or spent IEX resins, alternative adsorption media, RO concentrate, foamate (from FF), sludge, and biosolids from chemical precipitation and biological processes.

Spent media management from adsorption processes (GAC and IEX resins) currently include off-site disposal by incineration (via commercial incineration or cement kilns), thermal reactivation or regeneration for reuse, and landfill disposal. Emerging technologies described above that are being investigated for managing spent media include EAOP, SCWO, HALT, and Plasma Technology. These same technologies are being explored to treat sludge, biosolids, and concentrates such as foamate from FF.

6.4 PFAS Treatment Technologies for Dolby and JRL Leachates

Section 6.1 provides analysis of six technologies to treat for PFAS within liquid matrices such as leachate. GAC, IEX, and RO are commercially demonstrated technologies identified for potentially treating the leachate at Dolby and JRL. In addition, FF, EAOP, and adsorption using alternative media, are technologies that have demonstrated strong potential for treating PFAS. Each of these technologies is evaluated in subsequent sections of this Report with respect to treatment of the specific leachates from Dolby and JRL. In evaluating the technologies, it is recognized that the GAC, IEX, and the alternative adsorption technologies are similar in design and purpose and if used will be based on laboratory testing to determine the most efficient combination of PFAS feed stream(s) and adsorption media to attract and retain PFAS(6).

Of the PFAS technologies identified, only EAOP is a destruction technology that does not yield a residual side stream requiring further management. FF generates a foamate side stream, RO yields a side concentrate stream, and adsorption yields spent media requiring disposal. Sections 6.2 and 6.3 review technologies for solid wastes and residual side streams, respectively. Spent media associated with adsorption is assumed to continue to be managed by off-site incineration or thermal regeneration with replacement of virgin media. Foamate and RO concentrate are considered candidates for EAOP, super-loading onto IEX resin and storage or disposal, and stabilization followed by disposal of in a landfill. The ultimate selection of the residual side stream treatment technology will, to a large extent, be based on future solid waste regulations regarding the acceptability of landfills to receive PFAS wastes and the evolution and availability of destruction technologies to treat PFAS. In particular, super-loading of PFAS foamate or RO concentrate may represent a reasonable transition technology that would provide enhanced adsorption of PFAS to minimize leaching back into a landfill in the short term, alternatively the PFAS side streams could be isolated and stored until proven destruction technologies become available in the future. In contrast, stabilization/solidification of PFAS side streams would not represent a temporary transition until destruction technologies are available since the stabilization/solidification process would yield a solid matrix not conducive to anticipated future destruction technologies.

TABLE 6-1

PARTIAL LIST OF PFAS TECHNICAL RESOURCES CONSULTED

1. PFAS Technical and Regulatory Guidance Document, Interstate Technology and Regulatory Council (ITRC), 2022.
2. Review of Water Treatment Systems for PFAS Removal, Concave Environmental Science for European Refining, 2020.
3. PFAS Innovative Treatment Team (PITT), U.S.EPA, 2020-2022.
4. Drinking Water Treatment for PFAS Selection Guide, prepared for American Water Works Association (AWWA) by HDR, 2021.
5. PFAS Management and Treatment Options for Landfill Leachate, SWANA, November 2021.
6. Multi-Industry PFAS Study, U.S.EPA, 2021.
7. Treatment of Contaminants of Emerging Concern in Landfill Leachate, Vermont Department of Environmental Conservation, 2020.
8. PFAS at Wastewater Treatment Facilities and Landfill Leachate, prepared for Vermont Department of Environmental Conservation by Weston & Sampson.
9. Initiative to Evaluate the Presence of PFAS in Municipal Wastewater and Associated Residuals (Sludge/Biosolids) in Michigan, Michigan Department of Environment, Great Lakes and Energy (EGLE), 2020.
10. PFAS Removals and Increases in the Effluent of 13 New Hampshire WWTFs Due to the Effects of Biological Treatment Processes, University of New Hampshire Honors Theses, Zachary Harvell, 2020.
11. PFAS Cycling within Michigan: Connections between Contaminated Sites, Landfills, and WWTPs, Western Michigan University Masters Theses, Ross Helmer, 2021.
12. Treating PFAS Contaminated Wastewater and Landfill Leachate, Saltworks Tech, 2019.
13. PFAS within Landfills, Leachate and Generic Wastes, CDM Smith Insights, 2022.
14. Interim Guidance on the Destruction and Disposal of PFAS and Materials Containing PFAS, USEPA, December 2020.
15. Conceptual Leachate Treatment Scoping Study for New England Waste Services of Vermont Landfill, Brown and Caldwell, Prepared for Casella Waste Systems, October 2019.

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7. Treatment of Contaminants of Emerging Concern in Landfill Leachate, Vermont Department of Environmental Conservation, 2020.
8. PFAS at Wastewater Treatment Facilities and Landfill Leachate, prepared for Vermont Department of Environmental Conservation by Weston & Sampson.
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10. PFAS Removals and Increases in the Effluent of 13 New Hampshire WWTFs Due to the Effects of Biological Treatment Processes, University of New Hampshire Honors Theses, Zachary Harvell, 2020.
11. PFAS Cycling within Michigan: Connections between Contaminated Sites, Landfills, and WWTPs, Western Michigan University Masters Theses, Ross Helmer, 2021.
12. Treating PFAS Contaminated Wastewater and Landfill Leachate, Saltworks Tech, 2019.
13. PFAS within Landfills, Leachate and Generic Wastes, CDM Smith Insights, 2022.
14. Interim Guidance on the Destruction and Disposal of PFAS and Materials Containing PFAS, USEPA, December 2020.
15. Conceptual Leachate Treatment Scoping Study for New England Waste Services of Vermont Landfill, Brown and Caldwell, Prepared for Casella Waste Systems, October 2019.

TABLE 6-2

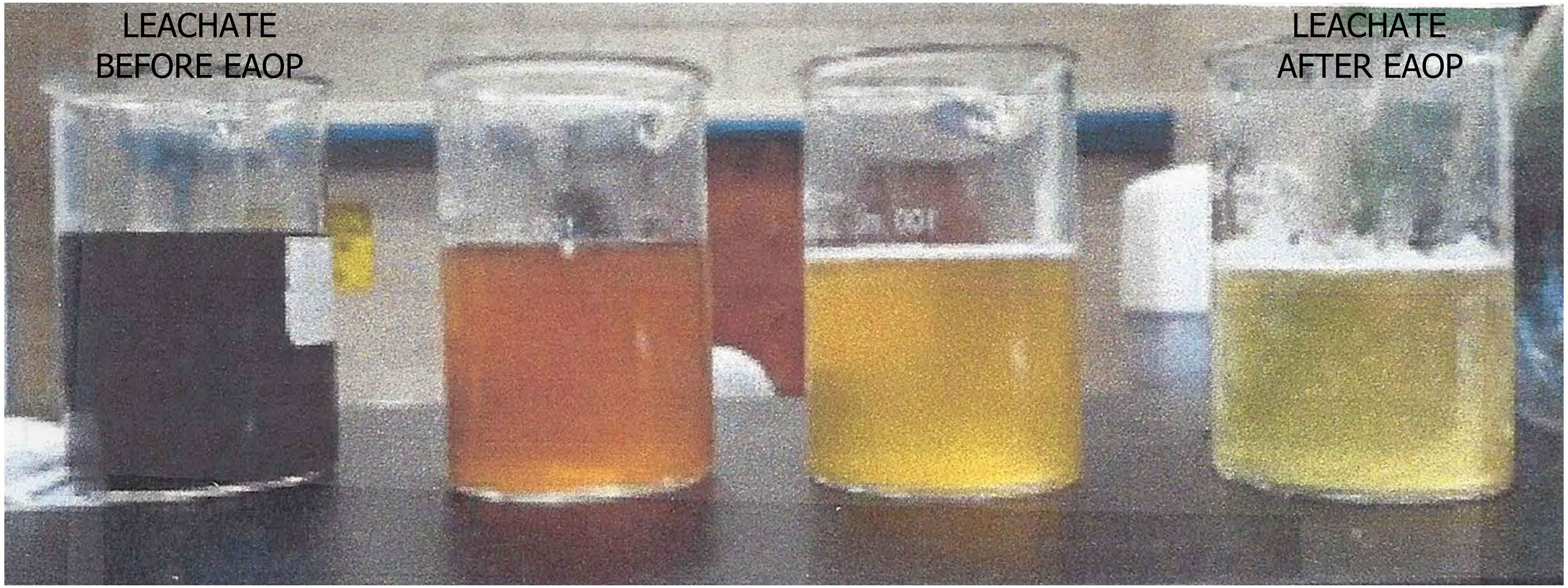
PARTIAL INVENTORY OF TREATMENT SYSTEMS DESIGNED FOR PFAS REMOVAL

Facility/Location	PFAS Levels (ng/l)	PFAS Clean-up Goal (ng/l)	Design Flow (MGD/gpm)	Co-Contaminants	Pretreatment	Residual Treatment	Comments
POTABLE WATER TREATMENT SYSTEMS							
A. Bituminous or Coconut Granular Activated Carbon (GAC) Systems							
A-1 Site from ITRC (1)	PFOA 1,800 - 14,000 ng/l	PFOA 15 ng/l	0.612/425	None Reported	None Identified	Regeneration Off-Site	Operational Since 2007
A-2 Site from ITRC (1)	PFOA 1,830; PFOS 1,150 ng/l	PFOA + PFOS 70 ng/l	0.202/140	TCE 77 ug/l	None Identified	Regeneration Off-Site	GAC Initially for VOC; Now for PFAS
A-3 Site from ITRC (1)	PFOA 1,000; PFOS 3,7000 ng/l	PFOA 40; PFOS 20 ng/l	0.324/225	None Reported	None Identified	Regeneration Off-Site	Operational Since 2015
A-4 Site from ITRC (1)	PFOA + PFOS 1,000 ng/l	PFOA + PFOS 70 ng/l	2.16/1,500	TOC 1 - 2 mg/l	None Identified	Regeneration Off-Site	Operational Since 2016
A-5 Site from ITRC (1)	PFBA; PFBS; PFPeA; PFHxA, PFOA, PFHpS 5 - 25; PFHxS; PFOS 170 - 270	PFOA + PFOS 70 ng/l	2.88/1,000	Chloroform 1 ug/l; TOC 0.55 mg/l	None Identified	Regeneration Off-Site	Operational Since 2017
A-6 Site from ITRC (1)	PFBA; PFBS; PFNA; PFHpA; PFDA 8 - 25;	PFOA + PFOS 70 ng/l	0.72/500	None Reported	None Identified	Regeneration Off-Site	Operational Since 2018
A-7 Site from ITRC (1)	PFBA; PFBS; PFNA; PFHpA; PFOA 2 - 25; PFHxA; PFOS 30 - 50; PFHxS 120	PFOA + PFOS 70 ng/l	1.15/800	None Reported	None Identified	Regeneration Off-Site	Operational Since 2018
A-10 Site from ITRC (1)	PFOA 500; PFOS 300 ng/l	PFOA + PFOS 70 ng/l	0.5/350	None Reported	None Identified	Regeneration Off-Site	Operational Since 2015
A-11 Site from ITRC (1)	PFBS; PFNA; PFHpA 3 - 15; PFOS 60; PFOA; PFHxS 100 - 200 ng/l	All PFAS ND	4.6/3,200	TCE 1 - 3 ug/l	None Identified	Regeneration Off-Site	GAC Initially for VOC; Now for PFAS
B-1 Site from ITRC (1)	PFBA&PFHpA 1 - 25; PFBS; PFHxA; PFPeA; PFOA 25 - 50; PFHxS; PFOS 700 - 1,000	PFOA + PFOS 70 ng/l	0.022/15	None Reported	None Identified	Regeneration Off-Site	Public Supply Since 2018
B-2 Site from ITRC (1)	PFBA; PFBS; PFHpA; PFHxA; PFOA 1 - 30; PFHxS; PFPeA, PFOS 50 - 100	PFOA + PFOS 70 ng/l	0.115/80	None Reported	None Identified	Regeneration Off-Site	Public Supply Since 2018
Ayer, MA - Spectacle Pond WTP					GAC	Regeneration Off-Site	Groundwater Supply
Hampton, NH - Mill Road WTP	PFOS, FFOA, PFHxS, PFNA; total 177 ng/l	PFHxS 18, PFOA 12, PFOS 15, PFNA 11	0.518/360	None Reported	GAC	Regeneration Off-Site	Groundwater Supply
Westfield, MA WTP	PFOA+PFOS >70 ng/l	PFOA, PFOS, PFNA, PFHxS, PFHpA combined 70	??	None Reported	GAC	Regeneration Off-Site	Groundwater Supply
B. Ion Exchange (IX) Resin Systems							
C-1 Site from ITRC (1)	PFOA 234; PFOS 648; PFBS 33; PFHxA 141; PFHpA 52; PFHxS 316; PFNA 10	PFOA and PFOS both 2.5 ng/l	0.266/185	TCE/PCE 230 ug/l; TOC 0.7 mg/l	None Identified	Single Use; Off-Site Regen	In service as Public Supply Since 2018
C-3 Site from ITRC (1)	PFHpA; PFBA; PFBS 25 - 65; PFOA; PFOS; PFPeA 85 - 100; PFHxA 180; PFHxS 300	PFOA + PFOS 70 ng/l	1.58/1,100	None Reported	None Identified	Single Use; Off-Site Regen	Operational Since 2018
C-4 Site from ITRC (1)	PFOA 26; PFOS 165; PFBA 11; PFBS 7; PFHxA 27	PFOA + PFOS 70 ng/l	0.86/600	TOC 1 mg/l	None Identified	Single Use; Off-Site Regen	Non-Potable in Use Since 2018
C-5 Site from ITRC (1)	PFOS+PFHxS 45,000; PFOA 500; Total PFAS 50,000	1 ng/l by Method 529 PFAS	0.288/200	TOC 5 mg/l; Fe 0.2 - 0.3 mg/l; TSS 1 - 3 mg/l	Filtration/IX pre- for TOC/Fe	Single Use; Off-Site Regen	Operational Since 2018
Ayer, MA - Grove Pond WTP	Not Defined	PFOA, PFOS, PFNA, PFHxS, PFHpA combined 70	??	Greensand Fe/Mn Removal	Fe/Mn	Single Use; Off-Site Regen	GW Supply; Anion IX Resin
C. Combined GAC and IEX Systems							
D-1 Site from ITRC (1)	PFOS 55;PFOA 27; PFBS 8; PFHxA 10; PFHpA 5; PFHxS 36	PFOA and PFOS both 2.5 ng/l	0.072/50	TOC 0.5 mg/l	Initial GAC/IX in Lead Lag	Single Use; Off-Site Regen	GAC/IX Configuration Changed to Lead/Lag IX
Pease AFB - Portsmouth, NH	Total PFAS >90,000 ng/l	PFHx5 18, PFOA 12, PFOS 15, PFNA 11	35 to 70 gpm	2 Bag Filters	Regenerable IEX Lead/Lag	GAC Off-Site; On-site IEX Regeneration	GW Source
D. Reverse Osmosis Systems No identified RO Potable Water Remediation for PFAS							
MUNICIPAL WASTEWATER TREATMENT SYSTEMS							
E-1 Site from ITRC (1)	PFPnA 10; PFHxA 19: PFHpA 3; PFOA 11; PFNA 4; PFDA 2; PFUmA <1; PFBS 4; PFHxS 5; PFOS 14	Not Defined	86.4/60,000	Typical Secondary Treatment Effluent Concentrations	Secondary Biological Treatment	Not Identified	Short-Term Pilot of Secondary Effluent
E-2 Site from ITRC (1)	PFPnA 10; PFHxA 19; PFHpA 3; PFOA 11; PFNA 4; PFDA 2; PFUnA <1	Not Defined	1.08/750	Typical Secondary Treatment Effluent Concentrations	Secondary Biological Treatment	Not Identified	Short-Term Pilot of Secondary Effluent
LANDFILL LEACHATE TREATMENT SYSTEMS							
Reverse Osmosis – Site A Confidential Client	PFBS 280; PFBA 1100; PFHpA 480; PFHxS 690; PFHxA 2100; PFOS 200; PFOA 820; PFPeA 880; Total PFA 6550	Not Defined; Greater than 99.9% Removal	Not Defined – Full Scale	Excessive Co-contaminants related to leachate	pH adjustment and Filtration	Not identified	Ful-Scale Leachate RO System
Reverse Osmosis – Site B Confidential Client	PFBS 4200; PFBA 2500; PFHpA 500; PFHxS 370; PFHxA 2200; PFOS 170;	Not Defined; Greater than 99.9% Removal	Not Defined – Full Scale	Excessive Co-contaminants related to leachate	pH adjustment and Filtration	Not identified	Full-Scale Leachate RO System

TABLE 6-2 (cont'd)

PARTIAL INVENTORY OF TREATMENT SYSTEMS DESIGNED FOR PFAS REMOVAL

Facility/Location	PFAS Levels (ng/l)	PFAS Clean-up Goal (ng/l)	Design Flow (MGD/gpm)	Co-Contaminants	Pretreatment	Residual Treatment	Comments
	PFOA 1600; PFPeA 770; 6:2FTS 360; NMeFOSAA 130						
Landfill Leachate in MA	PFOA >750 ng/l	PFOA+PFAS <50 ng/l	Pilot Scale	Leachate with high ammonia (>800 mg/l)	None	Not Applicable	Destruction Technology
Fractionate from Leachate FF destroyed by hydrothermal alkaline treatment (HALT)	Fractionate with PFOS 8,060; PFOA 1,256; PFHxS 3,140; PFHpS 236; PFBS 45; PFHxA 134; PFHxA 134; total PFAS 18,101	Not Defined; HALT Eff: PFOS 137; PFOA 7; PFHxS 22;PFBS 2.3; PFHpS 3.6; PFHxA 1.3; PFHxA 1.3; total PFAS 182	Not Applicable	Concentrated fractionate from landfill leachate	None	PFAS destroyed, no residual treatment required	Treatment is destruction not removal to another media; data provided by Aquagga
Leachate Direct Treatment with Supercritical Water Ox (SCWO)	12 PFAS with total PFAS of 25,000 ug/l	Not Defined; SCWO Eff: 2.6 ug/l	Not Applicable	Landfill Leachate	None	PFAS destroyed, no residual treatment required	Treatment is destruction not removal to another media; data provided by Aquarden
OTHER TREATMENT SYSTEMS							
D-2 Site from ITRC (1)	PFBS; PFDA; PFNA 5 - 10; PFBA; PFHpA; PFOA 10 - 30; 6:2FTS; PFHxA; PFPeA 30 - 50; PFOS 250	1 ng/l by Method 529 PFAS	0.432/300	None Reported	None Identified	Single Use; Off-Site Regen	Contaminated Pond Used for Golf Course Irrigation
Foam Fractionation of Contaminated GW Oakey Site in Australia	PFOS 2539; PFOA 435; PFHxS 939	Not Defined; Greater than 99.9% Removal	0.67/50	Bag Filters and Surfactant Addition	Bag Filters and Surfactant Addition	Foamate Concentration and Disposal	Full-Scale Fixed Treatment System in Operation Since 2019



NOTE:
1. PHOTO COURTESY OF ACLARITY.

FIGURE 6-1
RAW TO TREATED LEACHATE
STUDY FOR TREATABILITY OF PFAS IN
LEACHATE FROM STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 6-1, 12/19/2022 3:03:30 PM, jrl

7.0 TREATMENT ALTERNATIVES AND ASSESSMENTS

This section describes a number of treatment alternatives identified to reduce the PFAS(6) concentrations in the Dolby and JRL leachate to 20 ng/l. Table 7-1 provides a summary of the leachate quality and leachate flows for both Dolby and JRL that affect the treatment alternatives. Regardless of the treatment alternative considered, it is assumed that each alternative will include landfill cover optimization to reduce the daily leachate volumes generated at both the Dolby and JRL landfills in an effort to minimize the volume and cost of leachate treatment for PFAS. For purposes of this section, it is estimated that treatment of leachate will commence at both Dolby and JRL beginning in 2024.

7.1 Dolby Landfill Leachate Management Alternatives

PFAS treatment alternatives for the Dolby leachate include:

- Off-site disposal of the raw leachate at a regional treatment facility that would provide both biologic and PFAS treatment of the leachate;
- PFAS treatment of the leachate at the Dolby site followed by biological treatment of the leachate at the EMWWTP; and
- Treatment of the Dolby leachate at the EMWWTP for both biologic parameters and PFAS.

7.1.1 Off-Site Disposal of Dolby Leachate at a Regional PFAS Treatment Facility

The State of Maine has received federal funding to support installation of a PFAS treatment system to serve the entire state (Mainebiz, 2022).

If the Dolby leachate (average flow of 110,400 gpd in 2024) is trucked to a regional facility, a tank-truck loading station (similar to that at JRL) would need to be constructed adjacent to the leachate storage pond. Assuming an average tank-truck volume of 8,000 gallons per truckload (under current conditions), it would require about 14 truckloads per day (at 365 days per year) or about 25 truckloads per day if hauling leachate 200 days per year. As final cover is installed on Dolby III, the leachate volume is projected to decrease to about 88,500 gpd, which would still require about 20 truckloads, 200 days per year. For planning purposes, a distance of 125 miles from Dolby to a regional facility was used for the Study (i.e., approximate annual trucking cost in 2024 of $3.75M to $4.7M). A wastewater treatment facility that accepts leachate for conventional biological treatment was contacted relative to a projected cost for leachate treatment (without PFAS), and a budget rate of $0.04/gallon was quoted as the tipping fee. For budgetary purposes, it is likely that once PFAS treatment operations become available, the tipping fee could easily double or triple to $0.10/gallon, or more. Based on the anticipated cost for trucking and treatment, the option of disposing Dolby leachate at a regional facility is not expected to be an effective alternative, even if the Dolby leachate volume is reduced to 88,500 gpd as the geomembrane cover upgrade for the Dolby III Landfill is completed.

It is unlikely that raw leachate would be trucked from Dolby to a regional treatment facility due to the volume (over 4,000 truckloads per year). However, if the PFAS treatment alternative selected for Dolby includes PFAS side streams, concentrates, or residuals, then trucking those wastes to a regional facility could be a cost effective and a reliable method for disposing/reducing/destroying the concentrated PFAS waste resulting from treatment of the Dolby leachate.

In considering how the Dolby leachate or PFAS side stream treatment could be implemented as part of a regional approach, a number of improvements would need to be constructed at Dolby, and firm pricing for trucking and tipping must be established to evaluate cost-benefit. Potential treatment and disposal of PFAS side streams from Dolby at an off-site facility are further discussed in the respective leachate management scenarios in Section 8.9.

7.1.2 PFAS Reduction at Dolby, Concentration of Residuals with On-site or Off-site Treatment or Disposal of PFAS Side Streams, and Discharge to EMWWTP

This treatment alternative entails constructing an “upfront bulk” PFAS reduction process at the Dolby facility, managing waste streams from the PFAS reduction process either on-site or off-site, and pumping the PFAS-treated effluent to the EMWWTP for biological treatment to remove BOD5, ammonia, and other conventional pollutants prior to discharge to the Penobscot River. The average daily leachate flow in 2024 is projected at 110,400 gpd and the projected average daily flow during the month exhibiting the maximum overall flow is projected at 198,000 gpd (based on historical peaking factors); the overall peak daily leachate flow at Dolby has exceeded 864,000 gpd. The 198,000 gpd flow was initially considered for preliminary hydraulic sizing of the PFAS treatment process at Dolby but was reduced to 150,000 gpd through inclusion of the existing Dolby leachate storage pond (2-MG working volume) as a flow buffer relative to sizing the treatment operations. As discussed in Section 3.1.2, spring leachate flows from Dolby can be extremely erratic with peaking factors as high as eight times the annual average daily flow. Unless leachate flows can be substantially reduced, it will be necessary to provide additional leachate storage at the Dolby site to avoid over-sizing of the treatment operations to address several weeks of spring flow conditions. Preliminary estimates indicate an additional 22 MG of on-site leachate storage could be necessary to avoid use of multiple-treatment units that would be used for only a few months each year.

The three evolving technologies that show promise for an "upfront bulk" PFAS reduction at Dolby are FF, EAOP and RO. All three technologies are considered potentially viable for the Dolby leachate, and additionally EAOP could be used in conjunction with FF or RO to treat the foamate or concentrate side streams, respectively. Two potential locations have been identified to house the PFAS treatment operations at Dolby: (1) adjacent to the leachate storage pond and pump station; or (2) in a cleared, flat area formerly used as a construction staging area about 1,000 feet south of the leachate storage pond. For the subject Study, it is assumed that the treatment unit(s) and support operations will be located at the former construction staging area.

The **first PFAS Reduction Treatment Alternative at Dolby** (Dolby FF/Foamate Concentrate/ Foamate Management/EMWWTP Discharge) is to locate the FF treatment process at Dolby, modify the existing pump station to elevate raw leachate from the leachate storage pond to the FF treatment unit, providing additional off-line storage of leachate during spring high-flow periods, construct a return line from the FF process to a new pump station wet well, continue to use the existing leachate pipeline to discharge the pretreated leachate (i.e., raffinate) to EMWWTP for biological treatment, and discharge to the Penobscot River. As a stand-alone treatment process, FF typically includes multiple fractionator columns (working in series) within the same treatment unit, addition of surfactants to increase ("boost") the leachate foaming potential, and accumulation of a side stream of foamate (i.e., PFAS concentrated wastewater). Depending on the foamate volume, it may undergo fractionation a second time to create more raffinate and further concentrate the PFAS before the foamate is treated by media loading, EAOP destruction, or stabilization for off-site disposal. As a contingency to ensure raffinate compliance with the PFAS(6) IDWS cleanup goal, IEX resin treatment may be included with the FF unit to ensure the raffinate is compliant with the PFAS(6) IDWS. A flow schematic of the treatment process is presented as Figure 7-1. Construction elements of this alternative include:

- Modifying the existing pump station and pipeline to elevate raw leachate from the leachate storage pond to the FF treatment units.
- Complete site preparation for situating the FF treatment unit and support operations adjacent to the new pump station, including a foundation pad, containment area, and electrical control panel with three-phase power.
- Mobilize two FF units that are fully integrated with instrumentation and controls (I&C), including flow meters, pH meter, thermometer, ORP meter, level controls, and auto dialer

to allow remote monitoring and alarms. Combined, the two FF units are expected to treat leachate at a flow of 100 to 150 gpm.

- The vent from the FF unit(s) is equipped with a provisional carbon filter, although based on FF monitoring reported from other treatment sites, off-gas treatment may not be warranted.
- Construct a return treated effluent (raffinate) pipeline from the FF unit to a new wet well that is equipped with pumps to discharge the raffinate to the existing pipeline that extends to the EMWWTP for treatment of BOD5, TSS, ammonia, and other conventional pollutants.
- Installing standby generators (one at the leachate storage pumping station and one at the FF treatment location) capable of providing continued pumping and treatment in the event of a power outage.
- Locate an office trailer and support facilities for the operators adjacent to the FF unit.
- Construct a second leachate storage pond at the Dolby site as well as the necessary pipelines and pumps to transfer and store excess leachate flows during the springtime when leachate flows are significantly greater than the flow through capacity of the FF treatment units.
- Provide foamate treatment via a destruction process such as EAOP, super-loading onto IEX resin or stabilization/solidification and disposal in a landfill. Pilot testing is anticipated to assist in selecting the final technology for treating the residual side stream.

The preliminary design assumes two mobile containers (standard 40-ft by 8-ft Conex-type container) with an FF treatment unit inside. Each FF treatment unit will include three FF flow-through reactors connected in series designed to treat leachate at a constant flow of 66 gpm (higher flows can be accommodated by using additional FF units or designing a reactor for a specific leachate makeup solution). Each FF unit is equipped with recirculation pumps and air injectors and includes dosing equipment to add surfactant at various locations to provide optimal conditions for the foam fractionation to occur. A pretreatment system using sand filters and/or bag filters is included to filter suspended solids from the raw leachate prior to foam fractionation. Influent, effluent (i.e., raffinate), and foamate sample taps will be provided throughout the FF treatment process. The FF container will be winterized, insulated and heated to withstand winter conditions in Maine.

Although preliminary FF bench-scale testing of the Dolby leachate alone removed a significant portion of the total PFAS and the PFAS(6) to below the IDWS cleanup goal, as a contingency, an optional adsorption operation would be included for FF treatment implemented at Dolby. The adsorption process would provide additional removal of total PFAS and give greater confidence for meeting the PFAS(6) goal in a reliable manner. The actual need for the post-FF adsorption process would ultimately be confirmed or dismissed based on pilot-scale testing.

The FF process is typically set-up with fractionators in series or parallel with multiple recycle steps to optimize the reaction kinetics and a separate foamate treatment line that may include multiple smaller fractionators. The process is operated with two objectives: generate a treated effluent (raffinate) that meets the PFAS(6) IDWS cleanup goal; and reduce the volume of foamate as much as practical by subjecting the foamate to a follow-up fractionation to further concentrate the PFAS as well as generate additional raffinate. The concentrated foamate is diverted to holding tanks for either destruction (on-site or off-site), trucking to a regional treatment facility, super-loading onto IEX resin, or stabilizing/solidifying the concentrated foamate into a non-leachable concrete mass using a pozzolanic material. The three-reactor series would produce approximately 3 to 5 percent super concentrated foamate by volume. To accomplish further volume reduction, a separate concentrator unit is provided to reduce the volume to approximately 0.3 to 0.5 percent. Assuming the foamate is concentrated to about one percent by volume of the influent flow and that the PFAS(6) is removed to the 20 ng/l goal, the concentrated foamate would represent 1,100 gpd with a PFAS(6) concentration of between 200 and 450 μg/l (200,000 to 450,000 ng/l).

Another possibility for treating foamate is to mobilize an EAOP unit to either the Dolby or JRL site and to truck foamate between the landfill sites with foamate treatment limited to just one site. Additional temporary foamate storage would be required at the site selected for the foamate treatment. This single site foamate treatment option is discussed in Section 7.3.1.

The **<u>second PFAS Reduction Treatment Alternative at Dolby</u>** (Dolby EAOP/EMWWTP Discharge) is to locate an EAOP treatment process at Dolby. Similar to the FF alternative, site improvements need to be implemented at Dolby to modify the existing pump station, construct a new wet well and pump station, install additional off-line leachate storage, complete site preparations, provide standby power, locate an office trailer and support facilities, and continue to use the existing leachate pipeline to discharge the PFAS-treated leachate to EMWWTP for biological treatment and discharge to the Penobscot River. As a stand-alone treatment process, EAOP does not require the addition of oxidants or other chemicals and no PFAS side streams are generated that require further management. The only utilities necessary are electricity and potable water. A flow schematic of the treatment process is presented as Figure 7-2.

In sizing the EAOP process for Dolby, the PFAS and leachate flow information summarized in Table 7-2 were used. The two Dolby leachate samples collected on June 15 and June 29 had elevated PFAS levels in comparison to the other two samples collected during high groundwater conditions (and thus more diluted). In particular, the PFAS(6) concentration during the June 29 sampling episode was the most significant and was used for determining the number of EAOP electrodes and associated energy demand. An EAOP model predicts that to treat the PFAS(6) flow from Dolby to below 15 ng/l would require 128 electrodes, equivalent to 16 mobile EAOP units running in parallel. This preliminary design includes eight additional electrodes as redundancy. Each EAOP unit is equipped with ten Magnéli phase Ti_4O_7 anodes and ten titanium-mesh cathodes. A chemical dosing pump is included in the EAOP unit to allow for the addition of chemicals such as polymers or pH adjustment to enhance the electrochemical process, if necessary. An optional pretreatment cartridge filter (for removing suspended and settleable solids) may be installed to protect the anodes and cathodes at a later date, if desired. To power the EAOP units, the total AC power required is projected at about 1,500A of 3-phase 240V power. Taps for both influent and effluent will be provided to allow sampling. The EAOP units will be winterized, insulated and heated to withstand winter conditions in Maine.

The **third PFAS Reduction Treatment Alternative at Dolby** (Dolby RO/Concentrate Management/EMWWTP Discharge) is to locate a RO treatment process at Dolby and implement similar site improvements as outlined in the two previous options. This option continues to use the existing leachate pipeline to discharge the RO permeate (i.e., treated leachate containing PFAS(6) below the IDWS cleanup goal) to EMWWTP for biological treatment, and discharge to the Penobscot River.

Membrane treatment technologies (such as RO) separate compounds from the leachate using mechanical filtration and externally applied pressure to overcome the osmotic pressure of the target compounds. Two waste streams are generated: the permeate that is treated and free of PFAS (roughly 88 to 90% by volume); and a concentrate stream (roughly 10 to 12% by volume) that must be subsequently managed via destruction, stabilization or volume reduction by technologies such as EAOP, super-loading on IEX, or stabilization/solidification. The concentrate stream has a PFAS concentration about six to seven times greater than the raw leachate. The RO process can be designed for one pass, two passes, or three treatment passes, depending on the leachate characteristics and the desired PFAS removal. In addition, one vendor offers a system incorporating an ultra-high-pressure RO (up to about 1,800 psi) to maximize PFAS recovery and minimize concentrate volume. Other than a prefilter to remove solids and a pH adjustment step, there is no other pretreatment necessary for RO. The RO process does include an alkaline and acid clean in-place (CIP) system and dosing system containing an antiscalant. A flow schematic of the treatment process is presented as Figure 7-3.

The challenge of RO technology is to reduce and separately manage the 10 to 12 percent by volume of side stream concentrate. The concentrate (roughly 11,000 to 13,000 gpd), can be trucked to a regional treatment facility, processed via EAOP, reduced in volume using super-loading on IEX resin, or be stabilized/solidified using a pozzolanic material and disposed in a landfill. Pilot testing will ultimately clarify the concentrate management approach.

7.1.3 Continue to Send Raw Leachate to EMWWTP and Provide Tertiary Treatment of the EMWWTP Effluent for PFAS Reduction

The **fourth treatment alternative for Dolby** is to continue using the existing pump station and leachate pipeline to divert raw leachate to the EMWWTP, implement the necessary site improvements described in the previous alternatives, construct additional off-line storage at both Dolby and the former GNP storage pond adjacent to the EMWWTP, continue treating the combined Dolby leachate and East Millinocket sanitary wastewater using the EMWWTP biological process, and construct a tertiary treatment process that would include iron and manganese removal, tertiary ceramic membrane filtration (UF quality effluent), and adsorption to remove PFAS from the effluent before discharge to the Penobscot River. The following discussion assumes GAC as the tertiary treatment adsorption media, although pilot isotherm testing would eventually clarify the optimum adsorption media for incorporation (e.g., GAC, IEX, or fluoro-sorb).

One of the disadvantages of this alternative is that instead of only treating the leachate from Dolby for PFAS (average flow of 110,400 gpd in 2024), the combined East Millinocket sanitary wastewater and the Dolby leachate (roughly 453,000 gpd in 2024) will be treated as one stream via the iron and manganese removal, tertiary ceramic membranes, and tertiary adsorption process (essentially three times the Dolby flow). Further, the peak flows observed at EMWWTP also include the peak leachate flows from Dolby (limited to 600 gpm by the pump capacity) and peak spring flows from East Millinocket inclusive of spring I/I contributions. Therefore, for planning purposes, the average day flow is assumed as 453,000 gpd and the maximum monthly flow is 877,000 gpd (representative of the maximum month flow in 2021). Higher peaking flow factors were considered since EMWWTP personnel noted flows as high as 2 MGD have occurred during peak spring flows. One modification projected for this alternative is to reduce the volume of off-line storage necessary at Dolby by incorporating the former GNP lagoon adjacent to the

EMWWTP to provide about 8.1 MG of storage. It is hopeful that the storage in the existing Dolby leachate lagoon, the additional leachate storage at Dolby to be constructed, the addition of the former GNP lagoons, and the EMWWTP aeration lagoons can provide the volume to equalize leachate flows to allow management of the high (springtime) flow volumes. Even with the additional off-line storage constructed at Dolby and the former GNP storage lagoons, the maximum flows to the tertiary pretreatment and adsorption process may range from 877,000 gpd to 1,300,000 gpd. Prior to embarking on a final design for this option, a more detailed flow balance of the system should be completed and the final maximum flow through the PFAS treatment system determined. A flow schematic of the treatment process is presented as Figure 7-4.

Further analysis of the viability of the EMWWTP effluent to serve as feed water to a PFAS adsorption process will need to address the variability of effluent quality from the existing aerated lagoon process (which is permitted to discharge effluent with BOD5 and TSS as high as 50 mg/l during portions of the year). In short, the aerated lagoon effluent quality is not an ideal feed water for a tertiary adsorption process and will need rigorous pretreatment. For example, the secondary effluent has elevated iron and manganese concentrations that need to be lowered to 0.3 mg/l for iron and 0.05 mg/l for manganese in order to not compromise the adsorption efficiency, and the equivalent of a UF unit needs to be installed. Even then, the UF effluent will likely have TOC and ammonia levels above recommended pretreatment guidelines of 1 mg/l and 0.5 mg/l, respectively.

The anticipated adsorption treatment process includes a dedicated iron and manganese pretreatment followed by a ceramic (constructed of silicon carbide) membrane filtration prior to PFAS removal. The iron and manganese removal process is an integrated pre-engineered system that utilizes a proprietary manganese dioxide media in a mobile treatment unit. Iron and manganese are co-precipitated and filtered out of solution after being oxidized with sodium hypochlorite. The filter bed is typically backwashed one to three times per week to remove the accumulated iron and manganese. The technology does not require a long contact time, coagulants, or permanganate to regenerate the media similar to a greensand filter. The iron and manganese reactors are provided in parallel to produce a maximum flow of between 877,000 and 1,300,000 gpd and to provide process redundancy. As noted above, should the maximum flow increase, the size of the treatment unit operations would also need to increase.

The effluent from the iron and manganese pretreatment is passed through a 6-mm strainer screen to remove large debris material that is then delivered into a rapid-mix chamber at the head end of the ceramic membrane filter where a coagulant (such as alum) is injected to bind up organic material and improve membrane filterability. The feed water gravity-flows into a membrane feed channel where the flow is split into various membrane treatment units. The UF membranes remove suspended solids, turbidity, and microorganisms. Membranes are kept clean throughout the cycle with frequent backwash rinses and automated clean in-place (CIP) cycles using chlorine, acid, and caustic. At the end of a membrane treatment cycle, the unit is drained, backwashed, and rinsed to evacuate solids build-up. The process to be installed at EMWWTP includes two parallel units that are inclusive of strainers, permeate pumps, backwash pumps, drain pumps, air scour blowers, permeate/backwash tanks, and the CIP chemical dosing systems.

The tertiary PFAS removal by GAC follows the ceramic membrane filtration process. The PFAS removal is accomplished using two GAC adsorption units operating in parallel with each unit comprised of two GAC adsorption vessels operating in series (total of four GAC units). Each GAC unit is equipped with 20,000 pounds of media. For GAC, the empty bed contact time (EBCT) is 10 minutes per vessel (the EBCT for IEX or fluoro-sorb adsorption is 3 minutes). Prior to the adsorption process, a sodium bisulfite dosing system is provided to reduce chlorine concentration remaining from the secondary treatment.

Site preparation at the EMWWTP for situating the iron and manganese removal, ceramic membrane filtration, and PFAS adsorption process includes a common tertiary treatment building adjacent to the chlorine contact tank at the EMWWTP, including heated building and electrical control panel with three-phase power and process water. The driveway and building doors will be laid out to easily accommodate media change-outs. The building will be a single-story building similar in design to the existing control, blower, and chemical storage buildings at the EMWWTP. The building will be winterized, insulated and heated to withstand winter conditions in Maine. Some of the unique site development necessary for this option includes:

- Construct a pump station to elevate the biologically treated EMWWTP effluent to the tertiary treatment building that houses the iron and manganese removal process, the ceramic membrane filters, PFAS adsorption vessels, influent transfer pumps, and filtrate pumps.
- A filtrate return line will need to extend from the new tertiary treatment building to the head of the EMWWTP or the line that extends from the grit chamber to the aerated lagoons.
- I&C associated with the tertiary treatment operation will be integrated with the existing supervisory control and data acquisition (SCADA) system that is on-line at the EMWWTP. Sample taps will be located at the influent and effluent of the iron and manganese

process, at the ceramic membrane effluent, between the GAC units, and for the final effluent, so that PFAS breakthrough of the media can be easily established.

- The GAC media will be a coconut-shell-based product (for cost estimating). Spent GAC media would need to be sent off-site for regeneration and/or disposal. The treatment process will be designed to allow simple change-out of the exhausted carbon. For planning purposes, it is assumed that spent GAC will be managed by the GAC vendor and that virgin GAC will be reinstalled as part of the change-outs.
- The tertiary effluent would be discharged to the Penobscot River via the existing outfall at the EMWWTP.

7.2 Juniper Ridge Landfill Leachate Management Alternatives

PFAS treatment alternatives for the JRL leachate include:

- Off-site disposal of the raw leachate at a regional treatment facility that would provide both biologic and PFAS treatment of the leachate; and
- PFAS treatment of the leachate at the JRL site, followed by biologic treatment of the leachate at the NDWWTP.

The above treatment alternatives will involve removing PFAS in the leachate at either the front-end or tail-end of the treatment process, with the final process selection based on effectiveness of the treatment process with respect to meeting the PFAS(6) IDWS cleanup goal and overall treatment cost. Note that unlike for Dolby, PFAS treatment of the JRL leachate at the tail-end of the NDWWTP is not considered feasible due to the large-volume of wastewater flows associated with the NDWWTP.

7.2.1 Off-Site Disposal of JRL Leachate at a Regional PFAS Treatment Facility

This alternative is similar to the regionalization approach outlined in Section 7.1.1 for the Dolby leachate and assumes that JRL leachate and/or PFAS side streams are trucked to a regional facility for processing.

While it is unlikely that raw leachate would be trucked from JRL to a regional facility due to the volume (69,300 gpd or about 16 tank-truckloads at 200 days per year in 2024), it should be noted that the projected volume of leachate for JRL will incrementally drop to less than 10,000 gpd as final cover is installed over the completed waste cells. Depending on the tipping fee charged by the regional facility, at some point it could be cost effective to truck leachate from JRL to a regional facility. For planning purposes, a distance of 80 miles to the regional facility was used for the Study (i.e., approximate annual trucking cost in 2024 of $1.92 million).

Similar to Dolby, if the treatment alternative eventually selected to manage PFAS at JRL includes PFAS side streams, concentrates, or residuals, then trucking the concentrates to a regional facility could be a cost effective and reliable method for disposing/reducing/destroying the concentrated PFAS waste from JRL.

In considering how treatment of the JRL leachate or associated PFAS side streams could be implemented as part of a regional approach, a number of improvements would need to be constructed at JRL, and the waste disposal pricing must be established.

7.2.2 PFAS Reduction at JRL, Concentration of Residuals and On-site or Off-site Treatment or Disposal of PFAS Side Streams and Discharge to NDWWTP

This management alternative entails constructing an "upfront bulk" PFAS reduction process at the JRL site adjacent to the existing leachate storage tank, managing side streams from the PFAS reduction process either on-site or off-site, and trucking the treated effluent to the NDWWTP for biological treatment to remove BOD5, ammonia, and other pollutants, prior to discharge to the Penobscot River. The average daily flow for 2024 is projected to increase from 42,000 gpd (2020-2021 average) to about 69,300 gpd due to additional open areas planned for JRL in the next several years, with the maximum flow assumed to be 114,400 gpd (based on a 165 percent peaking flow factor). Higher peaking flow factors were considered, but because the leachate storage tank at JRL has a 0.912-MG working storage volume for flow equalization, the maximum month peaking factor of 165 percent was used to size the hydraulic capacity for the treatment process. For each JRL alternative developed, it is expected that the leachate storage tank will be modified to include a mixing system to homogenize the leachate prior to PFAS treatment. The mixing would also eliminate stratification and ice formation in the winter months.

Similar to Dolby, the three evolving technologies that show promise for an "upfront bulk" PFAS reduction are FF, EAOP, and RO. All three technologies are considered potentially viable for the JRL leachate, and EAOP could potentially be used in conjunction with FF or RO to treat the PFAS concentrated foamate side stream or the RO concentrate. The fourth PFAS treatment technology for the JRL leachate is extensive on-site physical-chemical and biological pretreatment of the leachate using a MBR and followed by PFAS adsorption.

The **first PFAS Reduction Treatment Alternative for JRL** (JRL FF/Foamate Concentrate/Foamate Management/Discharge to NDWWTP) is to locate a FF treatment process at JRL adjacent to the existing leachate storage tank, construct a new pump station to elevate raw leachate from the storage tank to the FF treatment unit, construct a new treated effluent storage tank that is equipped with pumps to elevate the treated raffinate to the tank-truck loading station, and continue to truck the pretreated leachate to the NDWWTP for biological treatment and discharge to the Penobscot River. As a stand-alone treatment process, FF typically includes the addition of surfactants to increase the foaming potential of the leachate and a foamate side stream is generated that requires further concentration and either off-site or on-site treatment and disposal. A flow schematic of the treatment process is presented as Figure 7-5. Construction elements of this alternative include:

- Modifying the existing 0.912-MG storage tank with a mixing system to homogenize the leachate and prevent stratification and ice formation during winter months.
- Constructing a new 0.5-MG treated holding tank for storing the PFAS-treated leachate prior to trucking the treated leachate to the NDWWTP.
- Install a new pump station and pipeline to elevate raw leachate from the existing leachate storage tank to the FF unit. The existing pump station and pipeline to the tank-truck loading station will remain in-place and valves will be installed to provide flexibility to allow raw leachate to be pumped to the tank-truck loading station.
- Complete site preparation for situating the FF unit(s) and support operations adjacent to the leachate storage tank, including a foundation pad and electrical control panel with three-phase power.
- Mobilize an FF treatment unit that is fully integrated with I&C including flow meters, pH meter, thermometer, ORP meter, level controls, and auto dialer to allow remote monitoring and alarms. The FF treatment unit for JRL would be similar to the FF treatment unit described for Dolby (i.e., FF reactors, chemical feeds, break tank, foamate storage, and concentration would be located in several Conex-type containers; each FF unit is equipped with recirculation pumps, air injectors and dosing equipment; the FF capacity is about 66 gpm per unit or could be a custom design system with higher flow capacity). A distinction between the Dolby and JRL sites is that JRL only requires a single FF unit rather than two at Dolby due to the lesser leachate flows.
- Foamate will be managed similar to the description provided for Dolby. Assuming the foamate can be concentrated to about one percent by volume of the influent flow and that the PFAS(6) is removed to the 20 ng/l goal, the concentrated foamate would

represent 700 gpd with a PFAS(6) concentration of between 200 and 300 μg/l (200,000 to 300,000 ng/l).

  - Another possibility for treating foamate is to mobilize an EAOP unit to either the Dolby or JRL site and to truck the foamate between sites with foamate treatment limited to just one site. Additional foamate storage would be required at the site selected for the foamate treatment. This foamate treatment option is presented in Section 7.3.1.

- The vent from the FF unit is equipped with a provisional carbon filter, although based on monitoring at previous treatment sites, off-gas treatment has not been warranted.
- Constructing a return raffinate (treated effluent) pipeline from the FF unit to a new treated effluent holding tank that is equipped with pumps to discharge to the existing tank-truck loading station.
- Continue to discharge the raffinate (treated effluent) from the FF process to the NDWWTP for treatment of BOD5, TSS, ammonia, and other conventional pollutants, and then discharge to the Penobscot River.
- Integrating the electrical controls for the treatment facilities to the existing standby generator at JRL such that continued treatment can progress in the event of a power outage.
- Locate an office trailer and support facilities for the operators adjacent to the FF unit.

The **<u>second PFAS Reduction Treatment Alternative at JRL</u>** (JRL EAOP/NDWWTP Discharge) is to locate the EAOP treatment process adjacent to the existing leachate storage tank and implement similar site improvements as described above for the FF system at JRL. Provisions would still exist to allow the raw leachate from the existing storage tank to be pumped directly to the tank-truck loading station. The treated effluent with reduced PFAS would continue to be trucked to the NDWWTP for biological treatment and discharge to the Penobscot River. As a stand-alone treatment process, EAOP does not require the addition of oxidants or other chemicals and no PFAS side streams are generated that require further management. A flow schematic of the treatment process is presented as Figure 7-6.

Mobilize an EAOP unit that is fully integrated with I&Cs including flow meters, pH meter, thermometer, ORP meter, level controls, and an auto dialer to allow remote monitoring and alarms. The EAOP process proposed is similar to the EAOP at Dolby, except that the EAOP design model calls for 72 reactors in nine mobile units operating in parallel. An additional mobile unit with eight reactors is included for redundancy. Power requirements are 890A of 240VAC, 3-phase power. Each reactor is equipped with ten Magnéli phase Ti_4O_7 anodes and ten titanium-mesh cathodes. An optional pretreatment cartridge filter may be installed, if desired. Both influent and effluent taps will be provided to allow sampling. The unit will be winterized, insulated and heated to withstand winter conditions in Maine. An optional polymer day tank and dosing pumps may be provided to increase the leachate oxidation process. Several additional elements to include at JRL for EAOP treatment of PFAS include:

- Integrating the electrical controls for the treatment facilities to the existing standby generator at JRL such that continued treatment can progress in the event of a power outage.
- Construct a return treated effluent pipeline from the EAOP unit to a new treated effluent storage tank that is equipped with pumps to discharge to the existing tank-truck loading station.
- Continue to discharge the PFAS-pretreated leachate from the EAOP unit to the NDWWTP for treatment of BOD5, TSS, ammonia, and other conventional pollutants, and then discharge to the Penobscot River.
- Locate an office and support trailer for the operators adjacent to the EAOP unit.

The **third PFAS Reduction Treatment Alternative at JRL** (JRL RO/Concentrate Management/ NDWWTP Discharge) is to locate a RO treatment process at JRL adjacent to the storage tank similar to the option for RO at Dolby. Site improvements are similar to those described immediately above. The concept for RO treatment at JRL is similar to Dolby, although due to the complex chemistry of the JRL leachate, it is likely that a two-pass or three-pass RO process would be installed rather than a single-pass system as projected for Dolby. A flow schematic of the treatment process is presented as Figure 7-7.

The challenge of this technology, similar to Dolby, is to reduce and separately manage the concentrated PFAS side stream. The concentrate (roughly 6,930 to 8,300 gpd), can be trucked to a regional treatment facility, processed via EAOP, reduced in volume using super-loading on IEX resin, or be stabilized/solidified into a non-leachable concrete structure using a pozzolanic material for disposal in a landfill. Pilot testing will ultimately clarify the concentrate management approach.

The **fourth PFAS Reduction Treatment Alternative at JRL** (JRL Pretreatment via Physical-Chemical and Biological Treatment/GAC or IEX for PFAS Removal/Sludge Concentrate/Sludge

Disposal/Discharge to NDWWTP) is to construct a physical-chemical and biological pretreatment unit operation and a PFAS adsorption process adjacent to the leachate storage tank, construct a new pump station and pipeline to divert raw leachate from the storage tank to the physical-chemical and biological pretreatment reactor, construct a new treated effluent storage tank that is equipped with pumps to elevate the treated effluent to the tank-truck loading station, and continue to truck the pretreated leachate to the NDWWTP for additional biological treatment and discharge to the Penobscot River. The physical-chemical and biological treatment processes will generate an inorganic and waste activated sludge (WAS) that will need to be thickened and trucked off-site for disposal. Both the inorganic and WAS will likely contain PFAS. A flow schematic of the treatment process is presented as Figure 7-8. In addition to the common site improvements discussed for the previous alternatives, other construction elements of this alternative include:

- Implementing a robust pretreatment system that includes flocculation, coagulation and precipitation, and a MBR that yields an UF quality effluent that would theoretically allow tertiary PFAS adsorption as a separate unit operation. As noted in Section 3.3.2, the JRL leachate is extremely complex with elevated concentrations of ammonia, iron, chloride, hardness, TDS, anions, and cations, and TSS that should be reduced or removed prior to biological treatment in a MBR. In order to accomplish this necessary pretreatment, a physical-chemical unit operation including pH adjustment, coagulation, flocculation, and precipitation may be necessary to protect the MBR process. Due to the elevated iron and manganese in the JRL leachate, a dedicated iron and manganese removal unit operation may need to follow the physical-chemical process depending on pilot results. This pretreatment process would primarily generate an inorganic sludge that will require thickening and off-site management. The inorganic sludge will likely contain PFAS.
- Construct a biological treatment operation adjacent to the existing leachate storage tank. It is envisioned that a MBR would be constructed in a concrete structure situated below the ground surface to provide UF effluent quality and provide insulation of the biological process, which is temperature sensitive. Due to the quality of the leachate (particularly the high ammonia concentration), a supplemental source of carbon (e.g., Micro C or glycerin) and phosphorus will need to be dosed into the biological process to maintain the proper carbon-to-nitrogen-to-phosphorus ratio. An acid neutralization step will also be included to prevent air stripping of ammonia that occurs at a pH above about 8.2. The MBR process will be fully integrated with blowers, diffusers, mixers, return activated sludge (RAS) pumps, WAS pumps, and the chemical feeds described above. I&C will include flow meters, pH meter, temperature control, dissolved oxygen (DO) meter, ORP meter, level controls, and an auto dialer to allow remote monitoring and alarms.

- The biological process will yield WAS that needs to be polymer-thickened to provide sufficient decanting and thickening. The decant will be recycled to the head of the biological process and the thickened sludge will be loaded into tank-trucks and trucked to a regional treatment facility for final treatment and disposal. Based on a projected sludge yield similar to other biological facilities and thickened solids content of 4.5 to 5.0 percent, it is projected that about 8 to 10 truckloads per month of thickened sludge will need to be managed off-site. It is projected that the thickened WAS will contain some PFAS that partition onto the sludge during the biological process.
- Mobilize an adsorption unit for PFAS removal that is fully integrated with I&C, including flow meters, pH meter, thermometer, pressure gauges, level controls, and auto dialer to allow remote monitoring and alarms. The adsorption unit(s) will be designed in a lead/lag arrangement with an empty bed contact time of 10 minutes for GAC (3 minutes for IEX or fluoro-sorb). The treatment unit will be winterized, insulated and heated to withstand winter conditions in Maine.
- Construct a new tertiary treatment building to house the iron and manganese removal, physical-chemical process, MBR pumps and equipment, chemical feed equipment, and the PFAS adsorption processes.
- Construct a treated effluent pipeline from the adsorption unit to a new treated effluent holding tank that is equipped with pumps to pump the treated leachate to the existing tank-truck loading station.
- Transport the treated effluent from the physical-chemical and biological pretreatment and PFAS reduction process to the NDWWTP for discharge to the Penobscot River. In contrast to the other PFAS treatment alternatives occurring at the JRL site, it should be noted that the treated effluent from the MBR and adsorption processes will be very clean and will not require full biological treatment at the NDWWTP.
- Integrating the electrical controls for the treatment facilities to the existing standby generator at JRL such that continued treatment can progress in the event of a power outage.
- Locate an office trailer and support facilities for the operators adjacent to the MBR unit.

7.3 Partial Integration of Dolby and JRL PFAS Treatment Facilities

A number of the previous PFAS treatment alternatives evaluated included FF and EAOP at both Dolby and JRL. Another conceptual alternative is to locate separate FF unit operations at both

Dolby and JRL, and to establish a single EAOP operation at the JRL site. In this situation, the FF foamate from Dolby would be transported by tank-truck to the JRL EAOP operation, be combined with the JRL FF foamate, and then process the combined foamate through the JRL EAOP unit.

Another alternative that would also include integrating the Dolby and JRL treatment operations, would be to truck the leachate from JRL to the EMWWTP, combine both the JRL and Dolby leachate with the sanitary wastewater from East Millinocket, treat the combined wastewater via the existing EMWWTP biologic treatment process, and then construct a tertiary PFAS treatment system at the tail-end of the treatment plant, prior to discharge to the Penobscot River.

7.3.1 Implement FF at Dolby and JRL with EAOP Treatment of Foamate at JRL

The **first partial leachate integration alternative** is to implement FF at both Dolby and JRL, the treated raffinate from Dolby and JRL continues to be discharged to EMWWTP and NDWWTP, respectively. The foamate from Dolby is trucked to JRL, combined with the JRL foamate and then treated together in a single EAOP treatment process.

At Dolby, the same site improvements outlined in Section 7.1.2 would need to be constructed. In addition, a foamate holding tank and loading station at Dolby needs to be installed. The preliminary design assumes two mobile containers (standard 40-ft by 8-ft Conex-type containers) each with three flow-through reactors in series designed to treat leachate at a flow of 66 gpm. The FF reactors are operated in series to provide continuous flow treatment. Although preliminary FF bench-scale testing of the Dolby leachate alone removed a significant portion of the total PFAS and the PFAS(6) to below the IDWS cleanup goal, as a contingency, an optional adsorption operation with a lead/lag configuration has been included. The adsorption unit would provide additional removal of total PFAS and give greater confidence to meeting the PFAS(6) goal in a reliable manner. The concentrated foamate is diverted to a foam concentrator and then to a concentrate foamate holding tank sized to manage the foamate from both Dolby and JRL.

- Foamate will be diverted to a new holding tank equipped with pumps for loading tank-trucks with PFAS-concentrated foamate that will be trucked to the EAOP process at JRL. Assuming the foamate can be concentrated to about one percent by volume of the influent flow and that the PFAS(6) concentration in the raffinate are removed to the 20 ng/l goal, the concentrated foamate would represent 1,100 gpd with PFAS(6) concentration between 200 and 450 μg/l.

At JRL, the FF treatment process would be located adjacent to the existing 0.912-MG leachate storage tank, and the same site improvements outlined in Section 7.2.2 would need to be implemented. The preliminary design for JRL assumes a single FF unit with three flow-through reactors in series to handle a peak flow of 66 gpm and average flows of about 50 gpm. Similar to the previous analysis for FF, an optional IEX adsorption operation with a lead/lag arrangement is included. The concentrated foamate from JRL is then combined with the foamate trucked from Dolby. The new foamate holding tank will need sufficient capacity to hold the foamate from both Dolby and JRL (roughly 1,800 gpd) and an EAOP unit capable of treating the combined volume of JRL and Dolby foamate needs to be constructed. Figure 7-9 also shows the flow schematic of the treatment process at Dolby and JRL.

The concentration of PFAS in the combined foamate is calculated as the weighted average of the two leachates assuming a 100-fold concentration factor and that each PFAS species has the same capture efficiency with no losses. Thus, the anticipated PFAS concentration is approximately 396 μg/l (396,000 ng/l) with a combined flow of about 1,800 gpd.

The combined treatment of the foamate was modeled in the same fashion as the Dolby and JRL leachates, although the confidence for this scenario is less. It is projected that a single mobile unit with eight EAOP reactors is needed. This includes two EAOP reactors for redundancy. The system would draw 98A using 240VAC, 3-phase power and treat about 657,000 gallons per year. At very high PFAS concentrations, one EAOP manufacturer noted that shorter-chain PFAS may not react in the same manner as compared when at lower concentrations, possibly leading to compromised removals of those species. However, the high concentrations should improve mass transport of the PFAS to the electrode surface, thus improving treatment and allowing for higher-applied current to speed the reactions. Pilot testing will allow confirmation and provide better treatment removal and cost projections.

7.3.2 Combine JRL and Dolby Leachate at EMWWTP

The **second partial leachate integration alternative** is to continue discharging the Dolby leachate to the EMWWTP and truck the JRL leachate to the existing leachate unloading pad at the EMWWTP. The two leachate volumes (110,400 gpd from Dolby and 69,300 gpd from JRL) would combine with roughly 360,000 gpd of sanitary wastewater from East Millinocket. The combined sanitary and leachate flow (540,000 gpd) then receives biological treatment followed by an iron and manganese removal, tertiary ceramic membrane filtration, and PFAS adsorption at the tail-end of the EMWWTP. There are several potential advantages of this hybrid system. First, this alternative would consolidate the PFAS treatment process to a single facility. Second, the EMWWTP has available hydraulic capacity to handle the leachate volume from JRL. Third, as the leachate volume from JRL declines, the cost for trucking will likewise drop. Fourth, the operations and maintenance (O&M) costs to run a tertiary PFAS removal process at one location will likely be less than the cost of running two separate treatment plants.

As previously discussed, one of the disadvantages of this alternative is that instead of only treating the Dolby and JRL leachate, this alternative also treats the sanitary wastewater from East Millinocket via the PFAS tertiary treatment process. A second concern to evaluate for this alternative is the pollutant loading to the EMWWTP, particularly from a nitrogen loading perspective. A final issue to evaluate is whether the tertiary pretreatment process that includes iron and manganese treatment and ceramic membrane filtration will be of sufficient quality to provide adequate pretreatment prior to the PFAS adsorption step. A flow schematic of the treatment process is presented as Figure 7-10. Construction elements of this alternative include:

- This alternative locates the tertiary pretreatment and PFAS adsorption process for reducing PFAS at the tail-end of the EMWWTP and continues using the existing pump station and pipeline to elevate raw leachate from the Dolby leachate storage pond to the EMWWTP.
- Leachate from JRL will continue to be stored in the JRL leachate storage tank and then loaded into tank-trucks and hauled to EMWWTP in lieu of the NDWWTP. EMWWTP already has a tank-truck unloading pad that would be used to divert the JRL leachate into the EMWWTP biological process.
- Complete site preparation for situating the pretreatment operations and PFAS adsorption process in a common tertiary treatment building adjacent to the chlorine contact tank at the EMWWTP, including heat for the building, electrical control panel with three-phase power, and process water (see Section 7.1.3). The driveway and building doors will be sized and positioned to easily accommodate media change-outs. The building will be a single-story building similar in design to the existing control, blower, and chemical storage buildings at the EMWWTP. The building will be winterized, insulated and heated to withstand winter conditions in Maine. Construct a pump station to elevate the biologically treated EMWWTP effluent to the tertiary treatment building that houses the iron and manganese removal process, the ceramic membrane filters, adsorption units, influent transfer pumps, and filtrate pumps.
- Mobilize separate pre-engineered iron and manganese treatment processes, ceramic membrane filters, and PFAS adsorption units with fully integrated instrumentation and controls (I&C) including flow meters, pH meter, pressure gauges, thermometer, ORP meter, level controls, and auto dialer to allow remote monitoring and alarms. The PFAS

adsorption units are capable of holding 20,000 pounds of GAC media) and would be operated in series (lead/lag configuration). I&C associated with the tertiary treatment operation will be integrated with the existing supervisory control and data acquisition (SCADA) system that is on-line at the EMWWTP. Sample taps will be located at the influent and effluent of the iron and manganese process, at the ceramic membrane effluent, between the adsorption units, so that PFAS(6) breakthrough of the adsorption media can be easily established.

- The GAC media will be a coconut-shell-based product (for cost estimating). Spent GAC media would need to be sent off-site for regeneration and/or disposal. The treatment process will be designed to allow simple change-out of the exhausted carbon. For planning purposes, it is assumed that spent GAC will be managed by the GAC vendor and only virgin media will be replaced when spent media is exhausted.
- The tertiary effluent would be discharged via the existing outfall at EMWWTP to the Penobscot River.

TABLE 7-1

DOLBY AND JUNIPER RIDGE LANDFILLS LEACHATE FLOWS AND ANALYTICAL SUMMARY[1]

Parameter/Pollutant	Acronym Name	Units	Dolby Sampling Event[5]					JRL Sampling Event[6]				
			MEDEP #1 9/23/2021	BGS #1 2-May-22	BGS #2 15-Jun-22	MEDEP #2 29-Jun-22	Dolby Average[7]	MEDEP #1 7-Dec-22	BGS #1 2-May-22	BGS #2 15-Jun-22	MEDEP #2 26-May-22	JRL Average[7]
LEACHATE FLOWS												
Average Flow (2020 - 2021)	Qavg	gpd	-	-	-	-	127,000	-	-	-	-	42,200
Average Flow (2024)	Qavg	gpd	-	-	-	-	110,400	-	-	-	-	69,300
Maximum Month Flow (2024)	Qmax mo	gpd	-	-	-	-	150,000	-	-	-	-	114,400
Estimated Average Flow (2043)	Qavg	gpd	-	-	-	-	88,500	-	-	-	-	9,000
PFAS CLEAN-UP GOAL[2]												
Sum of Six (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA)	Sum of Six	ng/l	-	-	-	-	20	-	-	-	-	20
ANALYTICAL SUMMARY												
A. Conventional/Nutrients												
Biochemical Oxygen Demand	BOD5	mg/l	NS	6.1	<2.0	NS	4.0	NS	140	110	NS	125
Total Organic Carbon	TOC	mg/l	NS	16.3	22.5	NS	19.4	NS	443	482	NS	462.5
Total Suspended Solids	TSS	mg/l	NS	42	<5.0	NS	21	NS	53	40	NS	46.5
Ammonia as Nitrogen	NH3-N	mg/l	NS	7.27	9.85	NS	8.56	NS	685	678	NS	681.5
pH	-	s.u.	NS	7.5	7.7	NS	7.6	NS	7.4	7.5	NS	7.45
B. Toxic Metals												
Arsenic	As	mg/l	NS	NS	<0.005	NS	<0.005	NS	NS	0.406	NS	0.406
Zinc	Zn	mg/l	NS	<0.05	<0.05	NS	<0.05	NS	<0.1	<0.1	NS	<0.1
C. Toxic Organics												
Alpha Terpineol	-	ug/l	NS	<5	<5	NS	<5	NS	49.2	23.5	NS	36
Benzoic Acid	-	ug/l	NS	<50	<50	NS	<50	NS	234	<200	NS	117
p-Cresol	-	ug/l	NS	<5	<5	NS	<5	NS	108	63	NS	86
Phenol	-	ug/l	NS	<5	<5	NS	<5	NS	53.5	<20	NS	27
Volatile Organic Compounds	VOC	ug/l	NS	NS	ND	NS	ND	NS	NS	740	NS	740
D. Anions/Cations												
Barium	Ba	mg/l	NS	0.077	0.063	NS	0.07	NS	0.853	1.16	NS	1.01
Bromide	Br	mg/l	NS	NS	0.15	NS	0.15	NS	NS	81.2	NS	81.2
Calcium	Ca	mg/l	NS	104	111	NS	108	NS	239	244	NS	242
Magnesium	Mg	mg/l	NS	40.6	77.6	NS	59.1	NS	160	201	NS	181
Potassium	K	mg/l	NS	44.2	77.4	NS	60.8	NS	894	1130	NS	1012
Sodium	Na	mg/l	NS	15.1	28.9	NS	22	NS	2130	2570	NS	2350
Strontium	St	mg/l	NS	0.414	0.639	NS	0.527	NS	2.37	2.93	NS	2.65
Bicarbonate	HCO3	mg/l	NS	509	760	NS	635	NS	2,810	3570	NS	3190
Chloride	Cl	mg/l	NS	14	28	NS	21	NS	5,100	5800	NS	5450
Fluoride	F	mg/l	NS	<0.2	<0.2	NS	<0.2	NS	0.22	0.26	NS	0.24
Nitrite/Nitrate	NO2/NO3	mg/l	NS	0.3	0.27	NS	0.285	NS	<0.1	1.9	NS	0.95
Sulfate	SO4	mg/l	NS	27	28	NS	27.5	NS	150	120	NS	135
E. Other Non-Conventional Parameters												
Alkalinity as CaCO3	-	mg/l	NS	509	760	NS	635	NS	2,810	3570	NS	3190
Hardness as CaCO3	-	mg/l	NS	427	597	NS	512	NS	1,260	1440	NS	1350
Iron	Fe	mg/l	NS	12.8	1.27	NS	7.0	NS	9.24	8.34	NS	8.79
Manganese	Mn	mg/l	NS	4.68	1.03	NS	2.9	NS	2.51	2.25	NS	2.38
Total Dissolved Solids	TDS	mg/l	NS	550	910	NS	730	NS	9,900	12000	NS	10950
Conductivity	-	µmho/cm	NS	1,100	1412	NS	1256	NS	19,000	24000	NS	21500
Turbidity	-	NTU	NS	NS	12.5	NS	12.5	NS	NS[4]	NS[4]	NS	NS[4]
Surfactants	-	mg/l	NS	NS	0.151	NS	0.151	NS	NS	1.6	NS	1.6
F. Six State of Maine Regulated PFAS												
Perfluorooctanesulfonic	PFOS	ng/l	84.7	129	912	542	417	29.4	148	108	71.5	89.2
Perfluorooctanic Acid	PFOA	ng/l	159	114	562	3080	979	182	1,410	1190	914	924
Perfluoroheptanoic Acid	PFHpA	ng/l	79.2	43	89	286	124	110	652	677	578	504
Perfluorononanoic Acid	PFNA	ng/l	26	22.2	190	411	162	10.9	68.7	54.8	37	42.9
Perfluorohexanesulfonic	PFHxS	ng/l	<2.1	16.7	12.2	80.2	27	72.8	316	390	343	280
Perfluorodecanoic Acid	PFDA	ng/l	2.52	<2.02	31	27.2	15	4.77	32.1	23.4	<20	15.1
Sum of Six PFAS[2]	PFAS(6)	ng/l	351	325	1796	4426	1725	410	2,627	2443	1944	1856
G. Other Unregulated PFAS												
Perfluorobutanesulfonic Acid	PFBS	ng/l	2.41	<2.02	<1.96	2.15	1.1	333	1,770	2560	2010	1668
Perfluorobutanoic Acid	PFBA	ng/l	72.2	28.2	39.4	42.6	45.6	299	1,340	1970	1640	1312
Perfluorodecanesulfonic Acid	PFDS	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20

TABLE 7-1 (cont'd)

DOLBY AND JUNIPER RIDGE LANDFILLS LEACHATE FLOWS AND ANALYTICAL SUMMARY[1]

Parameter/Pollutant	Acronym Name	Units	Dolby Sampling Event[5]					JRL Sampling Event[6]				
			MEDEP #1 9/23/2021	**BGS #1 2-May-22**	**BGS #2 15-Jun-22**	**MEDEP #2 29-Jun-22**	**Dolby Average[7]**	**MEDEP #1 7-Dec-22**	**BGS #1 2-May-22**	**BGS #2 15-Jun-22**	**MEDEP #2 26-May-22**	**JRL Average[7]**
Perfluorododeanoic Acid	PFDoDA	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluoroheptanesulfonic Acid	PFHpS	ng/l	2.7	<2.02	6.4	16.7	6.5	<1.95	<20	<20	<20	<20
Perfluorohexadecanoic Acid	PFHxDA	ng/l	<2.1	<4.05	<3.91	<3.7	<2	<3.9	<40	<40	<40	<40
Perfluorohexanoic Acid	PFHxA	ng/l	89.8	43.3	58	65.4	64.1	392	2,050	2250	2040	1683
Perfluoronanesulfonic Acid	PFNS	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluorooctadecanoic Acid	PFODA	ng/l	<2.1	<4.05	<3.91	<3.7	<2	<3.9	<40	<40	<40	<40
Perfluorooctanesulfonamide	PFOSA	ng/l	<2.1	<2.02	2.56	<1.85	1	<1.95	<20	<20	<20	<20
Perfluoropentanesulfonic Acid	PFPeS	ng/l	<2.1	<2.02	<1.96	<1.85	<2	10.4	35	51.7	61.1	39.6
Perfluoropentanoic Acid	PFPeA	ng/l	74.1	34.6	43	40	48	189	1,150	1260	1270	967
Perfluorotetradecanoic Acid	PFTA	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluorotridecanoic Acid	PFTrDA	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
Perfluoroundecanoic Acid	PFUnA	ng/l	<2.1	<2.02	4.18	2.46	2	<1.95	<20	<20	<20	<20
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	ng/l	<2.1	<2.02	17.4	11.3	7	3.48	<20	<20	<20	<20
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	ng/l	2.44	<2.02	10.8	72.9	22	62.2	345	384	272	266
2,3,3,3-Tetraflluoro-2-[1,1,2,2,3,3,3-Heptaflluoropropoxy]-Propanoic Acid	HFPO-DA	ng/l	<2.1	<50.6	<48.9	<46.2	<2	<48.8	<500	<500	<500	<500
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	ng/l	<2.1	<2.02	<1.96	<1.85	<2	<1.95	<20	<20	<20	<20
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	ng/l	<2.1	<2.02	4.9	5.66	2.6	20.7	83	88.1	46.8	59.7
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	ng/l	5.8	3.18	39.8	48.5	24.3	3.82	<20	23.4	<20	<20
Sum of All PFAS Compounds[3]		ng/l	601	434	2023	4734	1948	1,723	9,400	11007	9283	7853

Notes:

[1] Database includes sampling funded by MEDEP SWD in 4th quarter 2021 and 2nd quarter 2022 and sampling funded by BGS for State-Owned landfill leachates on May 2, 2022 and June 15, 2022.

[2] PFAS values are State of Maine IDWS established June 21, 2021 for six PFAS analytes combined in drinking water. IDWS = 20 ng/l.

[3] Values less than the analytical detection limit are assumed as zero when calculating the sum and averages.

[4] JRL leachate was too dark and opaque for reading.

[5] Dolby leachate samples collected as grab from CB-3 manhole location.

[6] JRL leachate samples collected from tank-truck loading station.

[7] Average of four sampling events.

TABLE 7-2

DOLBY LEACHATE AND EMWWTP INFLUENT/EFFLUENT DESIGN SUMMARY[1]

Parameter/Pollutant	Acronym	Units	Dolby CB-3 May-22	Dolby Leachate Pond Eff. May-22	Town of East Millinocket May-22	EMWWTP Influent May-22	EMWWTP Effluent May-22	Dolby CB-3 Jun-22	Dolby Leachate Pond Eff. Jun-22	Town of East Millinocket Jun-22	EMWWTP Influent Jun-22	EMWWTP Effluent Jun-22	Dolby Leachate Pond Eff. Average	EMWWTP Effluent Average
1. DESIGN FLOWS														
A. Average Flow (2020 - 2021)	Qavg	gpd		-	-	-	-		-	-	-	-	127,000	470,000
B. Average Flow (2024)	Qavg	gpd											110,400	453,000
B. Maximum Month Flow (2024)	Qmax mo	gpd		-	-	-	-		-	-	-	-	150,000	877,000
C. Estimated Average Flow (2042)	Qavg	gpd		-	-	-	-		-	-	-	-	88,500	431,500
2. LEACHATE/WASTEWATER QUALITY														
A. Conventional/Nutrients														
Biochemical Oxygen Demand	BOD5	mg/l	3.4	6.1	110	14	5.6	11	<2.0	72	46	6.7	3.1	6.2
Total Organic Carbon	TOC	mg/l	22.3	16.3	NS	14.2	7.64	38.5	22.5	NS	21.1	11.2	13.8	9.4
Total Suspended Solids	TSS	mg/l	88	42	88	8.6	6.3	70	<5.0	60	7.3	10	23.5	8.2
Ammonia as Nitrogen	NH3-N	mg/l	9.2	7.27	NS	4.5	3.5	19.7	9.85	NS	8.24	7.61	8.6	5.6
pH	s.u.	-	7.0	7.5	7.1	7.6	8.0	7.1	7.7	7.3	7.9	8.2	7.6	8.1
B. Toxic Metals														
Arsenic	As	mg/l	NS	NS	NS	NS	NS	0.031	<0.005	NS	0.005	0.01	<0.005	<0.005
Zinc	Zn	mg/l	<0.05	<0.05	NS	<0.05	<0.05	<0.05	<0.05	NS	<0.05	<0.05	<0.05	<0.05
C. Toxic Organics														
Semi-Volatile Organics	SVOCs													
Alpha Terpineol	-	μg/l	<5	<5	NS	<5	<5	<5	<5	NS	<5	<5	<5	<5
Benzoic Acid	-	μg/l	<50	<50	NS	<50	<50	<50	<50	NS	<50	<50	<50	<50
p-Cresol	-	μg/l	<5	<5	NS	<5	<5	<5	<5	NS	<5	<5	<5	<5
Phenol	-	μg/l	<5	<5	NS	<5	<5	<5	<5	NS	<5	<5	<5	<5
Total Volatile Organic Compounds	VOCs	μg/l	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	ND
D. Anions/Cations														
Barium	Ba	mg/l	0.093	0.077	NS	0.024	0.03	0.186	0.063	NS	0.042	0.039	0.07	0.035
Bromide	Br	mg/l	NS	NS	NS	NS	NS	0.222	0.151	NS	0.134	0.082	0.151	0.082
Calcium	Ca	mg/l	108	104	NS	77.8	54.5	135	111	NS	99.1	54	108	54
Magnesium	Mg	mg/l	49.2	40.6	NS	25.3	11.3	116	77.6	NS	66.7	16.4	59.1	13.9
Potassium	K	mg/l	53.4	44.2	NS	28.3	11.9	117	77.4	NS	67.1	16.3	60.8	14.1
Sodium	Na	mg/l	17.6	15.1	NS	35	54	42.1	28.9	NS	37.1	53.2	22.0	54
Strontium	St	mg/l	0.438	0.414	NS	0.356	0.295	0.848	0.639	NS	0.566	0.315	0.527	0.305
Bicarbonate	HCO3	mg/l	607	509	NS	322	183	1200	760	NS	691	240	635	212
Chloride	Cl	mg/l	18	14	110	58	93	46	28	90	46	87	21	90
Fluoride	F	mg/l	<0.2	<0.2	0.25	<0.2	<0.2	<0.2	<0.2	0.35	<0.2	<0.2	<0.2	<0.2
Nitrite/Nitrate	NO2/NO3	mg/l	0.22	0.3	<0.1	2.6	0.94	<0.1	0.27	NS	2.4	0.6	0.29	0.77
Sulfate	SO4	mg/l	19	27	10	23	14	<10	28	13	17	13	27.5	13.5
E. Other Non-Conventional Parameters														
Alkalinity as CaCO3	-	mg/l	607	509	NS	322	183	1200	760	NS	691	240	635	212
Hardness as CaCO3	-	mg/l	474	427	NS	298	183	813	597	NS	522	202	512	193
Iron	Fe	mg/l	18.4	12.8	NS	1.14	0.73	57.2	1.27	NS	1.67	1.36	7.04	1.05
Manganese	Mn	mg/l	5.31	4.68	NS	1.36	0.962	6.46	1.03	NS	1.35	0.83	2.86	0.90
Total Dissolved Solids	TDS	mg/l	710	550	280	680	340	1200	910	320	770	430	730	385
Conductivity	-	umho/cm	1300	1100	660	880	760	2200	1500	670	1400	800	1300	780
Turbidity	-	NTU												
Temperature	-	deg C												
Perchlorate	NaClO4	μg/l	NS	NS	NS	NS	NS	<0.05	<0.05	NS	0.055	0.124	<0.05	<0.05
Total Phosphorus	TP	mg/l	NS	NS	NS	NS	NS	0.098	0.027	NS	0.514	0.543	0.027	0.027
Surfactants	MBAS	mg/l	NS	NS	NS	NS	NS	0.26	0.07	NS	0.08	0.11	0.07	0.07
F. Per- and Polyfluoralkyl Substances														
a. Six State of Maine Regulated PFAS (2)														
Perfluorooctanesulfonic	PFOS	ng/l	129	119	3.69	68.8	31.5	912	52.6	2.61	34.6	30.2	85.8	30.9
Perfluorooctanic Acid	PFOA	ng/l	114	122	<1.97	69.8	34.4	562	90.4	<1.89	63.2	24.6	106	29.5
Perfluoroheptanoic Acid	PFHpA	ng/l	43	44.7	<1.97	29.6	13.4	89	41.5	<1.89	32.4	11.2	43.1	12.3
Perfluorononanoic Acid	PFNA	ng/l	22.2	23	<1.97	12.1	6.42	190	16	<1.89	10	4.9	19.5	5.66
Perfluorohexanesulfonic	PFHxS	ng/l	16.7	5.83	<1.97	4.77	<2.04	12.2	2.5	<1.89	2.12	<1.88	4.17	ND
Perfluorodecanoic Acid	PFDA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	31	<1.86	<1.89	<1.91	<1.88	ND	ND
Sum of Six Regulated Compounds (2)	Sum of Six	ng/l	325	315	3.69	185	85.7	1796	203	2.61	142	70.9	259	78.3

TABLE 7-2 (cont'd)

DOLBY LEACHATE AND EMWWTP INFLUENT/EFFLUENT DESIGN SUMMARY[1]

Parameter/Pollutant	Acronym	Units	Dolby CB-3 May-22	Dolby Leachate Pond Eff. May-22	Town of East Millinocket May-22	EMWWTP Influent May-22	EMWWTP Effluent May-22	Dolby CB-3 Jun-22	Dolby Leachate Pond Eff. Jun-22	Town of East Millinocket Jun-22	EMWWTP Influent Jun-22	EMWWTP Effluent Jun-22	Dolby Leachate Pond Eff. Average	EMWWTP Effluent Average
b. Other Unregulated PFAS														
Perfluorobutanesulfonic Acid	PFBS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorobutanoic Acid	PFBA	ng/l	28.2	26.2	2.74	17.3	7.78	39.4	27.8	2.67	26	6.86	27	7.32
Perfluorodecanesulfonic Acid	PFDS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorododeanoic Acid	PFDoA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoroheptanesulfonic Acid	PFHpS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	6.4	<1.86	<1.89	<1.91	<3.76	ND	ND
Perfluorohexadecanoic Acid	PFHxDA	ng/l	<4.05	<4.04	<3.95	<3.91	<4.06	<3.91	<3.71	<3.76	<3.82	<1.88	ND	ND
Perfluorohexanoic Acid	PFHxA	ng/l	43.3	41.9	2.04	29	15.3	58	42.5	2.12	36.4	15.8	42.2	15.6
Perfluoronanesulfonic Acid	PFNS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorooctadecanoic Acid	PFODA	ng/l	<4.05	<4.04	<3.95	<3.91	<4.08	<3.91	<3.71	<3.78	<3.8	<3.76	ND	ND
Perfluorooctanesulfonamide	PFOSA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	2.56	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoropentanesulfonic Acid	PFPeS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoropentanoic Acid	PFPeA	ng/l	34.6	35.3	<1.97	23.9	12.3	43	38.3	<1.89	32.3	11.3	36.8	11.8
Perfluorotetradecanoic Acid	PFTA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluorotridecanoic Acid	PFTrDA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
Perfluoroundecanoic Acid	PFUnA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	4.18	<1.86	<1.89	<1.91	<1.88	ND	ND
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	17.9	<1.86	<1.89	<1.91	<1.88	ND	ND
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	ng/l	<2.02	<2.02	3.34	<1.95	<2.04	10.8	<1.86	<1.89	<1.91	<1.88	ND	ND
2,3,3,3-Tetrafluoro-2-[1,1,2,2,3,3,3-Heptafluoropropoxy]-Propanoic Acid	HFPO-DA	ng/l	<50.6	<50.5	<49.4	<48.8	<51.1	<48.9	<46.4	<47.2	<47.7	<46.9	ND	ND
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	<1.96	<1.86	<1.89	<1.91	<1.88	ND	ND
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	ng/l	<2.02	<2.02	<1.97	<1.95	<2.04	4.9	<1.86	<1.89	<1.91	<1.88	ND	ND
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	ng/l	3.18	3.06	<1.97	<1.95	<2.04	39.8	<1.86	<1.89	<1.91	<1.88	ND	ND
Sum of All PFAS Compounds (3)	Total PFAS	ng/l	434	421	11.81	255	121	2023	312	7.4	237	105	366	113

Notes:

[1] Database includes two round of sampling in May and June 2022 by SME.

[2] PFAS State of Maine IDWS for drinking water for six PFAS analytes established June 21, 2021 at 20 ng/l.

[2] Values less than analytical detection limit assumed as zero in calculating average concentration

FLOW SCHEMATIC FOR PFAS TREATMENT
USING FOAM FRACTIONATION
AT DOLBY LANDFILL AND DISCHARGE TO EMWWTP

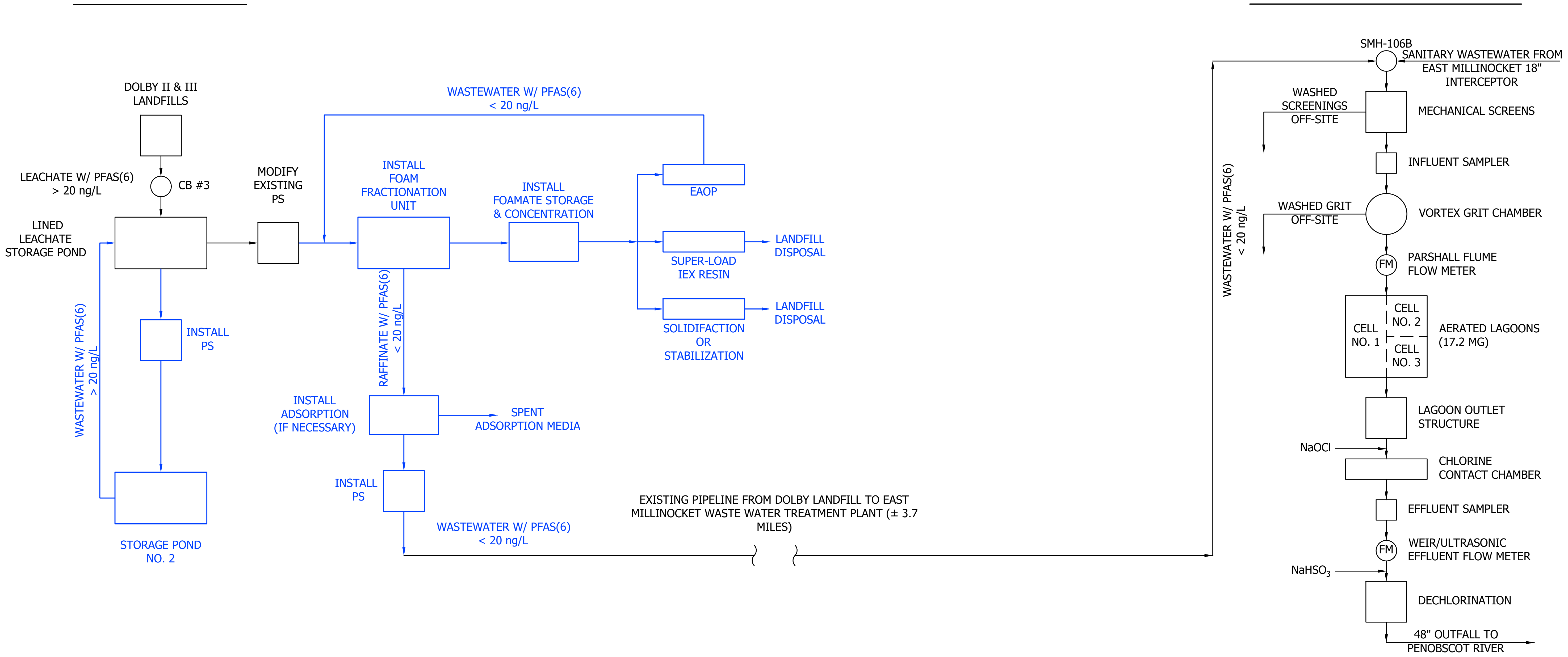


FIGURE 7-1
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-1, 12/19/2022 3:03:26 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT USING ELECTROCHEMICAL ADVANCED OXIDATION PROCESS AT DOLBY LANDFILL AND DISCHARGE TO EMWWTP

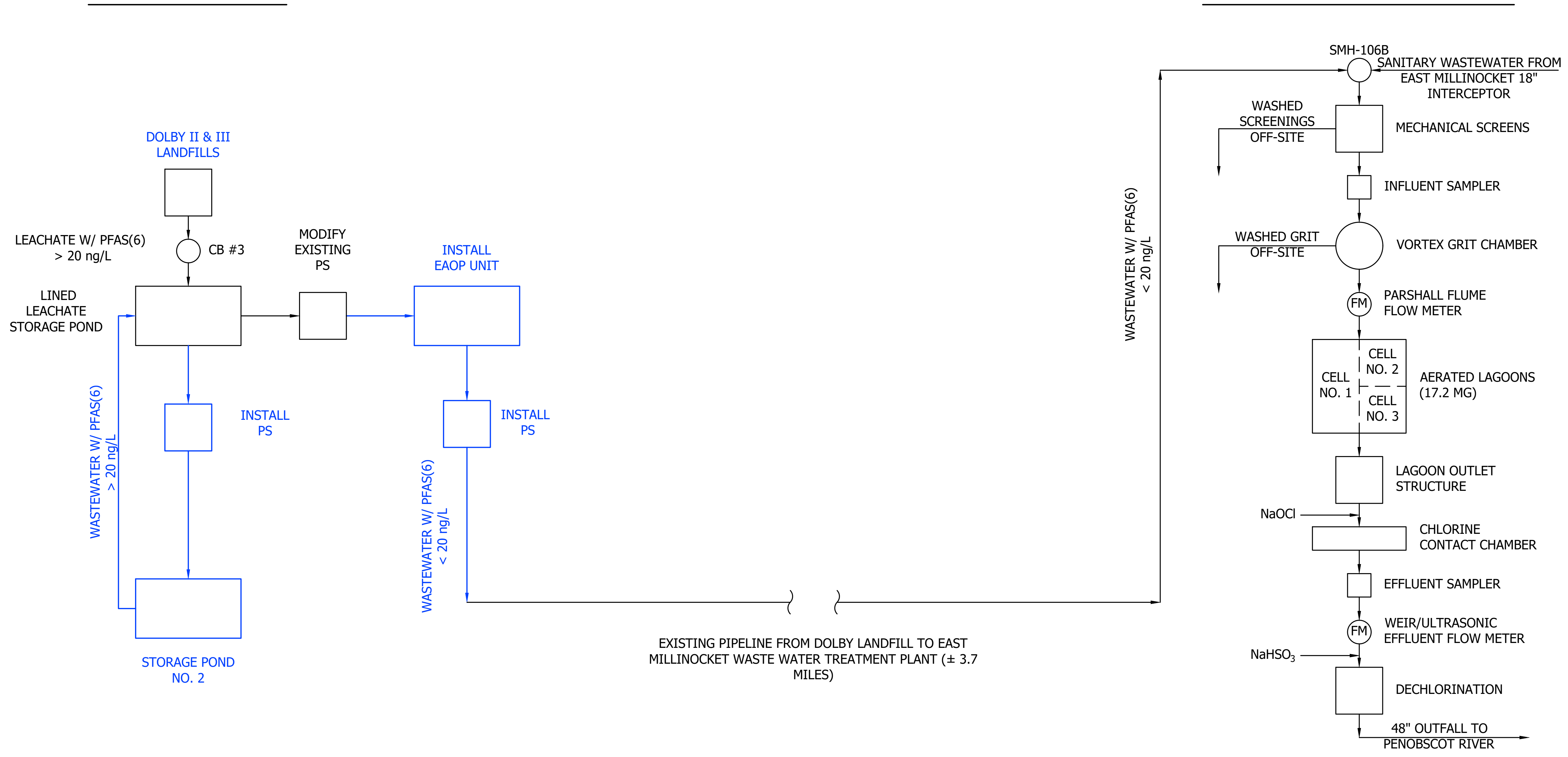


FIGURE 7-2
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-2, 12/19/2022 3:03:26 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT USING REVERSE OSMOSIS PROCESS AT DOLBY LANDFILL AND DISCHARGE TO EMWWTP

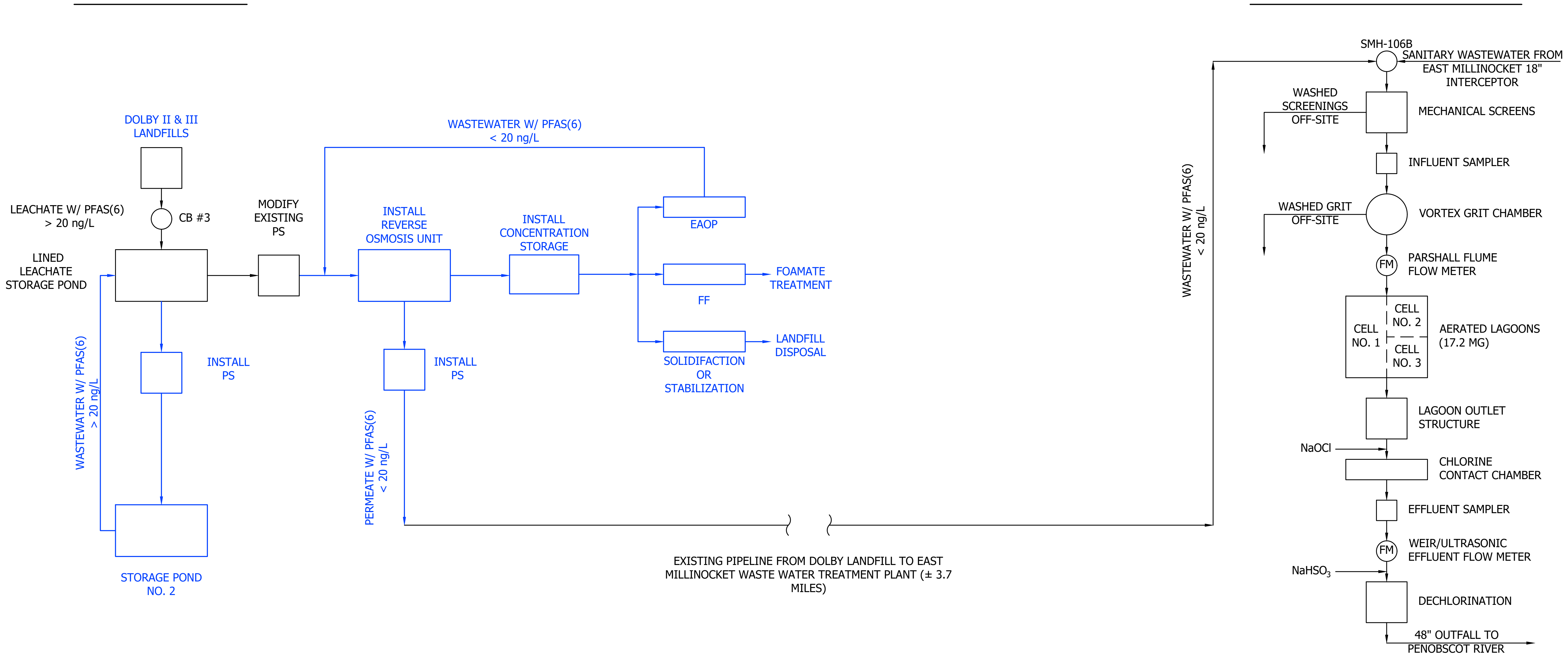

FIGURE 7-3
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

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\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-3, 12/19/2022 3:03:27 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT USING GRANULAR ACTIVATED CARBON/ION EXCHANGE AT EMWWTP

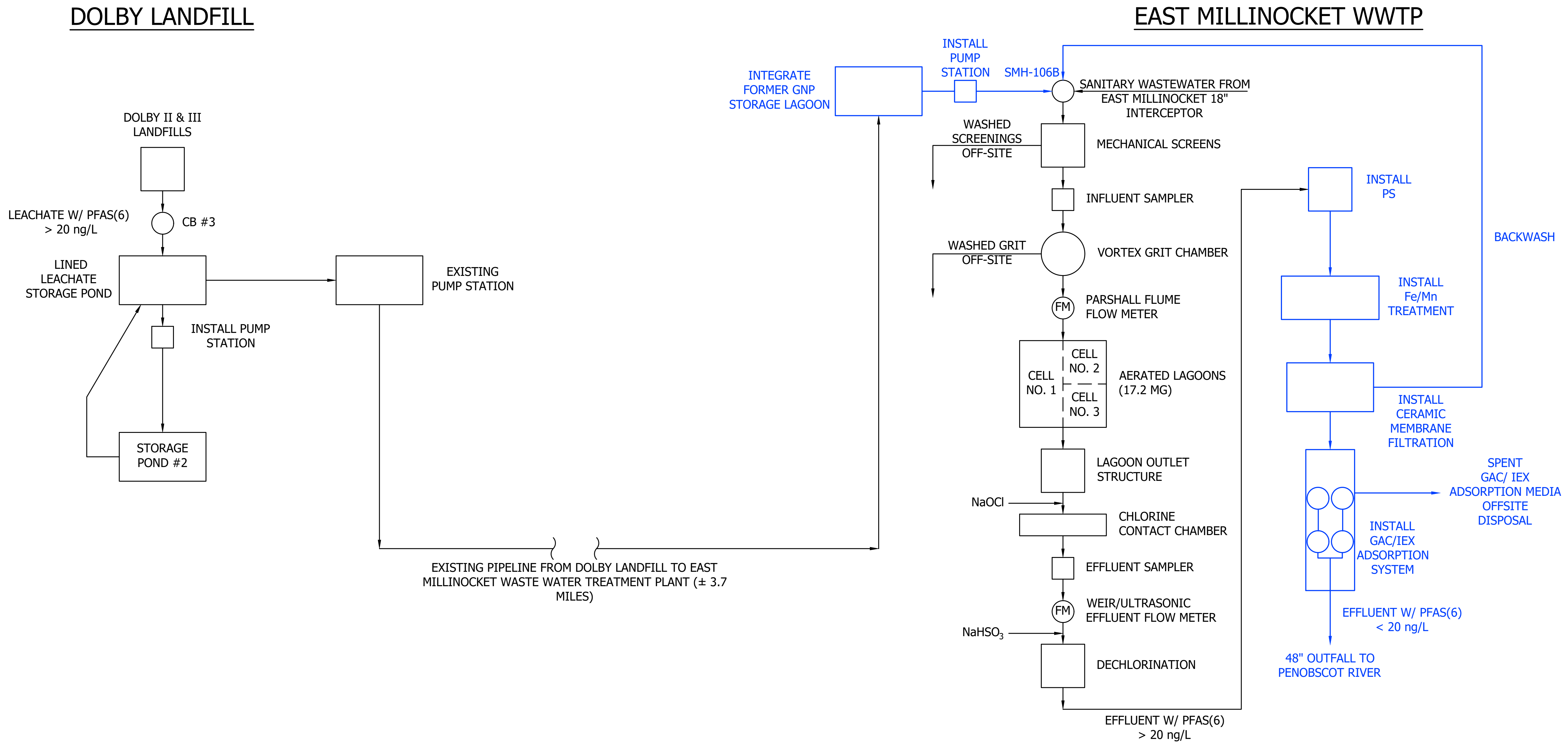

FIGURE 7-4
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-4, 1/11/2023 3:23:09 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT
USING FOAM FRACTIONATION AT JRL AND DISCHARGE TO NDWWTP

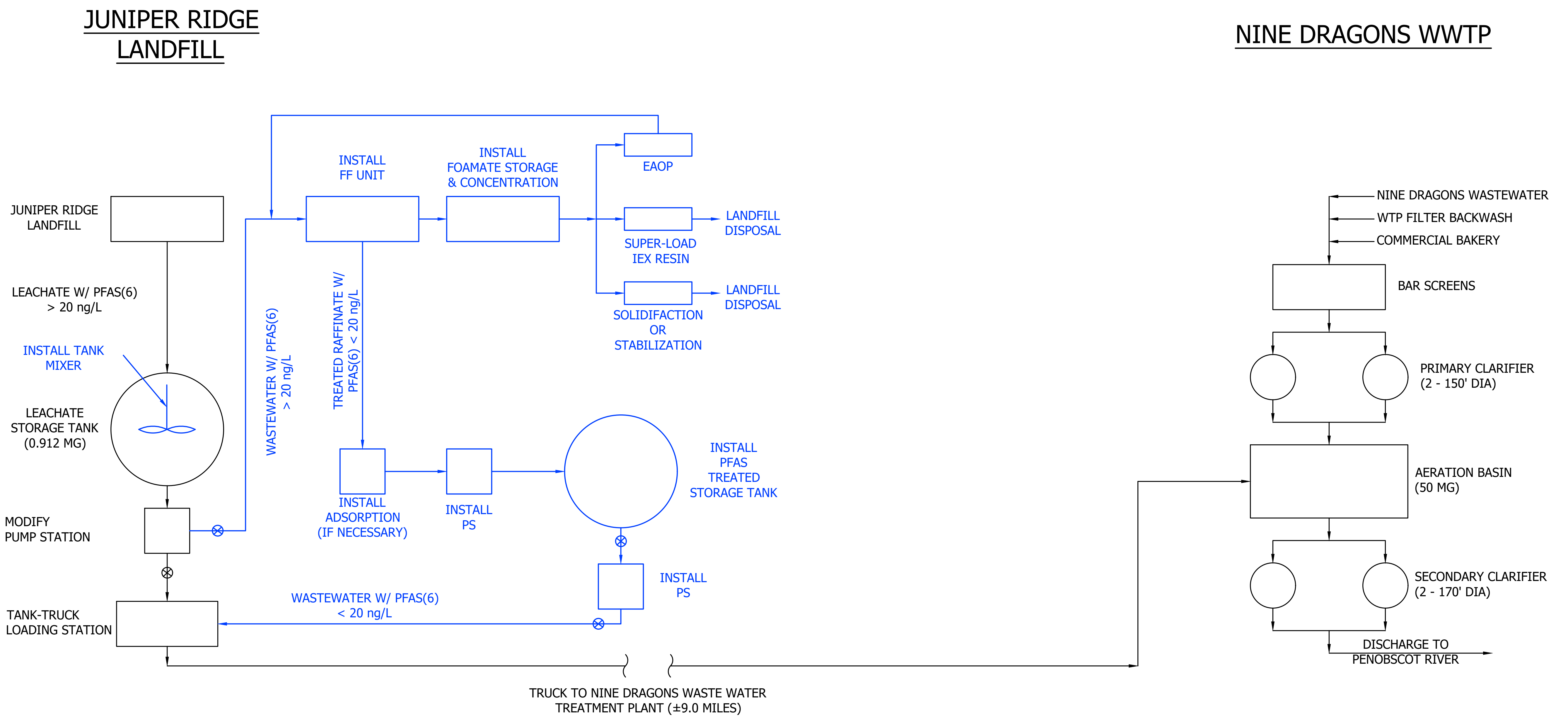

FIGURE 7-5
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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ENGINEERS

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\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-5, 12/19/2022 3:03:28 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT USING ELECTROCHEMICAL ADVANCED OXIDATION PROCESS AT JRL AND DISCHARGE TO NDWWTP

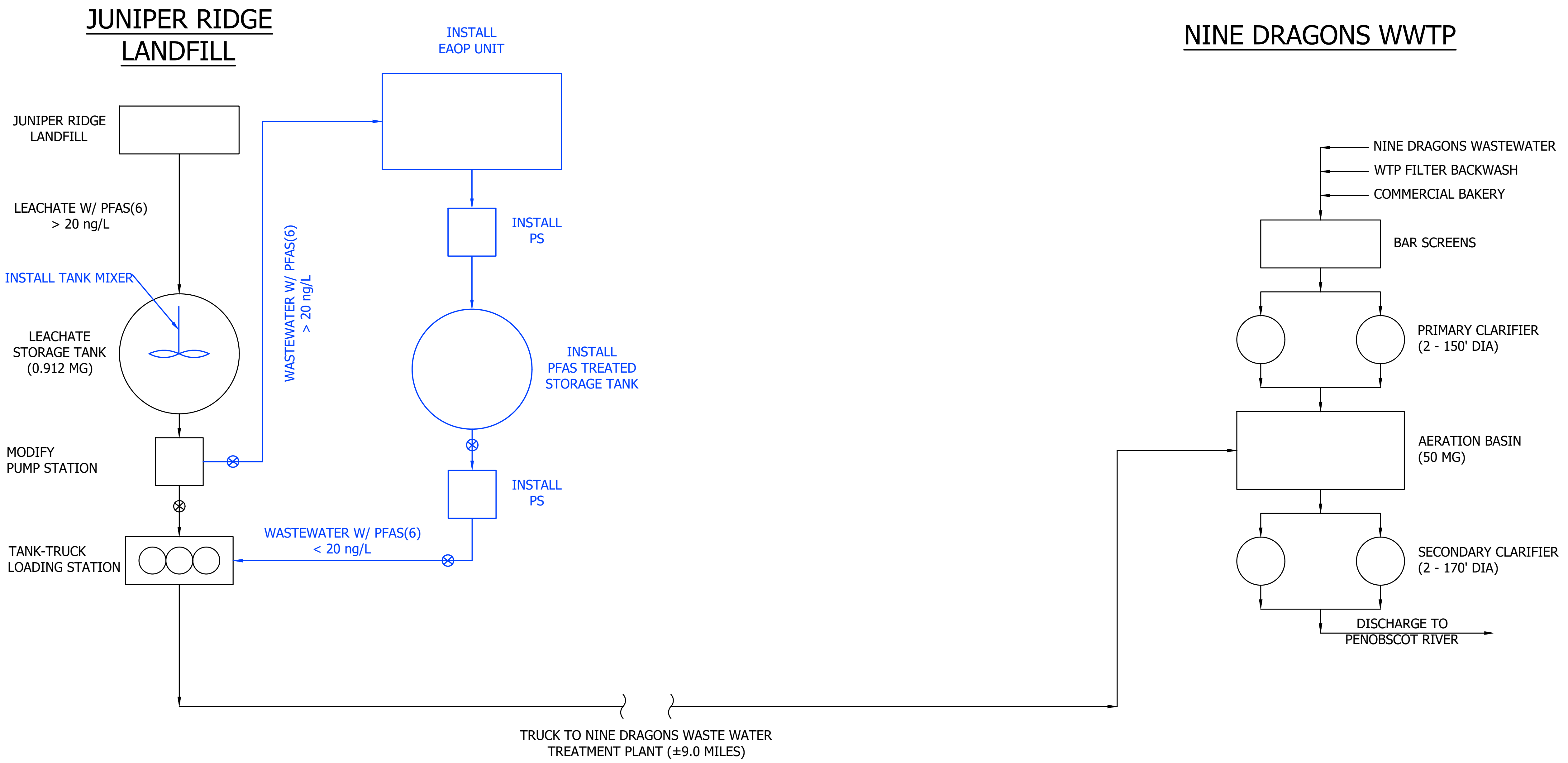

FIGURE 7-6
STUDY FOR TREATABILITY OF PFAS IN
LEACHATE FROM STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

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DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-6, 12/19/2022 3:03:28 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT USING REVERSE OSMOSIS PROCESS AT JRL AND DISCHARGE TO NDWWTP

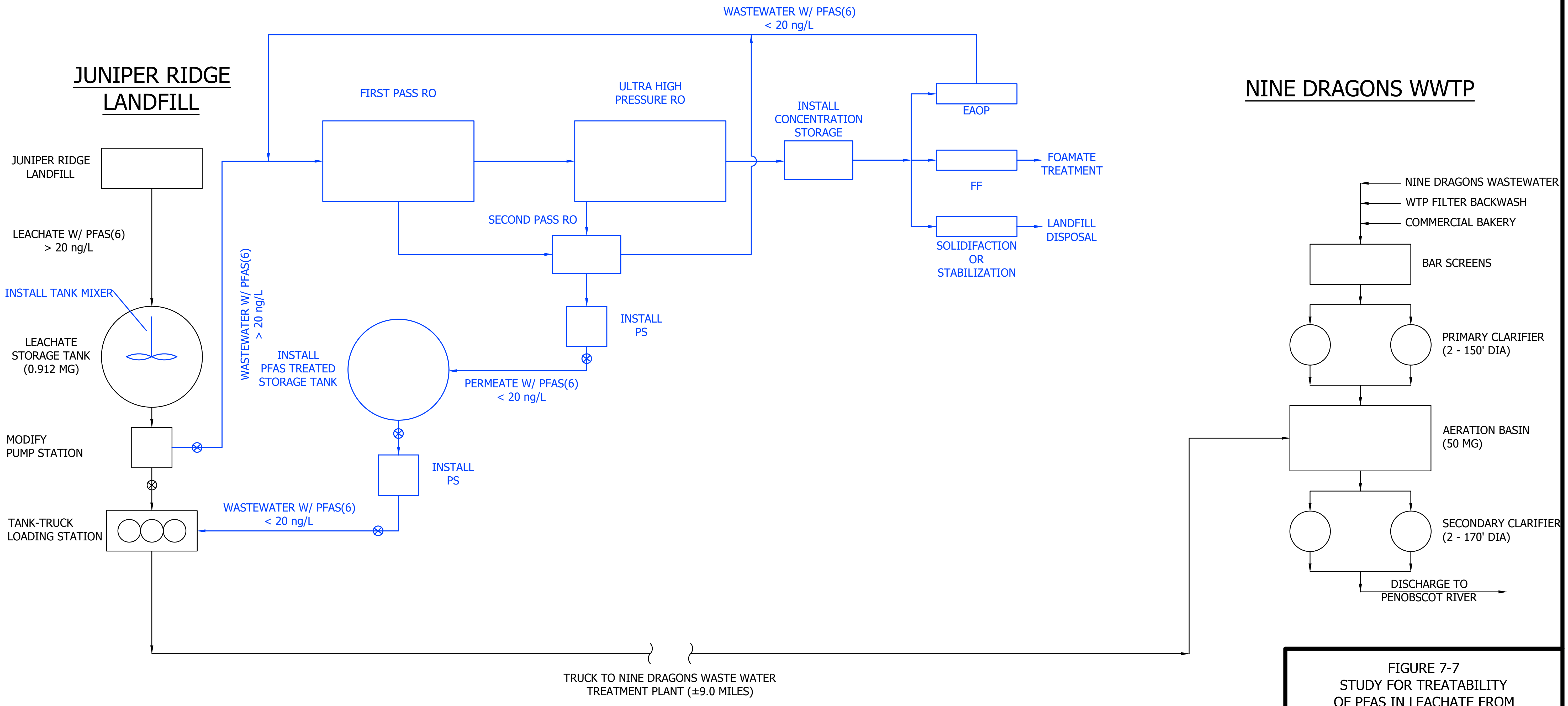

FIGURE 7-7
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-7, 12/19/2022 3:03:28 PM, jrl

FLOW SCHEMATIC FOR ON-SITE BIOLOGICAL TREATMENT W/ PFAS POLISHING AT JUNIPER RIDGE LANDFILL

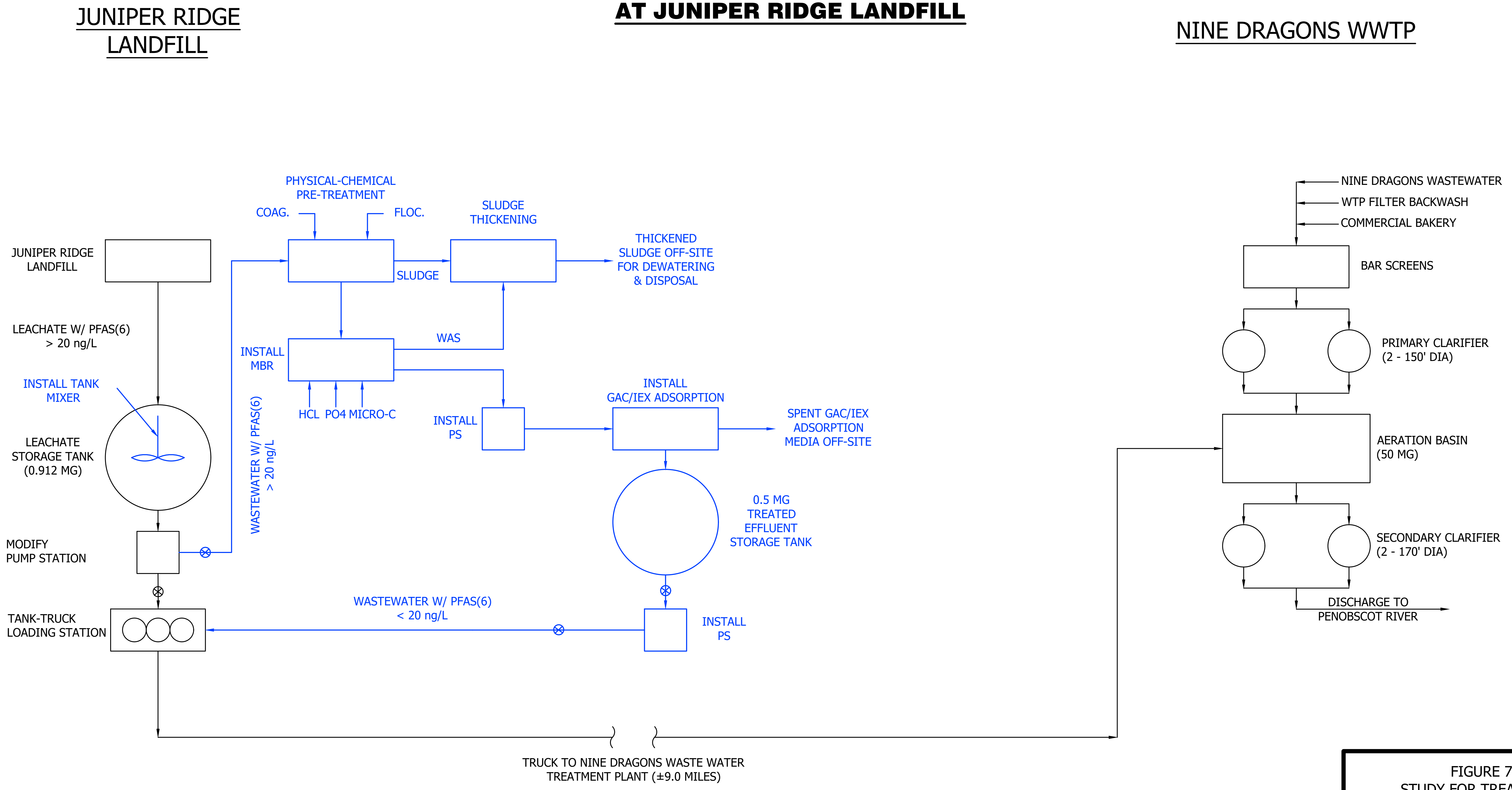

FIGURE 7-8
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 1/11/2023

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-8, 1/11/2023 3:22:54 PM, jrl

FLOW SCHEMATIC FOR PFAS TREATMENT USING FOAM FRACTIONATION AT DOLBY LANDFILL AND JRL W/ FOAMATE TREATMENT AT JRL

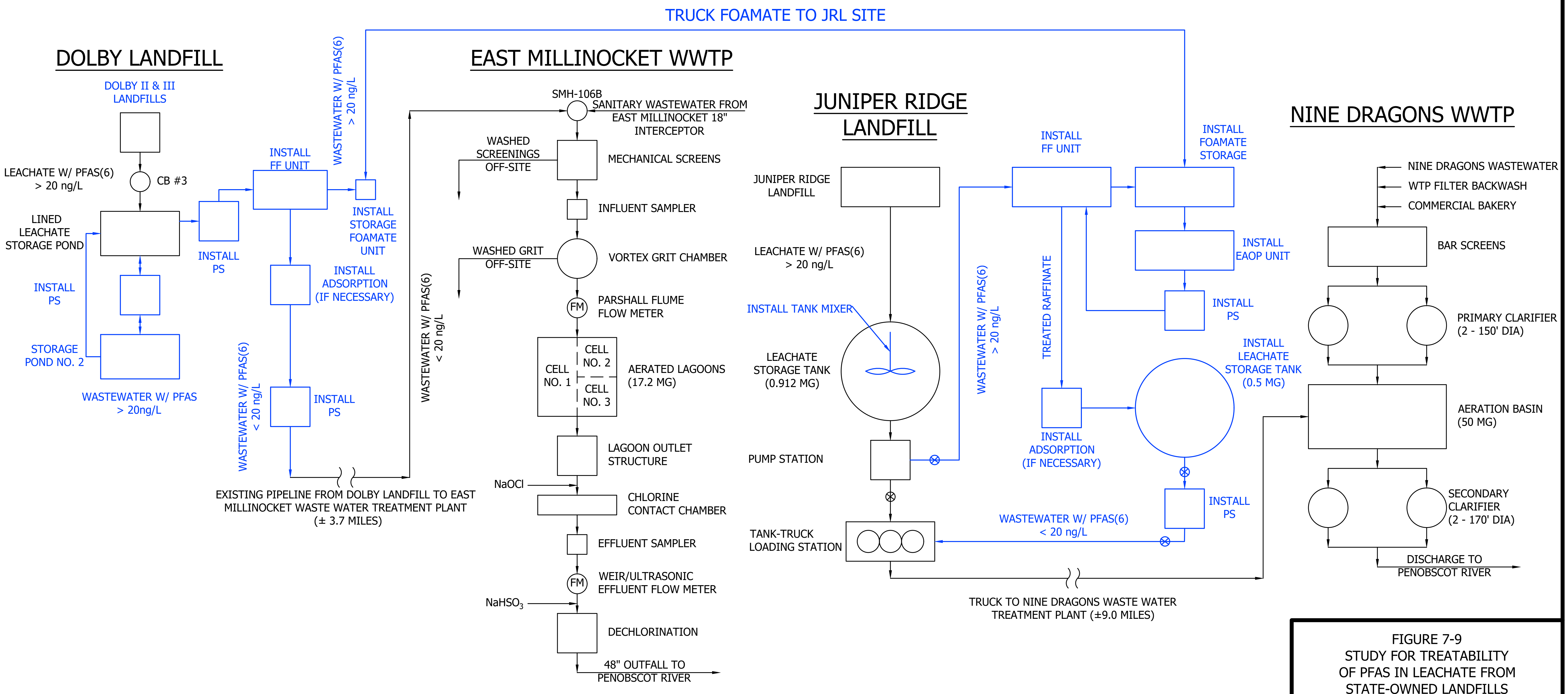

FIGURE 7-9
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
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DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-9, 12/19/2022 3:03:29 PM, jrl

FLOW SCHEMATIC FOR DOLBY AND JRL COMBINED PFAS TREATMENT USING GRANULAR ACTIVATED CARBON/ION EXCHANGE AT EMWWTP

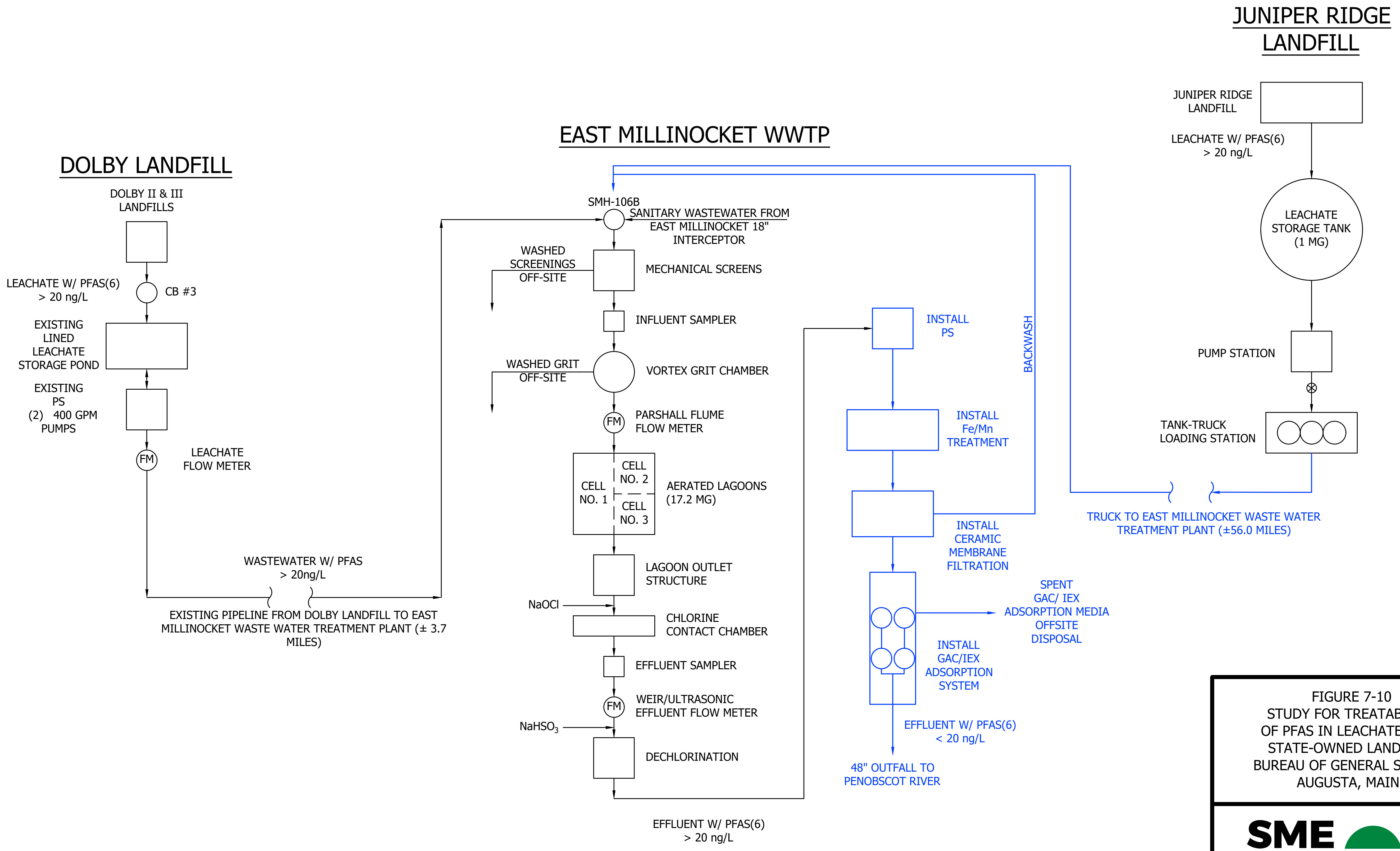

FIGURE 7-10
STUDY FOR TREATABILITY
OF PFAS IN LEACHATE FROM
STATE-OWNED LANDFILLS
BUREAU OF GENERAL SERVICES
AUGUSTA, MAINE

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 12/19/2022

\\NSERVER\cfs\Crawford Engineering\BGS PFAS Study\ACAD\SCHEMATICS.dwg, FIGURE 7-10, 12/19/2022 3:03:30 PM, jrl

8.0 LEACHATE TREATMENT EVALUATION

This section discusses the alternatives that are considered most likely to be viable for treating the Dolby and JRL leachates. This section also discusses leachate volume management at both the Dolby and JRL landfill sites and identifies methods to control and/or reduce leachate flows from Dolby and JRL that in turn affect the cost of PFAS treatment. Many of the PFAS treatment alternatives discussed in this section utilize PFAS removal using granular activated carbon (GAC), ion exchange (IEX) resin, or other proprietary media such as Fluoro-sorb 200 adsorbent. For purposes of this section and for brevity, these media are collectively referred to as adsorption media, unless a specific media is discussed.

8.1 Cover Optimization and Leachate Volume Reduction

Regardless of the leachate treatment alternatives discussed in this section, installation of geomembrane covers at both landfills should be implemented as soon as practical to reduce the volume of leachate generated and the associated cost of PFAS treatment. The Dolby III Landfill is in the process of undergoing a geomembrane cover upgrade that is expected to be complete in approximately 2025 and the inactive waste filling areas at JRL are covered with intermediate geomembrane to minimize leachate generation. The Dolby II Landfill (approximately 63 acres) has received a final soil cover and there are no current plans for a geomembrane cover upgrade for that landfill. The Dolby III Landfill (approximately 65 acres) has been closed with a soil final cover and is in the process of having the soil cover upgraded to a geomembrane cover. Geomembrane covers are essentially impervious to infiltration of precipitation that ultimately is converted to leachate. The geomembrane upgrade (in progress) for Dolby III is expected to reduce the annual quantity of leachate only moderately, for reasons presented in Section 3.1 of this report. In summary, once the Dolby III cover has been fully upgraded, the average leachate flow into the Dolby leachate storage pond is expected to be on the order of 88,500 gpd and will consist of leachate from Dolby III (mostly groundwater) and leachate from Dolby II (which is mostly precipitation infiltration). Significant Dolby leachate reductions can best be achieved by upgrading the Dolby II cover to a geomembrane.

As mentioned earlier in this Report, the daily leachate flows at Dolby are highly variable and can increase by 100 to 800 percent above the average leachate flow in the springtime. PFAS treatment of the high springtime flows on a real-time basis is considered impractical in that the number of on-site treatment units would need to be increased substantially. For purposes of the Study, a portion of the high springtime flows will be stored in a second leachate pond that would be constructed at the Dolby site or at the former GNP pond adjacent to the EMWWTP if PFAS treatment at the EMWWTP is implemented. The former GNP pond could provide about 8.1 MG of storage. Determination of the second pond volume will be driven by the projected springtime leachate inflows and the treatment capacity of the PFAS treatment units selected. PFAS treatment technologies were evaluated using multiple treatment units operating essentially full-time with the excess leachate temporarily stored in the second leachate pond until leachate flows decrease to the point at which the temporarily stored leachate can be treated for PFAS. Because PFAS treatment technologies are relatively new, there has been little, if any, consideration to constructing large-scale treatment units for leachate. As time progresses, it is likely that large-scale PFAS treatment units will become available to treat flows like that from Dolby; until that time, reduction of leachate volume generated is likely to be the most efficient way to control leachate treatment costs.

At JRL, the current permitted area for the existing landfill is about 100 acres. The last cell for the permitted area is expected to be constructed in 2027 and filled before 2030. JRL is operated as a series of adjacent and contiguous waste cells; once a cell has been filled, an interim geomembrane cover is placed over the portions of the cell that will become inactive until adjacent cell(s) are completed. In this way, the JRL operation minimizes the volume of precipitation infiltrating the waste and the amount of leachate generated. The final geomembrane cover will be placed over JRL in phases starting in 2023 and is expected to continue until approximately 2030 if the proposed 20-acre expansion is not accepted by MEDEP. If the 20-acre expansion (mentioned in Section 3.0) is approved and implemented, the final covering will likely extend to 2042, when the overall landfill capacity is expected to be reached. By the end of 2043, with the final and intermediate geomembrane covers in place, the leachate volume generated by the waste is projected to decline to less than 10,000 gpd as indicated in Table 3-2.

Cover optimization, upgrade, and/or cover scheduling is not included within the scope of the subject Study for either Dolby or JRL and, likewise, the associated cost for cover construction is not included in the capital cost projections for treating leachate containing PFAS.

8.2 Site Improvements

With the exception of off-site disposal for the raw leachate from Dolby and/or JRL at a regional PFAS treatment facility, all of the other alternatives developed for treatment of leachate containing PFAS include a series of site improvements that must be implemented to integrate the respective PFAS treatment systems. Site improvements include modifying existing pump stations, constructing new pump stations, installing leachate pipelines, providing additional leachate flow equalization capacity at Dolby or utilization of the former GNP lagoon adjacent to the EMWWTP, site foundations, trailer pads and containment, new electrical service(s), extending process water lines, and providing an office space. Some of the treatment alternatives include annual lease and operation contracts that are categorized as annual O&M costs, while other elements of the respective alternatives include purchase of equipment that is categorized as capital expenditures. Depending on the PFAS treatment alternative, the estimated capital cost for site improvements is projected to range between $7.6 and $8.5 million for Dolby, and $2.6 to $3.5 million for JRL. By comparison, capital costs for site improvements at water treatment plants are typically lower because the influent is usually near drinking water quality at the outset.

The site improvements for locating wastewater treatment facilities at a landfill are significant, necessary, and costly, but do not provide any actual PFAS reduction.

8.3 Off-Site Disposal of Leachate at a Regional PFAS Treatment Facility

This alternative was developed understanding that federal funding has been received by the State of Maine to support installation of a PFAS treatment system at an existing wastewater treatment facility for regional use. This alternative would result in roughly 20 to 25 tank-truck loads per day of leachate being hauled from Dolby for about 125 miles 200 days per year; and about 15 to 18 tank-truck loads of leachate being hauled from JRL for about 80 miles 200 days per year. The leachate hauling cost alone is estimated to run about $8.4 million/year for Dolby, and $3.96 million/year for JRL (in 2022 dollars), excluding any tipping fee for the leachate treatment.

Based on the significant volume of leachate, the cost for hauling, and because a regional PFAS treatment facility may be years away from becoming reality, off-site disposal of leachate at a regional PFAS treatment facility is eliminated from further consideration for the Study. Although this alternative is clearly not feasible at this time, there are two caveats. First, the volume of leachate from JRL is projected to decrease from about 69,300 gpd in 2024 to less than 10,000 gpd in 2043; if a regional PFAS treatment facility is located in Maine, at some point in time, it may be viable to truck the JRL leachate to the facility rather than treating it for PFAS on-site. Second, if a regional PFAS treatment facility does come to fruition, trucking side stream wastes containing PFAS from Dolby and JRL could be a feasible means of treatment and disposal.

8.4 FF of Leachate and Indirect Discharge

Foam fractionation is a “bulk upfront” pretreatment process that provides the ability to remove PFAS from leachate using an aqueous bubbling system that results in an effluent (raffinate) containing less than 20 ng/l of PFAS(6) and a PFAS-concentrated liquid (foamate). The raffinate requires follow-up biological treatment for conventional pollutants and the foamate can be disposed or destroyed. The typical FF unit for the Study consists of an 8-feet-wide by 40-feet-long metal Conex-type box that contains three FF reactors in series. Each FF treatment unit is fully integrated with I&C, including flow meters, pH meter, thermometer, ORP meter, level controls, and a Wi-Fi connection to allow remote monitoring and alarms.

Two leachate treatment alternatives using FF for PFAS removal were evaluated for the Study: one to reduce the PFAS contaminant concentrations at Dolby, and the second for PFAS reduction at JRL. Both alternatives are discussed below. Each FF treatment unit is expected to have a capacity of about 60 gpm.

8.4.1 FF of Dolby Leachate, Foamate Concentration, and Side Stream Treatment

This alternative focuses on the upfront transfer of PFAS from the Dolby leachate to a smaller foamate side stream using FF technology with discharge of the treated effluent (raffinate) sent to the EMWWTP for biological treatment, disinfection, and discharge to the river. The generated foamate is further concentrated in volume and is then treated via media super-loading, EAOP, stabilization or solidification, or off-site disposal, as discussed in Section 8.9. The primary advantage of this alternative is that the FF incorporates a simple process for removing PFAS from the leachate that does not require extensive pretreatment to remove other pollutants. Further, the other pollutants such as BOD5, ammonia, and cations/anions are not oxidized or treated by FF, helping with process efficiency.

Hydraulically, the Dolby leachate flow during the springtime can increase up to 864,000 gpd (600 gpm). Section 7.0 outlines the concept to provide additional leachate storage at Dolby beyond the existing 2 MG of working storage capacity in the existing leachate storage pond that is needed to reduce the maximum flow to a more manageable 150,000 gpd.

Two FF vendors were provided the leachate flows and analytical results presented in Table 7-1. Both vendors approached implementation of FF in a similar fashion. Both would mobilize two FF units with pre-filters and three FF reactors in each unit due to the high maximum flow encountered in the high-volume spring months. Foamate concentration and treatment would be completed in a separate treatment unit. The approach for dealing with the foamate side stream differs, with one vendor focusing on concentrating the foamate and then loading the foamate onto a proprietary IEX media; the second vendor focusing on foamate concentration and encapsulation into solid blocks using a pozzolanic stabilization process (i.e., Portland cement and/or proprietary admixtures) to solidify the PFAS, making it non-leachable. FF side stream management is further discussed in Section 8.9.

The FF reactors are operated in series, providing for continuous flow treatment. Depending on the leachate characteristics, the FF process may be set-up to have one or two passes through the fractionators, there may be recycling and the foamate removal and processing may include separate passes to further concentrate the PFAS. Each reactor is equipped with recirculation pumps and air injectors, and dosing equipment is provided to dose surfactant at various locations along the reactor series to improve foaming characteristics. Raffinate is typically removed from the first reactor series and transferred to a second reactor where it is subject to additional foam fractionation. The FF is continued until raffinate meeting the 20 ng/l goal is achieved, at which time the raffinate is diverted to EMWWTP for biological treatment. An IEX adsorption unit is included with the FF unit in the event FF alone is not capable of attaining the 20 ng/l goal. The concentrated foamate is diverted to storage tanks for further treatment or disposal. The series of three reactors produce a concentrated foamate volume of approximately 3 to 5 percent of the original influent volume. For further volume reduction, a concentrator unit is provided to reduce the volume to approximately 0.3 to 0.5 percent. Assuming the foamate is concentrated to about 0.5 percent by volume of the influent flow and that the PFAS(6) are removed to the 20 ng/l goal, the concentrated foamate would represent 550 gpd with a PFAS(6) concentration of between 400 and 900 μg/l (400,000 and 900,000 ng/l).

The capital and O&M costs for treating the Dolby leachate by FF are summarized in Table E-1 of Appendix E. For FF, there are associated site development and mobilization costs that are categorized as capital expenditures (CAPEX), and annual lease, operation, and other annual O&M costs that are annual operations expenditures (OPEX). The projected CAPEX cost in year one is estimated at $7.66 million, while the annual OPEX cost is estimated at about $1.88 to $3.31 million each year for five years (the range presented includes annual cost if FF is capable of reducing PFAS(6) to below 20 ng/l by itself or if IEX adsorption is required to attain the 20 ng/l). The estimated 5-year present worth cost for FF at Dolby is calculated as $15.8 to $22.0 million. Note that the present worth cost is dominated by the site improvements, in particular the cost of off-line leachate storage. The calculated present worth cost of leachate treated is roughly $89,100 to $124,100 per MG. The cost for PFAS removal (i.e., FF, foamate concentration, and/or further treatment) at Dolby is the least expensive treatment option evaluated. The ancillary support and site improvement costs to implement the FF alternative at Dolby are not inconsequential. Aside from the cost of this alternative, there are other noteworthy observations.

- FF has been demonstrated to successfully reduce PFAS concentrations in bench-scale and pilot studies of leachate and AFFF-contaminated waters. Further, the leachate from Dolby was successfully treated to near or less than the PFAS(6) concentration of 20 ng/l in a separate bench-scale laboratory study.
- The EMWWTP continues to provide biological treatment of the Dolby leachate for conventional parameters such as BOD5, TSS, and ammonia, as well as disinfection before discharge to the river.
- The only FF side stream requiring further management and disposal is the foamate (i.e., there are no adsorption media or solids requiring disposal).

8.4.2 FF of JRL Leachate, Foamate Concentration and Side Stream Treatment

This alternative is similar to the FF analysis described for Dolby. There are a couple of nuances relative to applying FF at JRL as compared to Dolby. The first difference is the daily peaking factor for leachate flow at JRL is 165 percent, which can be handled by the existing, on-site 0.912-MG leachate storage tank and therefore there is no additional need for raw leachate storage at JRL as compared to Dolby. However, the treated raffinate from the FF process at JRL requires a separate tank to provide raffinate storage for efficient trucking of the raffinate to the NDWWTP. Similar to Dolby, the generated foamate side stream at JRL is further concentrated in volume and then treated via media loading, EAOP, stabilization, or disposed off-site as discussed further in Section 8.9. A second difference between Dolby and JRL, is JRL only requires one FF unit rather than the two units necessary to handle the larger Dolby leachate flows.

The same advantages of this technology at Dolby also apply at JRL. The FF reactors are operated in series and equipped similar to those for Dolby. An IEX column in a lead/lag configuration is included similar to Dolby in the event FF alone is not capable of attaining the 20 ng/l goal. The concentrated foamate at JRL is diverted to a storage tank, and a concentrator unit is provided to reduce the volume to approximately 0.3 to 0.5 percent of the influent leachate volume. Assuming the foamate is concentrated to about 0.5 percent by volume of the influent flow, the concentrated foamate would represent 350 gpd with a sum of six PFAS concentration of between 400 and 600 μg/l (400,000 to 600,000 ng/l).

The capital and O&M costs for treatment of the JRL leachate are summarized in Table F-1 of Appendix F. Although the ancillary support and site improvements to implement this alternative are less than at Dolby, these CAPEX are not insignificant. The CAPEX cost is estimated at about \$2.6 million and the annual OPEX cost is \$1.05 to \$1.8 million. The estimated 5-year present worth cost is between $7.17 to $10.4 million (again a range is presented to recognize the potential need for IEX polishing of the raffinate). The calculated present worth cost is calculated as $72,200 to $105,000 per MG of leachate treated at JRL. The unit cost per MG treated at JRL is significantly less than for Dolby due to the needed site improvements at JRL in comparison to Dolby. Aside from the cost of this alternative, there are a few other observations to note.

- FF has been demonstrated to successfully reduce PFAS concentrations in bench-scale and pilot studies using landfill leachate and AFFF-contaminated waters. Further, the leachate from JRL was successfully treated to near or less than the PFAS(6) concentration of 20 ng/l by two independent vendors.
- The NDWWTP would continue to provide biological treatment of the JRL leachate for conventional parameters such as BOD5, TSS, and ammonia, before discharge to the river.
- The only FF side stream requiring further management and disposal is the foamate (i.e., there is no adsorbent media or biosolids requiring disposal); that is further discussed in Section 8.9.

8.5 EAOP Leachate Treatment

Two leachate treatment alternatives using EAOP for PFAS removal were evaluated for the Study: one to reduce the PFAS contaminant concentrations in the Dolby leachate, and the other for PFAS reduction in the JRL leachate. Both alternatives would be implemented at the respective landfill sites with the resulting treated effluent from Dolby going to the EMWWTP for biological treatment and the JRL treated effluent going to the NDWWTP for biological treatment. The Electrochemical Advanced Oxidation Process (EAOP) destroys organic pollutants within wastewater using production of in process oxidants without the use of chemical additives.

8.5.1 EAOP of Dolby Leachate and Indirect Discharge to EMWWTP

This alternative focuses on the destruction of PFAS in the Dolby leachate by way of EAOP technology with discharge of the treated effluent piped to the EMWWTP. A significant potential upside to this technology is there are no side stream wastes generated that require management or disposal. Another advantage of the technology is that EAOP oxidizes the ammonia and organic materials in the leachate and, thus, the need for subsequent treatment for conventional pollutants at the EMWWTP is reduced. The same concept described for managing peak springtime leachate flows at Dolby as described for FF also apply to implementing EAOP.

In sizing the EAOP process for Dolby, the PFAS results summarized in Table 7-1 were used as the basis for conceptual design. The Dolby leachate samples collected on June 15 and June 29, 2022, had higher PFAS concentrations in comparison to the two other leachate samples collected during high-groundwater conditions (and, thus, the leachate samples were more dilute). In particular, the PFAS(6) concentration from the June 29 sampling was the highest concentration and was used for determining the number of electrodes (i.e., anodes and cathodes) and the associated high energy (i.e., electricity) demand. A total of 16 mobile EAOP units are needed to treat the typical equalized daily peak leachate flows from Dolby.

The capital and O&M costs for treating the Dolby leachate using EAOP are summarized in Table E-2 of Appendix E. The CAPEX cost is estimated at about $7.62 million and the annual OPEX cost is $5.3 million. The estimated 5-year present worth cost is about $30.6 million. The calculated present worth cost per MG of leachate treated is projected at about $172,750. The cost for active PFAS removal from leachate via EAOP is projected higher than FF, although EAOP is a destruction technology that has the advantage of no PFAS-concentrated side streams that require additional management. Aside from the cost of this alternative, other observations of note are:

- Recently, several EAOP equipment suppliers have reported promising reductions of PFAS in leachate and its ability to destroy PFAS using lower energy demands than thermal incineration.
- EAOP unit operations can operate at ambient conditions, the units can be containerized and mobile, and there are no requirements for addition of chemical oxidants.
- The EMWWTP would continue to provide treatment of the Dolby leachate (and East Millinocket sanitary wastewater) for conventional parameters such as BOD5, TSS, and ammonia, and disinfection before discharge to the river.
- Potential limitations of EAOP technology include possible generation of toxic byproducts, incomplete destruction of some PFAS, efficiency losses due to mineral buildup (especially calcium carbonate) on the cathode, high cost of electrode replacements and energy, potential volatilization of contaminants, and possible safety issues related to high temperatures and pressures in the reactor. In addition, it would be necessary to determine and measure what the final end-products of oxidation will be for the conventional and non-conventional pollutants in the EAOP-treated leachate and if that treated effluent is conducive to treatment at EMWWTP.

Despite the above potential limitations, treatment of the Dolby leachate using EAOP appears promising. EAOP treatment of persistent pollutants such as PFAS has been demonstrated with the bench-scale and pilot testing. Pilot testing to confirm EAOP as an effective stand-alone treatment process should be considered on the Dolby raw leachate prior to progressing to a full-scale design. The pilot testing should document no adverse impacts on treated leachate quality (i.e., complete PFAS removal and no toxic byproduct formation) and the potential synergy of EAOP to reduce other conventional and non-conventional pollutants related to the leachate. It also should be noted that several vendors have indicated interest in coupling EAOP with technologies that produce PFAS side streams (like foamate from FF).

8.5.2 EAOP of JRL Leachate and Indirect Discharge to NDWWTP

This alternative is essentially the same as the Dolby option for treating leachate with EAOP, but adapted to the JRL site. There are a couple of differences between applying EAOP between these sites. The first difference is the leachate inflow peaking factor at JRL is 165 percent and, as such, the existing 0.912-MG leachate storage tank at JRL is adequate to provide a constant and sustained flow of raw leachate to the treatment unit. However, the EAOP-treated effluent requires a separate equalization tank to provide a buffer for scheduling trucking of the EAOP-treated effluent to the NDWWTP. In sizing the EAOP process for JRL, the PFAS results summarized in Table 7-1 were used for design basis. In particular, the PFAS(6) concentrations during the May 2 and June 15 sampling episodes (2,627 ng/l and 2,443 ng/l) were higher than the other two sampling events and are used for determining the number of electrodes and the energy demand. A total of nine mobile EAOP units with a total of 72 reactors are needed to treat the typical daily peak leachate flows from JRL.

The same advantages of using EAOP technology at Dolby also apply to JRL (i.e., destructive technology with no side stream, potential applicability for treating PFAS in leachate, oxidation of other conventional pollutants, no chemical additions, and treatment at ambient conditions). Likewise, the same potential disadvantages apply for EAOP at JRL (potential formation of toxic byproducts, potential incomplete destruction of some PFAS, efficiency losses due to mineral buildup, high cost for electrodes and high energy demand, potential volatilization of contaminants, and potential for unknown final oxidation products of conventional pollutants). The capital and O&M costs for treating the JRL leachate using EAOP are summarized in Table F-2 of Appendix F. The CAPEX cost is estimated at about $2.6 million and the annual OPEX cost is about $2.52 million. The estimated 5-year present worth cost is estimated at $13.5 million. The calculated present worth cost per MG of leachate treated is about $135,400. Similar to Dolby, the cost for active PFAS removal from leachate via EAOP is projected higher than FF.

Similar to Dolby, treatment of JRL leachate using EAOP appears promising, but should be confirmed by conducting a pilot test using raw JRL leachate. Pilot testing should document no adverse impacts on treated leachate quality occur (i.e., complete PFAS removal and no toxic byproduct formation) and assess the potential synergy of EAOP to reduce other conventional and non-conventional pollutants within the leachate. During this pilot testing, consideration should also be given to using EAOP to treat foamate specific to FF treatment of the JRL leachate.

8.6 Reverse Osmosis of Leachate and Indirect Discharge

Similar to the FF and EAOP leachate treatment alternatives, two RO treatment and indirect discharge options for PFAS removal were evaluated for the Study: one to reduce the PFAS contaminant concentrations in the Dolby leachate, and the other for PFAS reduction in the JRL leachate. Both alternatives would be implemented at the respective landfill sites with the resulting treated effluent from Dolby going to the EMWWTP for biological treatment and the JRL treated effluent going to the NDWWTP for biological treatment. The RO treatment process generates a concentrate stream roughly 10 percent by volume of the raw leachate that concentrates contaminants in the leachate (including the PFAS) that need subsequent treatment or management.

Historically, the primary application of RO is for treatment of brackish water or other drinking water supplies. Rochem Americas has patented an RO process that is more suitable for treating leachate as a result of a custom feed spacer that greatly reduces fouling and improves the cleanability and membrane life. Only recently, did Rochem market their RO treatment process, originally designed to treat complex leachate matrices, for the removal of PFAS from leachate.

8.6.1 RO of Dolby Leachate, Concentrate Management, and Side Stream Treatment

The same site work and flow buffering improvements at Dolby described for the FF and EAOP alternatives also apply for the RO option. In contrast to FF and EAOP that would be housed within mobile Conex containers, the RO option will require the construction of a dedicated RO Treatment Building roughly 60 feet by 70 feet to house two RO trains, each with a flow capacity of 75,000 gpd. Each train would consist of an 8-foot by 26-foot skid (for 1st pass and 2nd pass) and an 8-foot by 18-foot skid (for the high-pressure 2nd stage). There are a total of four skids, plus auxiliary tankage, pumps, and degassifier.

Chemical feeds include an initial pH reduction using sulfuric acid (projected use of 21 gpd of 98% solution), alkaline and acid cleaners, and an anti-scalant. It is projected that 275 kw of 480V/3-

phase power is required for Dolby (roughly 2,310,000 kw-hr/yr) with some 120V/1-phase for auxiliary pumps, etc.

Based on the proposed two RO treatment train layout, the change in quality from the raw leachate to the treated permeate and concentrate is significant. The concentrate volume is roughly 10 percent of the raw leachate (about 12,000 to 16,000 gpd) and the projected PFAS removals are generally less than the analytical detection limits. While not as pronounced as at JRL, another observation is the significant increase in contaminant concentrations in the rejected concentrate stream.

Two options considered for managing the concentrate were stabilization of the concentrate and reuse of the stabilized material as daily cover or EAOP to destroy the PFAS within the side stream concentrate. Due to the uncertainty of obtaining regulatory approval for stabilization, and use of a PFAS laden waste as a daily cover, and the unlikely ability to process 12,000 gpd of concentrate, the side stream treatment option proposed is to incorporate EAOP. For Dolby, five skids would be required, each equipped with eight reactors. In order to power the skids, the total AC power required is 1,500 amps of 3-phase 240V (roughly 2,310,000 kw-hr/yr).

The capital and O&M costs for treating the Dolby leachate using RO and EAOP to treat the concentrate are summarized in Table E-3 of Appendix E. The CAPEX cost is estimated at about $14.5 million and the annual OPEX cost is about $2.6 million. The estimated 5-year present worth cost is about $25.9 million. The calculated present worth cost per MG of leachate treated is in the range of $146,000. The cost for active PFAS removal from leachate via RO is projected higher than FF. Aside from the cost of this alternative, other observations of note are:

- The RO process is undoubtedly capable of reducing the PFAS(6) to below the clean-up objective of 20 ng/l.
- The primary challenge of this technology option is how to manage the RO concentrate stream that is significantly greater in volume than foamate from the FF process.
- This alternative includes a dedicated EAOP operation for treating the estimated 11,000 gpd of RO concentrate. EAOP is well-suited for treating PFAS with higher concentrations and low volume waste streams than treating more dilute and greater volume wastes such as leachate. Potential limitations of EAOP technology include possible generation of toxic byproducts, incomplete destruction of some PFAS, efficiency losses due to mineral buildup (especially calcium carbonate) on the cathode, high cost of electrode replacements and energy, potential volatilization of contaminants, and possible safety

issues related to high temperatures and pressures in the reactor. Pilot testing to confirm EAOP as an effective treatment process for RO concentrate should be considered on the Dolby leachate prior to progressing to a full-scale design.

- The EMWWTP would continue to provide treatment of the Dolby leachate (and East Millinocket sanitary wastewater) for conventional parameters such as BOD5, TSS, and ammonia, and disinfection before discharge to the river.

8.6.2 RO of Dolby Leachate, Concentrate Management, and Side Stream Treatment

This alternative is essentially the same as the Dolby option for treating leachate with RO and the concentrate being treated using EAOP, but adapted to the JRL site. There are a couple of differences between implementing RO and EAOP at JRL instead of Dolby, including the more extensive site development requirements at Dolby and the RO concentrate from JRL is much more concentrated than at Dolby. The effective removal of contaminants from the leachate by the RO process is impressive, however, the resulting concentrate is very high in salts, TDS, organics, and metals and may preclude the reuse of this stream other than to implement a destructive technology such as EAOP.

The same advantages of using RO in tandem with EAOP technology at Dolby also apply to JRL (i.e., RO permeate is effectively treated for PFAS(6), RO concentrate is much smaller in volume than the raw leachate, and EAOP is a destructive technology with no side stream, oxidation of other conventional pollutants, no chemical additions, and treatment at ambient conditions). Likewise, the same potential disadvantages apply for RO and EAOP at JRL (potential formation of toxic byproducts, potential incomplete destruction of some PFAS, efficiency losses due to mineral buildup, high cost for electrodes and high energy demand, potential volatilization of contaminants, and potential for unknown final oxidation products of conventional pollutants). The capital and O&M costs for treating the JRL leachate using RO and EAOP are summarized in Table F-3 of Appendix F. The CAPEX cost is estimated at about $8 million and the annual OPEX cost is $2.03 million. The estimated 5-year present worth cost is $16.9 million. The calculated present worth cost per MG of leachate treated is about $169,000. Similar to Dolby, the cost for active PFAS removal from leachate via RO and EAOP is projected higher than FF.

Similar to Dolby, treatment of JRL RO concentrate using EAOP appears promising, but should be confirmed by conducting a pilot test using JRL leachate. Pilot testing should document no adverse impacts on treated leachate quality occur (i.e., complete PFAS removal and no toxic byproduct formation) and assess the potential synergy of EAOP to reduce other conventional and non-conventional pollutants within the leachate.

8.7 Biological Pretreatment and Tertiary Adsorption for PFAS Removal

Biological treatment systems are “living” systems that rely on microorganisms to break down and remove organics in wastewater. The microorganisms utilize the organic substances as a nutritional source to support and sustain life and entails digestion/decomposition of organic pollutants to water, carbon dioxide, and biomass (i.e., sludge). The resulting treated wastewater is typically disinfected (if sanitary wastes are included) before release to a receiving water. For practical purposes, biological treatment removes little, if any, PFAS from wastewater and, as the effluent is purposely directed through adsorption media, which PFAS readily adheres to, results in a “polished” water before release.

Three leachate treatment alternatives were evaluated that utilize biological (i.e., secondary) treatment of the leachate to remove conventional wastewater pollutants, followed by tertiary filtration and PFAS polishing with adsorption. The first biological approach is to treat the combined EMWWTP effluent (including the Town sanitary wastewater) via pretreatment and then PFAS adsorption. The second biological approach is premised on pretreatment including a MBR at JRL followed by PFAS adsorption. The third biological treatment approach is to combine both the Dolby and JRL leachate at the EMWWTP and similar to the first biological approach, implement tertiary pretreatment of the EMWWTP effluent followed by PFAS adsorption. In contrast to FF, EAOP and RO alternatives, which focus on removing PFAS as the first step in the leachate treatment process, biological treatment of conventional pollutants followed by tertiary transfer of PFAS onto adsorption media, is a process where PFAS is removed as the last step of treatment.

8.7.1 Biological Pretreatment of Dolby Leachate at EMWWTP and PFAS Adsorption

This alternative continues to discharge raw leachate from Dolby to the EMWWTP, where the leachate and East Millinocket sanitary wastewater receives biological treatment, followed by iron and manganese removal, tertiary ceramic membrane filtration and PFAS removal by adsorption. The primary drawbacks to this alternative are the quantity of the EMWWTP effluent requiring tertiary treatment for effective PFAS removal and the quality of the secondary aerated lagoon effluent serving as feed water to the PFAS removal process.

Quantity. This alternative provides PFAS treatment of the effluent from the EMWWTP, which includes both the Dolby leachate (annual average flow of 110,400 gpd) and the sanitary wastewater from the Town (annual average flow of 340,000 gpd). Essentially, the treatment system must process, on average, 300 percent the volume of the Dolby leachate due to the sanitary wastewater contribution. Further, the flows from both Dolby and the Town have significant peaking factors during the spring months and the tertiary treatment operations must be sized to handle the peak flows (projected at 877,000 to as high as 1,300,000 gpd). Accordingly, the capital cost to accommodate the large peak flows and the quantity of adsorption media required is significantly increased.

Quality. The aerated lagoon effluent from the EMWWTP can have BOD5 and TSS concentrations as high as 50 mg/l (MEPDES permit daily maximum limit), TOC over 10 mg/l, iron over 1 mg/l, manganese at 0.9 mg/l, and ammonia approaching 10 mg/l. All of these concentrations exceed the prescribed contaminant pretreatment levels for effective PFAS adsorption. As identified in Section 7.1.3, to provide a feedwater to the PFAS adsorption unit operation, it will be necessary to install an iron and manganese removal process as well as a tertiary ceramic membrane filter.

Hydraulically, the leachate flows in the spring from Dolby can increase by 100 to 800 percent. Section 7.0 outlines the concept to provide additional leachate storage at Dolby beyond the existing 2 MG of working storage capacity in the existing leachate pond to reduce the maximum flow to 150,000 gpd. Unfortunately, the Town of East Millinocket has significant I/I that results in peak flows of over 375 percent (877,000 to 1,300,000 gpd) during the same spring season. Therefore, the iron and manganese removal process, the tertiary ceramic membrane filtration, and the adsorption unit operations for PFAS removal need to be sized to treat the combined maximum flow of 877,000 to 1,300,000 gpd.

Two vendors for supplying PFAS adsorption units were provided the flow and analytical results presented in Table 7-2. The first vendor proposed an iron and manganese removal pretreatment followed by a ceramic membrane filter and a PFAS adsorption process using coal-based (bituminous, sub-bituminous, or lignite) GAC media. The iron and manganese removal process utilizes a proprietary manganese dioxide media in a pre-engineered system that includes four reactors. The ceramic membrane filters include two parallel systems inclusive of permeate pumps, backwash pumps, drain pumps, air scour blowers, permeate/backwash tanks, and a CIP chemical dosing system. The GAC adsorption would be a pre-engineered system that includes two setups with lead/lag configuration (total of four GAC reactors), each containing 20,000 pounds (lbs) of GAC. This alternative requires a tertiary filtration and GAC treatment building (about 50 ft by 100 ft) to house the pre-engineered units including skid-mounted iron and manganese removal units, membrane filtration equipment, and GAC vessels. The GAC contact time at average flow conditions is estimated at 15 minutes and at peak flow about 8 minutes. Based on historical GAC isotherms, it is estimated that about 5,000 to 10,000 bed volumes (BV) (i.e., the total volume of the GAC reactors in a GAC treatment unit) of effluent would be treated prior to exhaustion of the GAC. At an average flow of 470,000 gpd, it is estimated that about 60,000 lbs of GAC will be exhausted per year for the GAC media. Exhausted carbon would require disposal via incineration or reactivation and replacement with fresh carbon delivered at a cost of about $3/lb, including disposal of the spent GAC.

The second vendor proposed iron and manganese pretreatment followed by sand filtration and a hybrid GAC/IEX resin system. The treatment units for this alternative are contained in a dedicated treatment building. The contact time through the GAC and IEX units is 10 minutes and 3 minutes, respectively. In general, this alternative was not developed as thoroughly as the first vendor and is not further evaluated.

The capital and O&M costs for PFAS treatment at the EMWWTP are summarized in Table E-4 of Appendix E. In contrast to the FF, EAOP, and RO technologies presented above, in which a supply vendor leases and provides operation support based on volume of leachate treated and managed, the biological processes evaluated are based on BGS purchasing and installing the necessary equipment in year one, with significantly reduced annual costs since there are no lease payments. The CAPEX cost is estimated at about $13.4 to $19.5 million (including the cost of equipment installation) and the annual OPEX cost is estimated at $0.84 million. The estimated 5-year present worth cost is projected at between $17.0 and $23.1 million. The present worth cost per MG of leachate treated is calculated to be in the range of $96,000 to $130,000. The capital cost of this alternative includes significant equipment purchase since the equipment must be capable of handling the peak spring flows (which essentially doubles the capital cost for the iron and manganese removal system, the ceramic membrane filters, and the GAC reactors). The OPEX cost is dominated by the significant media usage and the need to treat the peak flows during the spring conditions. Aside from the cost of this alternative, there are several other observations to note.

- Adsorption technologies are capable of reducing PFAS(6) to below the IDWS of 20 ng/l, a primary objective of the Study. However, the effluent quality from an aerated lagoon system such as EMWWTP is a less than desirable feedwater for a PFAS adsorption process. As a result, a complex series of post-secondary treatment is proposed to pretreat the effluent before polishing with adsorption media. Even with the implementation of the extensive tertiary pretreatment described above, the presence of ammonia and TOC in the EMWWTP effluent at a concentration over 1 mg/l may adversely impact the iron and manganese removal efficiencies and more importantly foul the adsorption media, which would greatly impact the bed life of the PFAS polishing method chosen. The equipment vendors for adsorption technologies strongly recommended pilot testing the EMWWTP effluent to ensure that effective treatment by adsorption is attainable.

- The EMWWTP would continue to provide treatment of the Dolby leachate for conventional parameters such as BOD5, TSS, and ammonia, and provide disinfection in advance of the PFAS polishing.
- Although sampling and testing indicated no contribution of PFAS from the town's sanitary wastewater, the roughly 340,000 gpd of sanitary wastewater will require PFAS polishing by adsorption due to the association with the Dolby leachate. This represents about a 325 percent increase in the total volume versus treating the Dolby leachate flow alone.
- The flows from both Dolby and the Town have significant peaking factors during the spring months and the tertiary treatment operations must be sized to handle those flows (projected at 877,000 to as high as 1,300,000 gpd). The capital cost to accommodate the large peak flows could be significant.
- During the Study, it was not possible to sample and test the WAS for PFAS from the EMWWTP aerated lagoon. It is highly probable that, at a minimum, long-chain PFAS have and will continue to partition onto the WAS. From a sludge management perspective, it would be preferable that PFAS are removed from the Dolby leachate prior to the EMWWTP to avoid dealing with a potentially PFAS-contaminated sludge side stream in the future. Dredging and dewatering of the aerated lagoon is projected to occur about every 20 to 30 years. The aeration lagoon was constructed in 2018.
- Spent adsorption media will require disposal. It is assumed that the spent media are taken to an incinerator where the PFAS-laden materials are destroyed or in the case of GAC are regenerated for reuse. As previously noted in Section 6.0, the U.S.EPA is further reviewing the potential incomplete byproducts from incineration, and the Department of Defense has issued a moratorium on incinerating any wastes that are contaminated with PFAS. None of the other developing PFAS destruction technologies are mature or commercially available, although there has been promising progress and it is only a matter of time before one of those developing technologies is available.

8.7.2 Pretreatment of JRL Leachate using Physical-Chemical and Membrane Bioreactor (MBR) and PFAS Adsorption

This alternative implements physical-chemical and biological pretreatment of the JRL leachate followed by PFAS adsorption, all occurring at the JRL site. The treated effluent, after adsorption, would conceptually have a PFAS(6) concentration less than 20 ng/l and the inorganic sludge and

WAS from the MBR process would be thickened and hauled off-site for dewatering, followed by disposal in a landfill or destruction at an off-site incinerator. The PFAS-polished effluent would continue to be hauled by tank-truck to the NDWWTP for discharge. The primary drawbacks to this alternative are the need for an extensive physical-chemical and biological pretreatment process due to the complex chemistry of the JRL leachate, and the JRL leachate is essentially treated twice for conventional pollutants (once at JRL and again at the NDWWTP).

Hydraulically, the leachate flows in the springtime from JRL can increase by 50 to 65 percent, which is significantly lower compared to the springtime increases at Dolby. It is projected that the existing 0.912-MG storage tank is adequate in size to provide the necessary buffer to handle the seasonally-high leachate volumes. The average and peak daily leachate flows at JRL for 2024 are projected as 69,300 gpd and 115,000 gpd, respectively.

The initial concept for this alternative was to install a MBR biological pretreatment system that would produce UF-quality (i.e., less than 0.1 micron) effluent followed by PFAS polishing by adsorption at JRL. However, as this concept was further developed and evaluated, a number of complications and issues due to the complex chemistry of the JRL leachate were identified relating to the need for biological pretreatment including:

- The leachate has high levels of iron, manganese, anions, cations, and TSS that should be reduced prior to biological treatment in the MBR. In order to accomplish this necessary pretreatment, a physical-chemical unit operation including pH adjustment, coagulation, flocculation, and precipitation is necessary to protect the MBR process. This pretreatment process will generate primarily an inorganic sludge that will require thickening and off-site management. The inorganic sludge will likely contain PFAS.
- The chloride concentration in the JRL leachate is extremely high (5,450 mg/l, more than 25 percent of the chloride concentration in seawater). The salt concentrations may warrant a higher grade of duplex or super-duplex stainless steel for the MBR cassettes and other metallic components that are in contact with the leachate to resist corrosion. In addition, the high total dissolved solids (TDS) and chloride concentrations will likely result in reduced biological effectiveness. Wastewaters (or leachate) with high salt contents disturb the metabolic function of microorganisms; activity loss in microorganisms results in a decline of the efficiency of the biological treatment process (Alipour, V. et al., 2017).
- The high alkalinity and hardness of the leachate will necessitate frequent acid cleaning of the membrane.

- The permeate TDS concentration will be very high (about 10,000 mg/l) and may require reverse osmosis (RO) treatment prior to the PFAS treatment unit.
- To denitrify the MBR effluent, the carbon-to-nitrogen-to-phosphorus ratio that is not in balance in the leachate due to the extremely high presence of ammonia (concentration 680 mg/l), will require dosing of supplemental carbon and phosphorus into the influent flow on a continuous basis.
- While other PFAS treatment alternatives require part-time operations, the extensive physical-chemical pretreatment followed by biological pretreatment and PFAS polishing, would necessitate two full-time operators due to the complexity of the treatment process, that includes biological monitoring on a daily basis.

The physical-chemical pretreatment followed by biological pretreatment and PFAS polishing process is very complex, labor intensive, energy intensive, demands significant chemical addition, and will generate two sludge side streams that will need to be thickened and hauled off-site for dewatering and disposal. Both sludge side streams will likely contain PFAS concentrations requiring attention. Both vendors consulted expressed concern that the JRL leachate may not be amenable to biological treatment using membrane technology regardless of the effectiveness of pretreatment. A report prepared by SWANA states that “the chemical nature of PFAS and their low concentration in leachate coupled with the complex nature of leachate, makes PFAS treatment prior to discharging to WWTPs technically infeasible” (SWANA, 2021). While this statement may not be completely accurate, it does resonate that physical-chemical and MBR pretreatment followed by PFAS adsorption for the JRL leachate does not seem technically practical, and at the very least would be extremely complicated and likely the costliest alternative considered for treating the JRL leachate.

If the JRL leachate quality was to change and become more dilute and pilot testing confirmed the viability of the physical-chemical and MBR process to yield an UF quality effluent, then the projected capital and O&M costs for that treatment alternative summarized in Table F-4 of Appendix F. The capital cost of this alternative is estimated at $17.0 million and includes significant equipment purchases since the vendors for such a treatment setup do not offer annual lease options. The annual OPEX cost is projected at $0.74 million and the estimated 5-year present worth cost is projected at between $20.2 and $22.4 million. The present worth cost per MG of leachate treated is calculated as $202,900. The cost of this alternative is high due to the combination of the complex physical-chemical and MBR pretreatment units, higher O&M costs (including labor, chemicals, energy, and sludge disposal), and adsorption media usage. Aside from the high cost of this alternative, as outlined above, it is questionable if this combination of unit operations is technically practical and capable of adequately treating the JRL leachate to the PFAS(6) IDWS cleanup goal.

8.8 Consolidate JRL and Dolby Leachate at EMWWTP

This alternative was proposed to treat the leachate from both Dolby and JRL at the EMWWTP for biological treatment and polish the effluent via tertiary treatment using adsorption media. As previously noted in Section 7.0, the potential advantages of a combined (i.e., Dolby and JRL) leachate treatment system at EMWWTP would negate any PFAS treatment from occurring at JRL. The combined process would take advantage of the available hydraulic capacity at EMWWTP and the O&M costs to operate a single tertiary PFAS removal process will be less than the cost of running two separate treatment systems. Potential disadvantages of this alternative include: this alternative requires that the East Millinocket sanitary wastewater also be treated via the PFAS tertiary treatment process; hauling cost from JRL to EMWWTP will be expensive; it is likely that long-chain PFAS will partition to the biomass that accumulates in EMWWTP aeration lagoon, which may eventually need to be managed as a special waste when the biomass is removed years from now; and as described in Section 8.7.1, the pretreatment system will require iron and manganese removal and tertiary ceramic membrane filtration, and even then it is possible that the pretreatment is insufficient to protect the PFAS polishing operation from fouling.

The combined pollutant loading to the EMWWTP, including the sanitary wastewater, Dolby leachate, and JRL leachate was evaluated. Table 8-1 summarizes the flow, pollutant loads, and analyzes the need for addition of supplemental carbon and phosphorus to provide the proper ratio of carbon-to-nitrogen-to-phosphorus. Due to the significant concentration of ammonia from JRL, the combined EMWWTP influent would be deficient in organic carbon and phosphorus. Supplemental carbon and phosphorus would need to be dosed to correct the carbon-to-nitrogen-to-phosphorus imbalance. Also, due to the significant concentration of ammonia in the JRL leachate, the composite influent ammonia concentration to the EMWWTP would increase from 7.2 mg/l (without JRL) to 112 mg/l (with JRL). Although there is currently no effluent limit for ammonia at the EMWWTP, an ammonia limit similar to the direct discharge limit for leachates (average daily limit of 4.9 mg/l) would likely be adopted if the JRL leachate is discharged to EMWWTP.

The EMWWTP is an extended aeration process with no capabilities to treat for ammonia. The extended aeration process does not include controlled aeration, sludge recycling, sludge withdrawal, and there are no dedicated anoxic, aerobic, and anaerobic zones in the process, necessary to attain nitrification and denitrification. For these reasons, and the pretreatment deficiency issue identified, the alternative of consolidating and treating the JRL leachate, Dolby leachate, and the Town's wastewater at the EMWWTP followed by tertiary polishing to remove PFAS is not technically viable and is eliminated from further consideration.

8.9 PFAS Side Stream Management

Throughout the discussion presented in this Section, it is noted that all of the treatment alternatives, with the exception of EAOP, generate a side stream that is tainted with PFAS and must be further managed. Potential side streams include foamate from FF, spent adsorption media, and biosolids and other sludge streams. Potential management options for these side streams include off-site disposal, concentrating the liquid waste streams and super-loading those waste streams onto IEX resins, concentrating the wastes and encapsulating that waste in Portland cement or in other stabilizing or solidification agents, concentrating the wastes for on-site destruction with EAOP or SCWO, and off-site incineration. In addition to considering the side stream management options separately at Dolby and JRL, several options were considered that consolidated EAOP treatment of the foamate and RO concentrate at the JRL site (i.e., foamate or RO concentrate from Dolby is hauled to JRL and then combined and treated with the JRL side streams). The side stream management options are discussed below.

8.9.1 Off-Site Disposal

Off-site disposal could include sending the waste stream to a regional PFAS management facility or to a landfill. Currently, there are no regional PFAS waste management facilities in the State of Maine. If a regional facility is developed, side streams from Dolby and JRL tainted with PFAS would be an excellent candidate for regional disposal and treatment.

Another alternative is to dispose of the PFAS wastes in a landfill. When PFAS residuals from leachate treatment are managed in the landfill, the landfill effectively becomes a terminal sequestration point for the PFAS (SWANA, 2021). Over time, the PFAS waste may become recycled in a loop from landfill-to-leachate-to-treatment-to-side-stream-waste-to-landfill, keeping the waste secured within the treatment cycle. Disposal of PFAS-tainted residuals in landfills will likely become a subject for future regulatory consideration and if such a practice will be allowed.

8.9.2 Super-Loading Concentrated PFAS onto IEX Resins

Several technology vendors are exploring "super-loading" liquid waste with concentrated PFAS onto proprietary IEX resin. The objective is to eliminate all free-water such that the IEX resin can pass the paint-filter test that is a requirement for disposal in landfills and secondly, to bind the PFAS in the resin to reduce the potential of PFAS leaching back into the landfill. This technology is being explored in particular to treat the foamate side stream from FF. Initial pilot applications have been promising. The concept is to concentrate the foamate to between 0.3 and 0.5 percent of the original treated leachate volume and then load the PFAS in the concentrated volume onto IEX resin with contact times in hours rather than minutes. Discussion with potential IEX vendors indicates preliminary studies have shown that PFAS adsorption results for this disposal method have been very good, although there has been some speculation that as IEX resin becomes super-loaded over time, that the long-chain PFAS will eventually preferentially attach to the resin and "bump-off" shorter-chain PFAS. The PFAS-laden IEX resin can be drummed and placed in a landfill or stored for future destruction. Landfill disposal of drummed PFAS-laden resin will likely be subject to future regulations including determining what test methodology will be appropriate for evaluating the long-term potential leaching of PFAS from the IEX.

8.9.3 Encapsulating the Wastes

Encapsulation of hazardous wastes within a solid matrix such as concrete, and subsequent disposal of the stabilized or solidified material in a landfill, is a common practice. The same technology is now being explored to encapsulate PFAS-containing residuals at several PFAS treatment projects. This technology is also being evaluated to treat concentrated foamate and RO concentrate. If solidification of contaminants of concern (i.e., PFAS) are physically bound or enclosed within a stabilized mass, chemical reactions can be induced between the stabilizing agent and the contaminants to reduce the PFAS mobility. PFAS-adsorption materials (i.e., admixtures) can be mixed with the PFAS-laden wastes to further reduce PFAS leachability from the solidified waste matrix. Stabilization and solidification techniques vary in their effectiveness depending on the waste characteristics (particularly the organic content of the waste matrix), PFAS types and concentrations, mixing approaches, and the admixtures used. A disadvantage of this technology is that the PFAS are not destroyed but instead are ultimately disposed in a landfill.

One encapsulation concept being investigated by vendors evaluating leachate treatment is to generate a granular friable material containing stabilized PFAS that could be used as landfill cover, while another concept is to simply dispose of the solidified material in a landfill. Similar to the discussion above regarding super-loading of PFAS onto IEX resin, the ultimate acceptance of encapsulating PFAS will depend on future regulations and if PFAS are indeed permanently bound to the admixture used for solidifying the wastes. Vendors have demonstrated successful encapsulation of PFAS using aggressive leaching procedures such as the toxicity characteristic leaching procedure (TCLP), but it is not clear what actual test methodology and what concentration of PFAS contained in the leaching solution will be acceptable to the regulatory agencies.

8.9.4 On-Site Destruction of PFAS Treatment Side Streams

The two PFAS destruction technologies identified in the Study to potentially treat foamate from FF are EAOP and SCWO. The treatment concept is to consolidate the foamate from both JRL and Dolby at the JRL site and to mobilize an EAOP or SCWO treatment unit to destroy the combined foamate. As previously described in this section, the foamate is concentrated to about 0.3 to 0.5 percent of the original leachate volume and then treated using an EAOP or SCWO reactor. It is estimated that the concentrated volume of combined Dolby and JRL foamate will be about 900 gpd with a PFAS(6) concentration of between 400 and 600 μg/l.

EAOP for the combined concentrated foamate was modeled in the same fashion as the two leachates separately. At very high PFAS concentrations, the importance of the shorter-chain substances may be increased since they may not react in the same manner as at lower concentrations, possibly leading to poorer removals of these species. However, the high concentration should improve mass transport of the PFAS to the electrode surface, improving treatment, and possibly allowing for higher applied current to be used to speed the reaction. Pilot testing will allow confirmation of the treatability and sizing of the EAOP units. For the combined foamate streams, it is projected that a single skid-mounted unit with eight reactors is needed with an electrical consumption of about 356,500 kw-hr per year.

The SCWO treatment method involves water (containing PFAS) heated to a temperature above 705°F (374°C) and pressurized to 221.1 bars (i.e., 221 atmospheres or 3,200 pounds per square inch), which is considered “supercritical,” and in the presence of an oxidizing agent (such as oxygen), supercritical water dissolves and oxidizes a broad array of hazardous organic substances. PFAS destructions of over 99 percent from use of SCWO have been reported. The capability to decompose an array of complex molecular compounds simultaneously makes SCWO promising for PFAS destruction, although implementation of SCWO at large-scale has been limited by several technical challenges. One SCWO vendor indicated that the energy required to implement SCWO is significant and proposed to blend the foamate concentrate with WAS contaminated with PFAS to take advantage of the fuel content of the WAS. In the absence of a supplemental fuel to reduce the energy needs, the vendor did not think SCWO could be cost competitive to other technologies. Another vendor cautioned on the long-term safety of using high-pressure vessels that could fail due to the potential corrosivity (i.e., high chloride content) of the leachate. This could be a particular concern for the JRL leachate, which has a chloride concentration of almost 5,500 mg/l.

8.9.5 Off-Site Incineration

Incineration is a mature technology that offers the possibility of destruction of PFAS waste streams, although incineration is being critiqued by regulatory agencies due to the possibility of incomplete combustion and hazardous byproduct generation. Incineration of spent adsorption media, biosolids, and solid wastes tainted with PFAS will continue to be considered a viable treatment technology recognizing that the process continues to be evaluated and critiqued as noted above. As previously noted, it is of interest that the U.S.EPA has announced further research on incineration of PFAS and the possibility of concern specific to incomplete combustion byproducts or ineffective reduction of PFAS. In addition, the Department of Defense has implemented a moratorium on incinerating any wastes contaminated with PFAS until further technical review is completed.

Typically, GAC is regenerated (also referred to as reactivation) by thermal activation at a temperature above 800°C in a rotary furnace in an atmosphere saturated with water vapor. The thermal process destroys the PFAS contained on the GAC and the resulting charcoal recovers nearly its full adsorption capacity. The resulting product is re-sold as reactivated carbon. For the Study, all alternatives evaluated that include GAC assume that the spent carbon will be taken to a centralized facility and managed separately, and all replacement GAC for Dolby and/or JRL will consist of virgin GAC.

8.10 Conceptual Capital Cost and Operation & Maintenance Cost Projections

The conceptual opinions of probable construction costs presented in this report are based on Class 5 construction estimates as defined by the Association for the Advancement of Cost Engineering (AACE) practices and standards. A Class 5 cost estimate is typically applicable for a Feasibility Study or Conceptual Study that is used to evaluate alternatives with various design approaches. The expected accuracy of a Class 5 estimate is between +100 to -50 percent.

The conceptual opinion of probable construction costs is based on recent project costs and equipment quotes from manufacturers and/or vendors. The conceptual capital cost reflects the June 2022 ENR Construction Cost Index (CCI) of 13110.5 and assumes design and construction engineering at 12 percent each of the construction subtotal, respectively. To address the accuracy of the Study, schedule and timing that includes volatile market pricing for materials and equipment, and a current erratic bidding market, a 40 percent construction and bidding contingency, is added to the total projected capital costs excluding design and construction engineering. No contingency has been applied to annual service lease contracts provided by vendors or to O&M cost estimates.

Present worth costs assume a 5-year life cycle for O&M and service contracts carry an interest rate of 5 percent. It was decided to use a five-year life cycle cost due to the changing volumes of leachate, the anticipation of evolving technologies and the associated unit pricing, and since a number of vendors indicated a willingness to re-negotiate service contracts as their leased equipment is essentially paid off during the first two to four years of service. Equipment cost provided by vendors for purchasing equipment is delineated as CAPEX and there is no adjustment for present worth. O&M costs associated with annual service contracts, lease payments, electrical costs, analytical testing and other O&M costs not included within the service contracts are delineated separately. The annual service contract cost and the O&M costs not included in the service contract were combined and converted to present worth values for estimating the overall cost to provide treatment. Present worth costs per million gallons of leachate treated were also estimated for Dolby and JRL. The estimated costs are summarized for Dolby and JRL in Table 8-2 and Table 8-3, respectively.

Assumptions used throughout the capital cost development for Dolby and JRL include the following:

- Leachate flow projections have been prepared for the 5-year life cycle from January 2024 through December 2028 based on historical flows, the anticipated landfill development, and the projected status for installing intermediate and final cover (summarized in Tables 3-1 and 3-2 for Dolby and JRL, respectively). Maximum monthly flows are projected based on historical leachate values and the implementation of flow equalization, particularly at Dolby.
- Buildings for the treatment units have been developed for both modular transportable units to house the PFAS treatment operations (FF and EAOP trailers at Dolby and JRL) and permanent insulated buildings with high clearances required for some PFAS treatment equipment (pretreatment and adsorption of PFAS options and RO treatment).
- Site work costs for infrastructure such as pump stations, piping, water line extensions, electrical runs, and equipment pads were developed based on preliminary site layouts, quantity take-offs, and applying unit costs.
- Purchased equipment includes a 50 percent allowance to account for installation, process piping, electrical, instrumentation and controls, and site civil work.

- For the Study, it was assumed that both Dolby and JRL have sufficient electrical power for new process equipment and that additional power distribution or transformers are outside the scope of this estimate.
- Unit operation and vessel sizing is based on standard system sizing provided by equipment vendors. Process equipment pricing is based on budgetary vendor quotes and/or on prices factored from previous projects. Additional vessel sizing can be evaluated during the detailed design.
- Alternatives that include PFAS adsorption considered GAC, IEX, and fluoro-sorb. Empty bed contact times of 10 minutes are used for GAC and 3 minutes for IEX and fluoro-sorb. Media usage assumes 5,000 BVs prior to change-out based on breakthrough isotherms from other sites treating for PFAS(6). Alternatively, if change-out is based on breakthrough of non-PFAS(6) substances such as the short-chain PFBA, the media usage per MG would be greater. Adsorption media change-out costs are based on a price of $3.00 per pound of GAC. Spent GAC will be reactivated and reused at other facilities. Replacement GAC assumes coal-based (bituminous or lignite) virgin GAC. The GAC replacement frequency will depend on the influent water quality and the ability to achieve the PFAS(6) IDWS clean-up goal of 20 ng/l. Adsorption media isotherm testing will be conducted prior to final selection of the media for a specific waste stream.

One general observation on the capital cost, particularly at Dolby, is that the site development cost for providing pump stations, pipelines, equalization, extending water, electrical lines, and other infrastructure is significant even though these civil engineering elements do not provide any direct PFAS removal.

TABLE 8-1

ANALYSIS OF BOD5-TO-NITROGEN-TO-PHOSPHORUS RATIO IF DOLBY AND JRL ARE BOTH TREATED AT EMWWTP

	JRL, Dolby , and East Millinocket Sanitary				Dolby and East Millinocket Sanitary		
	JRL (gpd)	Dolby (gpd)	East Millinocket Sanitary (gpd)	EMWWTP Influent (gpd)	Dolby (gpd)	East Millinocket Sanitary (gpd)	EMWWTP Influent (gpd)
2024	69,300	110,400	340,000	519,700	110,400	340,000	450,400
2025	60,800	110,400	340,000	511,200	110,400	340,000	450,400
2026	53,400	88,500	340,000	481,900	88,500	340,000	428,500
2027	46,800	88,500	340,000	475,300	88,500	340,000	428,500
2028	42,600	88,500	340,000	471,100	88,500	340,000	428,500
2029	37,300	88,500	340,000	465,800	88,500	340,000	428,500
2030	32,700	88,500	340,000	461,200	88,500	340,000	428,500
2031	34,500	88,500	340,000	463,000	88,500	340,000	428,500
2032	31,000	88,500	340,000	459,500	88,500	340,000	428,500
2033	27,900	88,500	340,000	456,400	88,500	340,000	428,500
2034	23,400	88,500	340,000	451,900	88,500	340,000	428,500
2035	21,100	88,500	340,000	449,600	88,500	340,000	428,500
2036	17,300	88,500	340,000	445,800	88,500	340,000	428,500
2037	17,300	88,500	340,000	445,800	88,500	340,000	428,500
2038	15,800	88,500	340,000	444,300	88,500	340,000	428,500
2039	14,500	88,500	340,000	443,000	88,500	340,000	428,500
2040	12,600	88,500	340,000	441,100	88,500	340,000	428,500
2041	10,900	88,500	340,000	439,400	88,500	340,000	428,500
2042	9,400	88,500	340,000	437,900	88,500	340,000	428,500

TYPICAL SANITARY WW CONCENTRATIONS

Parameter	Medium	Range
BOD5	220	110 to 400
TSS	220	100 to 350
Ammonia	25	8 to 35
Phosphorus	8	4 to 15

Parameter	JRL (mg/l)	JRL (lbs/d)	Dolby (mg/l)	Dolby (lbs/d)	East Millinocket Sanitary (mg/l)	East Millinocket Sanitary (lbs/d)	EMWWTP Influent (mg/l)	EMWWTP Influent (lbs/d)
BOD5	**125**	**72.2**	**4.0**	**3.7**	**91**	**258**	**89**	**334**
TSS	**47**	**27.2**	**19.4**	**17.9**	**74**	**210**	**68**	**255**
Ammonia	**682**	**394**	**8.6**	**7.9**	**7.2**	**20.4**	**112**	**423**
Phosphorus	**3.83**	**2.2**	**0.027**	**0.02**	**0.16**	**0.44**	**0.124**	**2.68**

Parameter	No JRL (mg/l)	No JRL (lbs/d)	Dolby (mg/l)	Dolby (lbs/d)	East Millinocket Sanitary (mg/l)	East Millinocket Sanitary (lbs/d)	Calculated EMWWTP (mg/l)	EMWWTP Influent (lbs/d)
BOD5	-	-	**4.0**	**3.7**	**91**	**258**	**73**	**262**
TSS	-	-	**19.4**	**17.9**	**74**	**210**	**64**	**228**
Ammonia	-	-	**8.6**	**7.9**	**7.2**	**20.4**	**7.9**	**28**
Phosphorus	-	-	**0.027**	**0.02**	**0.16**	**0.44**	**0.124**	**0.47**

Desired Carbon:Nitrogen:Phosphorus Ratio			
100	**5**	**1**	
Current Carbon: Nitrogen: Phosphorus Ratio (Dolby and Sanitary Only)			
262	**28**	**0.5**	**Appears to be TP deficient**
524	**56**	**1**	**BOD/N Ratio good**
100	**5**	**1**	
1120	**56**	**11.2**	**Pounds Necessary for C:N:P Ratio**
858	**-**	**10.7**	**lbs/day to be added for C:N:P ratio**
Carbon: Nitrogen: Phosphorus Ratio (JRL, Dolby and Sanitary Flows)			
334	**423**	**2.68**	
125	**158**	**1**	**Both BOD and TP are deficient**
100	**5**	**1**	
3160	**158**	**31.6**	**Pounds Necessary for C:N:P Ratio**
2826	**-**	**28.92**	**lbs/day to be added for C:N:P ratio**

TABLE 8-2

COST ESTIMATE SUMMARY FOR PFAS REMOVAL ALTERNATIVES AT DOLBY LANDFILL

CONSTRUCTION ELEMENT	FF/FOAMATE CONCENTRATION/ DISCHARGE TO EMWWTP	EAOP AND DISCHARGE TO EMWWTP	RO/CONCENTRATE MGMT DISCHARGE TO EMWWTP	DISCHARGE TO EMWWTP AND ADSORPTION POLISHING OF SECONDARY EFFLUENT
A. SITE WORK/PROJECT DEVELOPMENT AND EQUIPMENT CAPEX				
General Site Development				
Including Modify Existing Pump Station (PS) and Pipelines, Install Additional PS and Pipelines, Sitework and Slab Construction, Extend Electrical and Potable Water Lines, Additional Off-Line Storage Facilities, Standby Power, Trailers and Support Facilities, PS and Inf Pipeline from Storage to Treat	$4,430,000	$4,600,000	$4,600,000	$2,280,000
SUBTOTAL GENERAL SITE WORK	$4,430,000	$4,600,000	$4,600,000	$2,280,000
CAPEX FOR EQUIPMENT PURCHASE				
1. Equipment Purchases for FF Including Mobilization/Demobilization	$240,000	Not Applicable	Not Applicable	Not Applicable
2. Equipment Purchases for RO Treatment including: New RO Treatment Building; Other Elements to be Identified??	Not Applicable	Not Applicable	$4,290,000	Not Applicable
3. Equipment Purchases for EMWWTP Effluent Pretreatment and PFAS Adsorption Including: Physical-Chemical Fe/Mn Removal; Tertiary Ceramic Membrane Filters; GAC Adsorption System; Pipeline Modifications; New PS; Filtrate Return Lines and PS; and SCADA Integration	Not Applicable	Not Applicable	Not Applicable	$5.9 to $9.6 million
SUBTOTAL CAPEX FOR EQUIPMENT PURCHASES	$240,000	$0.00	$4,290, 000	$5.9 to $9.6 million
TOTAL GENERAL SITE WORK & CAPEX FOR EQUIPMENT PURCHASES	$4,670,000	$4,600,000	$8,890,000	$8.18 to $11.9 million
Engineering (12% of Construction Cost)	$561,000	$557,000	$1,060,000	$0.98 to $1.43 million
Construction Management (12% of Construction Cost)	$561,000	$557,000	$1,060,000	$0.98 to $1.43 million
Contingency (40% of Construction Cost)	$1,870,000	$1,860,000	$3,550,000	$3.27 to $4.76 million
TOTAL SITE WORK & CAPEX FOR EQUIPMENT PURCHASES	$7,660,000	$7,620,000	$14,500,000	$13.4 to $19.5 million
B. ANNUAL LEASE/OTHER O&M COSTS				
1. Mobilize and Operate FF/Concentration/Super-Loading IEX including: FF Lease/Service Contract; Super-Loading IEX O&M and Resin Disposal; Electrical (PFAS and Non-PFAS Related); Media Replacement; Analytical Testing; Program Management and Repair/Replacement Costs	$1.88 to $3.31 million	Not Applicable	Not Applicable	Not Applicable
2. Mobilize and Operate EAOP Process including: EAOP Lease/Service Contract; Electrical (PFAS and Non-PFAS Related); Analytical Testing; Program Management and Repair/Replacement Costs	Not Applicable	$5.31 million	Not Applicable	Not Applicable
3. Construct and Operate RO and Concentrate Treatment via EAOP including: RO Lease/Service Contract; EAOP Lease/Service Contract; Electrical (PFAS and Non-PFAS Related); Analytical Testing; Program Management and Repair/Replacement Costs	Not Applicable	Not Applicable	$2.624 million	Not Applicable
4. Construct and Operate Tertiary Pretreatment and Adsorption for PFAS Removal including: Electrical (PFAS and Non-PFAS Related); Media Replacement; Labor; Chemicals; Analytical Testing; Program Management and Repair/Replacement Costs	Not Applicable	Not Applicable	Not Applicable	$0.84 million
C. COST SUMMARY				
Capital Cost and Present Worth of Annual Leases and Other O&M				
PW Site Work/Capex for Equipment Purchases	$7.66 million	$7.6 million	$14.6 million	$13.4 to $19.5 million
PW Annual Lease/Other O&M Costs	$8.12 to $14.3 million	$23 million	$11.4 million	$3.64 million
TOTAL LIFE CYCLE PW COSTS	$15.8 to $22.0 million	$30.6 million	$25.9 million	$17.0 to $23.1 million
D. UNIT COST OF TREATMENT SUMMARY				
Estimated Volume of Leachate Treated Over 5-Years (MG)	177.5 MG	177.5 MG	177.5 MG	177.5 MG
Present Worth Cost/MG Leachate Treated	$89,000 to $124,000/MG	$173,000/MG	$146,000/MG	$96,000 to $130,000/MG

TABLE 8-3

COST ESTIMATE SUMMARY FOR PFAS REMOVAL ALTERNATIVES AT JUNIPER RIDGE LANDFILL

CONSTRUCTION ELEMENT	FF/FOAMATE CONCENTRATION/ DISCHARGE TO NDWWTP	EAOP AND DISCHARGE TO NDWWTP	RO/CONCENTRATE MGMT DISCHARGE TO NDWWTP	PC & BIOLOGICAL PRETREAT/ GAC ADSORPTION POLISHING DISCHARGE TO NDWWTP
A. SITE WORK/PROJECT DEVELOPMENT AND EQUIPMENT CAPEX				
General Site Development				
Including Modify Existing Pump Station (PS) and Pipelines; Install Additional PS and Pipelines; Sitework and Slab Construction; Extend Electrical and Potable Water Lines; New TE Storage Facilities; Standby Power; Trailers and Support Facilities	$1,470,000	$1,580,000	$1,510,000	$1,420,000
SUBTOTAL GENERAL SITE WORK	$1,470,000	$1,580,000	$1,510,000	$1,420,000
CAPEX FOR EQUIPMENT PURCHASE				
1. Equipment Purchases for FF Including Mobilization/Demobilization	$130,000	Not Applicable	Not Applicable	Not Applicable
2. Equipment Purchases for RO Treatment including: New RO Treatment Building; Other Elements to be Identified??	Not Applicable	Not Applicable	$3,400,000	Not Applicable
3. Equipment Purchases for P-C and MBR Pretreatment and PFAS Adsorption Including: Physical-Chemical and Fe/Mn Removal; MBR Pretreat; and GAC Adsorption System at JRL Site; and SCADA Integration	Not Applicable	Not Applicable	Not Applicable	$8,940,000
SUBTOTAL CAPEX FOR EQUIPMENT PURCHASES	$130,000	$0.00	$3,400,000	$8,940,000
TOTAL GENERAL SITE WORK & CAPEX FOR EQUIPMENT PURCHASES	$1,600,000	$1,580,000	$4,910,000	$10,400,000
Engineering (12% of Construction Cost)	$192,000	$190,000	$589,000	$1,240,000
Construction Management (12% of Construction Cost)	$192,000	$190,000	$589,000	$1,240,000
Contingency (40% of Construction Cost)	$640,000	$633,000	$1,960,000	$4,140,000
TOTAL SITE WORK & CAPEX FOR EQUIPMENT PURCHASES	$2,630,000	$2,590,000	$8,050,000	$17,000,000
B. ANNUAL LEASE/OTHER O&M COSTS				
1. Mobilize and Operate FF/Concentration/Super-Loading IEX including: FF Lease/Service Contract; Super-Loading IEX O&M and Resin Disposal; Electrical (PFAS and Non-PFAS Related); Media Replacement; Analytical Testing; Program Management and Repair/Replacement Costs	$1.05 to $1.8 million	Not Applicable	Not Applicable	Not Applicable
2. Mobilize and Operate EAOP Process including: EAOP Lease/Service Contract; Electrical (PFAS and Non-PFAS Related); Analytical Testing; Program Management and Repair/Replacement Costs	Not Applicable	$2.52 million	Not Applicable	Not Applicable
3. Construct and Operate RO and Concentrate Treatment via EAOP including: RO Lease/Service Contract; EAOP Lease/Service Contract; Electrical (PFAS and Non-PFAS Related); Analytical Testing; Program Management and Repair/Replacement Costs	Not Applicable	Not Applicable	$2.04 million	Not Applicable
4. Construct and Operate Tertiary Pretreatment and Adsorption for PFAS Removal including: Electrical (PFAS and Non-PFAS Related); Media Replacement; Labor; Chemicals; Sludge Disposal; Analytical Testing; Program Management and Repair/Replacement Costs	Not Applicable	Not Applicable	Not Applicable	$0.744 million
C. COST SUMMARY				
Capital Cost and Present Worth of Annual Leases and Other O&M				
PW Site Work/Capex for Equipment Purchases	$2.6 million	$2.6 million	$8 million	$17 million
PW Annual Lease/Other O&M Costs	$4.54 to $7.81 million	$10.9 million	$8.81 million	$3.21 million
TOTAL LIFE CYCLE PW COSTS	$7.18 to $10.4 million	$13.5 million	$16.9 million	$20.2 million
D. UNIT COST OF TREATMENT SUMMARY				
Estimated Volume of Leachate Treated Over 5-Years (MG)	99.6 MG	99.6 MG	99.6 MG	99.6 MG
Present Worth Cost/MG Leachate Treated	$72,000 to $105,000	$135,000	$169,000	$203,000

9.0 CONCLUSIONS AND NEXT STEPS

The Study to Assess Treatment Alternatives for Reducing PFAS in Leachate from State-Owned Landfills indicates there are four treatment technologies potentially available to reduce PFAS concentrations in the leachate from the Dolby and JRL landfills. As would be expected, each technology has its strengths and weaknesses, and each technology will involve significant start-up and operational costs. Pilot testing of the preferred PFAS treatment technology(s) is the next step toward reducing PFAS(6) concentrations in the Dolby and JRL leachates to less 20 ng/l.

9.1 PFAS Treatment Technology Summary

The principal objective of the Study to Assess Treatment Alternatives for Reducing PFAS in Leachate from State-Owned Landfills was to: identify PFAS treatment technologies that could potentially reduce PFAS(6) concentrations in the Dolby and JRL leachates to below the State of Maine IDWS of 20 ng/l. A search of current and emerging PFAS treatment technologies was conducted and resulted in identifying four technologies potentially effective for handling the PFAS(6) concentrations and leachate flows associated with Dolby and JRL. The four technologies identified were:

- Foam Fractionation (i.e., FF);
- Electrochemical Advances Oxidation Process (i.e., EAOP);
- Reverse Osmosis (i.e., RO); and
- Biological treatment followed by PFAS(6) polishing using adsorption (e.g., GAC, IEX, or alternative adsorbents such as fluoro-sorb).

Each of these technologies includes final treatment and continued discharge of the leachate by way of the EMWWTP (Dolby) and the NDWWTP (JRL).

The four identified technologies use widely differing treatment kinetics for how to reduce or destroy PFAS.

- FF is an "upfront bulk PFAS removal process" that does not require pretreatment of the leachate even when the leachate is carrying abundant co-contaminants (like those in the JRL leachate). The FF technology takes advantage of the unique air-water interface characteristics of PFAS (i.e., molecules with a hydrophobic head and hydrophilic tail) that preferentially adhere to and consolidate onto air bubbles. The air bubbles create a foam side stream of waste (i.e., foamate) that can be further reduced to a small volume of liquid waste containing concentrated PFAS that requires subsequent disposal.

- EAOP is a newly available technology that has shown promise for destroying PFAS. A significant upside to EAOP technology is that the PFAS are destroyed and there are no residual waste side streams that require subsequent management or disposal. There are potential limitations of EAOP technology for leachate treatment that need to be further demonstrated including: confirming no generation of toxic byproducts; confirmation of complete PFAS destruction; and establishment of a thorough understanding of what final byproducts of oxidation could remain relative to the other contaminants contained in leachate.
- RO utilizes porous membranes designed to separate and concentrate constituents from leachate at the molecular level. High pressure is applied to the leachate inflow forcing the smaller water molecules through the membrane, but restricting the larger molecules (like PFAS) from passing. RO results in side stream of concentrated PFAS and other contaminants that need disposal. Rochem Americas, Inc. operates an integrated two-pass RO leachate treatment system at numerous leachate management sites worldwide. Rochem has observed reductions for PFAS(6) in leachate at one facility from 2,285 ng/l to below the 1.9 ng/l detection limit, and total PFAS reductions from 6,900 ng/l to less than 1.9 ng/l using RO (SWANA, 2021). PFAS concentrate from that facility is typically stabilized by solidification with cement products. The solidified PFAS in turn has been used as daily landfill cover in a number of situations.
- Biological treatment in tandem with PFAS adsorption (often referred to as polishing) requires extensive pretreatment of the co-contaminants in the leachate prior to transfer of the PFAS onto adsorption media. Once the media becomes exhausted (i.e., no more capacity to hold PFAS(6)), the media must be removed, managed separately, and be replaced with new media. In the absence of sufficient leachate pretreatment (typically removing particulates in the leachate to an UF quality condition), the adsorption media may foul and/or other co-contaminants within the leachate could preferentially transfer to the media, thus depleting the media's effectiveness for PFAS adsorption. Unless effective conditions for PFAS treatment are maintained, adsorption media change-outs could become frequent and uneconomical.

Table 9-1 provides a summary of the advantages and disadvantages of the four leachate treatment technologies considered most likely to treat the Dolby and JRL leachates. **A primary**

conclusion of the Study is that FF is likely the most practical and most cost-effective treatment technology currently available for reducing PFAS(6) concentrations in the leachate from both Dolby and JRL. Key observations that distinguish the four technologies from one another are summarized below.

Foam Fractionation. The FF process is not energy or labor intensive, the process is resilient and has been demonstrated to not be adversely impacted by the co-contaminants in the Dolby and JRL leachate, and the FF process can be mobilized to Dolby or JRL using self-contained treatment units assembled in Conex containers or similar. The FF process is operationally simplistic and commercially viable, and aside from the potential need for the addition of a booster agent (surfactant) to optimize foam generation, there are no chemicals required for PFAS removal by FF. FF selectively removes PFAS from leachate and has little impact on other co-contaminants carried in the leachate. The FF-treated leachate will continue to be combined with the other influents to the EMWWTP or NDWWTP for biological treatment before discharge to the river.

FF has been demonstrated to successfully reduce PFAS concentrations in bench-scale and field pilot studies using leachate from Dolby and JRL as well as for full-scale cleanup of AFFF-contaminated groundwaters (which have been degraded to a quality similar to leachate). Perhaps of most importance, the PFAS(6) in leachate from JRL and Dolby was successfully treated to 20 ng/l or less by two independent vendors. FF generates a side stream of foamate with concentrated PFAS that must be managed separately.

Electrochemical Advanced Oxidation Process. EAOP focuses on destruction of PFAS in the Dolby and JRL leachates with discharge of the treated effluent to the EMWWTP and NDWWTP, respectively. In addition to the destruction of PFAS, EAOP leaves no residual waste to manage. Another advantage of this technology is that EAOP oxidizes the ammonia and organic materials in the leachate and, thus, subsequent treatment of those conventional pollutants at the EMWWTP and NDWWTP are significantly reduced. Other potential advantages of EAOP include operation at ambient conditions, ability to be contained in a mobile unit, and no requirement for chemical additives. EAOP treatment of persistent pollutants such as PFAS has been demonstrated using bench-scale and field pilot studies.

Field pilot testing of EAOP for both the Dolby and JRL leachates to confirm EAOP as an effective stand-alone treatment process should be considered prior to progressing to a full-scale EAOP design. The field pilot testing should document no adverse impacts on treated leachate quality (i.e., complete PFAS removal and no toxic byproduct formation) and the potential synergy of EAOP to reduce other conventional and non-conventional pollutants related to leachate. Finally, it should be understood that EAOP is an emerging technology for PFAS destruction and will require successful demonstration on the specific Dolby and JRL leachate before considering a full-scale design. Research completed for the Study did not reveal any EAOP full-scale leachate treatment applications, although pilot testing has been successful on a number of leachate wastes. It is also interesting to compare the high-energy demand and the layout of EAOP treatment units (requires mobilizing sixteen 40-foot Conex-type mobile units at the Dolby site) to the number of FF treatment units for Dolby (requires two FF mobile units of similar size). The application for EAOP to treat PFAS is likely more appropriate to the smaller volumes of more concentrated waste than raw leachate.

Reverse Osmosis. RO has been demonstrated to effectively remove PFAS from a multitude of waste matrices including leachate. Rochem Americas, Inc. has developed a multi-pass, high-pressure, RO system that is particularly well suited to leachate treatment. Based on the leachate chemistry at Dolby and JRL, it is expected that the Dolby and JRL leachate may need a dual-pass RO system with the residual stream further treated by an ultra high-pressure (UHP) RO stage. The challenge for RO treatment is the large volume of the PFAS side stream generated, which for Dolby is roughly 13,200 gpd and 8,300 gpd for JRL. Treatment of the RO concentrate is proposed to occur at the JRL site with concentrate from both JRL and Dolby being treated by a dedicated EAOP operation. While this treatment option seems effective for meeting the PFAS(6) goal, the RO and EAOP solution is more expensive than FF.

Biological Treatment with Follow-up Polishing to Remove PFAS. Polishing PFAS from clean water matrices has been implemented at numerous drinking water treatment facilities across the United States. The challenge in using this technology for removing PFAS from leachate is configuring a technically reliable and cost-effective pretreatment process that will protect and extend the useful life of the selected adsorption media given the large volumes of leachate to be treated.

For Dolby, the existing extended aeration lagoon system at the EMWWTP would continue to treat both the Dolby leachate and the sanitary wastewater from the Town for conventional pollutants (BOD5, TSS, ammonia, and a variety of other pollutants). The lagoon system has significant hydraulic capacity and has a limited capacity to buffer peak springtime leachate flows that are pumped from Dolby. Although the EMWWTP lagoon system consistently meets the limits of its associated MEPDES permit, the effluent quality from an aerated lagoon system such as EMWWTP is less than desirable for use as feedwater to a PFAS polishing process due to the presence of contaminants (e.g., BOD5, TSS, TOC, ammonia, iron, and manganese) that may have been treated by the aerated lagoon system, but not to concentrations necessary for feedwater to be polished by adsorption. Consequently, a complex series of post-secondary effluent pretreatment processes (i.e., iron and manganese removal and tertiary ceramic membrane filtration) would be necessary to clean the biologically treated wastewater before PFAS adsorption to avoid premature clogging and/or saturation of the adsorption media with other pollutants. Adsorbent media suppliers contacted for the Study consistently and strongly recommended pilot testing the EMWWTP effluent to ensure that adsorption will be technically effective and reliable at removing PFAS from the EMWWTP secondary treatment effluent.

A key disadvantage of using adsorption media for removing PFAS from the EMWWTP biologically-treated effluent is that the post-secondary effluent pretreatment and PFAS sorption processes must be sized to be over 300 percent larger than the average daily leachate flow to accommodate the sanitary wastewater flow from the Town (even though the Town's wastewater was tested to be essentially PFAS free for the Study). Another disadvantage of treating the combined (Dolby and Town wastewater) secondary effluent for PFAS before discharge to the river, is that even with the implementation of extensive pretreatment in advance of adsorption, it is projected that the presence of ammonia and TOC in the effluent (at concentrations over 1 mg/l) could adversely affect the removal efficiency of the adsorption media, leading to fouling and shortened bed life of the adsorption media. A third disadvantage is the sludge generated in the biological treatment lagoon system (that is dredged every 20 to 30 years), is likely to contain PFAS that have partitioned to the biosolids and eventually needs to be handled. Finally, this alternative is more expensive than FF at Dolby, and therefore based on the potential unreliability of this technology to consistently meet the PFAS(6) limit of 20 ng/l and the high cost of treatment, this alternative is not proposed for implementation.

For JRL, the existing NDWWTP secondary treatment system would continue to treat the JRL leachate and the Mill's wastewater flows. However, unlike the Dolby leachate and Town of East Millinocket wastewater flow situation, the JRL leachate flow is de minimis compared to the Mill's wastewater flow, making PFAS adsorption after biological treatment at NDWWTP economically impractical. Accordingly, if biological treatment followed by PFAS adsorption is considered for the JRL leachate, both processes will need to occur at the JRL site before the leachate is trucked to NDWWTP. On-site biologic treatment with PFAS adsorption conceptually could be successful using a MBR to treat the organic and ammonia constituents of the leachate. For the MBR to be successful, however, the leachate would need to first undergo iron and manganese removal and physical-chemical treatment including flocculation, coagulation, and precipitation to remove a variety of suspended pollutants and excessive cations and anions present in the JRL leachate. If the physical-chemical pretreatment is able to pre-condition the leachate so that it is amendable to biological treatment, the MBR process would in turn generate a UF quality effluent suitable for PFAS removal by adsorption. Both the physical-chemical and MBR pretreatment steps would result in sludge side streams that will likely contain PFAS that would need to be managed separately.

Leachate testing completed for the Study indicated the JRL leachate has a complex chemistry and carries considerable TSS, TDS, TOC, chloride, cation, and anion concentrations that must be lowered by physical-chemical pretreatment methods before the leachate is introduced to the MBR such that the leachate is amenable to biological treatment and to avoid membrane fouling. Of most concern, is whether the elevated levels of chloride and TDS can be decreased so that biological oxidation effectiveness is not compromised. Prior to selecting this alternative, it would be critical to demonstrate the biodegradability of the JRL leachate by conducting a pilot treatability study. At this stage, it is questionable if the combination of pretreatment operations is technically practical and whether the treatment process is capable of meeting the PFAS(6) IDWS cleanup goal. Implementing on-site physical-chemical and MBR pretreatment and PFAS adsorption processes for the JRL leachate would be complicated, expensive, labor intensive, energy intensive, requires significant chemical additives, and generates two sludge streams (potentially containing PFAS) that will require off-site dewatering and disposal. For these reasons, attempting to use biological pretreatment to precondition the JRL leachate is not considered technically viable; this alternative is the most expensive option considered for JRL and, therefore, is not proposed for implementation.

A third biological pretreatment option already dismissed from further consideration was to combine the Dolby and JRL leachate with the East Millinocket sanitary wastewater and to pretreat the combined EMWWTP effluent prior to PFAS adsorption. In summary, addition of the JRL leachate into the EMWWTP will dramatically change the composite wastewater chemistry particularly due to elevated ammonia levels that would not be conducive for treatment by the aerated lagoon technology at EMWWTP.

9.2 Residuals Management

With the exception of EAOP, which is a PFAS destruction technology, all of the PFAS treatment alternatives evaluated generate a PFAS residual side stream that must be managed (e.g., foamate, concentrate, sludge, and spent adsorption media). There are currently no solid waste regulations for PFAS disposal. Some solid waste market analysts have proposed to allow PFAS waste to be disposed in landfills, particularly if the leachate is collected and treated for PFAS (i.e., create a secure PFAS treatment cycle). Other analysts have proposed to bulk load PFAS removed from the leachate onto specially designed adsorption or ion exchange resin or encapsulate concentrated PFAS using cement or similar solidification measures to bind the PFAS from leaching after landfill disposal. Based on research completed for the Study, the most promising developing PFAS destruction technology that could be applied to treat the PFAS side streams from Dolby and JRL is EAOP. Other potential PFAS destruction technologies include SCWO and plasma destruction; however, those technologies are in development and are not available for full-scale use. Landfill disposal of PFAS-tainted residuals will likely be subject to future MEDEP determinations for if and how PFAS-containing wastes can be disposed in landfills.

Specific to FF being identified as the most promising technology for treating PFAS in leachate from Dolby and JRL, it is expected that the best near-term management practice for the side stream foamate is to either: 1.) concentrate the foamate and subsequently super-load it onto IEX resin separately at both Dolby and JRL, and dispose of the PFAS-laden resin in a landfill or, alternatively, store the resin until an effective PFAS destruction technology becomes available; or 2.) implement an EAOP treatment at JRL and consolidate the foamate from both landfills (i.e., haul the foamate from Dolby to JRL) for processing. As indicated in this Report, EAOP appears to be an available destruction technology, it would be useful to pilot test EAOP for PFAS removal using the Dolby and JRL foamate before making any significant investment in that technology.

9.3 Site Development Scope and Budget

Throughout Section 7.0 and in Section 8.2 of this Report, it has been noted that extensive site improvements are required to integrate the various PFAS treatment technologies into the existing landfill infrastructure at both Dolby and JRL. In addition, due to the high peaking factors related to the leachate flows, the capital cost of equalizing those flows for efficient use of the treatment technology will add cost, particularly for the Dolby site. In contrast to constructing a PFAS removal operation at the distribution end of a drinking water treatment plant, the variable leachate flows and the leachate chemistry at landfills pose a unique and complicated PFAS treatment challenge.

In addition to designing and constructing the Dolby and JRL PFAS treatment facilities to accommodate the various leachate flows and leachate quality, a number of site improvements will be necessary including, but not limited to, modification of existing pump stations, constructing multiple new pump stations, installing leachate pipelines, providing additional leachate flow equalization both at Dolby and EMWWTP, constructing equipment foundations and containment structures, extending process water lines, providing office trailers, and arranging new electrical services. These site improvements will be significant in cost, necessary, and unfortunately will not provide any actual PFAS reduction. While the cost to address consumption-driven peak flows at a drinking water treatment facility are typically in the range of 5 to 10 percent of the total construction cost, the percentage is expected to range from over 45 percent to about 30 percent for managing the peak leachate flows at Dolby and JRL, respectively.

9.4 Next Steps For Treatment Of Leachate Containing PFAS

Below are suggestions for the steps to move forward with plans for reducing PFAS in the Dolby and JRL leachate:

- Leachate quality monitoring, including testing for PFAS and conventional wastewater pollutants, should be increased to a monthly interval for 2023 to track seasonal changes in the leachate quality and quantity at Dolby and JRL. Potential PFAS treatment vendors will require this information for sizing treatment units and identifying any particular leachate pretreatment necessary to optimize PFAS reduction.
- Pilot testing of the FF technology at both the Dolby and JRL sites should be scheduled. Continuous flow pilot testing will allow better understanding of the operational parameters necessary for successful PFAS treatment using FF and is necessary to move from the feasibility phase to the full-scale design and implementation phase. Process control parameters to be optimized during the pilot testing may include surfactant dosing; reactor retention time; reactor sequencing and recycle flows; air injection rates, bubble size, injection locations, as well as confirm no adverse impacts from co-contaminants; confirm the need for any pretreatment (such as filtration or pH adjustment); and evaluate processes for optimal foamate concentration. Pilot testing will confirm the capability of FF to meet the PFAS(6) IDWS cleanup goal of 20 ng/l and identify if there is a need to provide adsorption polishing to consistently achieve the IDWS goal. Pilot testing also provides information for FF treatment vendors to develop confidence in process effectiveness before providing performance guarantees during the final design phase.
- The FF pilot testing will also provide the opportunity for demonstrating methods for concentration of foamate and follow-up foamate management. The estimated duration for FF pilot testing is three to four weeks at each location.
- EAOP pilot testing of the Dolby leachate and foamate, JRL leachate and foamate, and a composite Dolby and JRL foamate should also be considered. Continuous EAOP pilot testing on-site would last about two weeks per site and would be best conducted simultaneously with the FF pilot testing.

- In tandem with the pilot testing, a more detailed review of peak flows at JRL and Dolby (in particular) should be completed to better define the peaking factors and to evaluate the need for additional on-site leachate storage to address periods of high flows.
- Upon successful completion of the pilot testing phase, a refined design overview and cost estimate for reducing PFAS in the Dolby and JRL leachates should be prepared.
- If the Legislature and BGS confirm the desire to move forward with the full-scale implementation based upon a refined design and cost projection, a final lease agreement should be negotiated between the State and the selected vendor(s). In parallel, a separate design team should be selected to design and coordinate the purchase of any ancillary equipment not included in the FF lease agreement and to also prepare a design for all site improvement work (pump stations, pipelines, equalization tank(s), site preparation, drainage, etc.).
- If a decision is made to move forward with reduction of PFAS in leachate is made, BGS should anticipate vendor negotiations that involve long-term equipment leasing and operation. None of the vendors contacted for the Study offered a prepackaged treatment technology that would be for sale or ready for independent operation. It will also be necessary to resolve the fate of and responsibility for the foamate (i.e., concentrated PFAS waste) produced by the FF treatment process. The final deposition of the super-loaded IEX resin with concentrated PFAS will likely be subject to MEDEP solid waste permitting.

Regardless of the PFAS treatment alternative selected, the installation of a low-permeability geomembrane final cover over the Dolby II Landfill should be considered. Geomembrane cover(s) substantially reduce infiltration into the landfilled waste, which in turn is converted to leachate. Reduction of the Dolby leachate volume is especially important for controlling long-term PFAS treatment costs.

TABLE 9-1

SUMMARY OF ADVANTAGES, DISADVANTAGES, AND COSTS OF PFAS TREATMENT ALTERNATIVES

Parameter	FF at Dolby	FF at JRL	RO/FF Concentrate at Dolby	RO/FF Concentrate at JRL	Biological Pretreatment & PFAS Polishing at EMWWTP	Biological Pretreatment & PFAS Polishing at JRL	EAOP at Dolby	EAOP at JRL
Ability to Remove PFAS(6) to Below 20 ng/l	Highly Probable: FF has been Demonstrated on Full-Scale AFFF Sites and in one Bench-Scale Test; IEX polishing can be provided as Contingency to ensure <20 ng/l	Highly Probable: FF has been Demonstrated on Full-Scale AFFF Sites and on 2 JRL Leachates in Bench-Scale Tests; IEX polishing can be provided as Contingency to ensure <20 ng/l	Highly Probable: RO has been Demonstrated on Full-Scale Leachate and Other Difficult Wastes to Reduce PFAS < 20 ng/l	Highly Probable: RO has been Demonstrated on Full-Scale Leachate and Other Difficult Wastes to Reduce PFAS < 20 ng/l	Questionable: Adsorption Treatment Requires Extensive & Effective Pretreatment; Maximum Flows are also a Concern to GAC Usage	Highly Doubtful: Complex JRL leachate chemistry is difficult to pretreat and MBR capability to biologically pretreat is unlikely; adsorption likely compromised	Very Promising: EAOP has been Demonstrated on Bench- and Pilot-Scale AFFF and Leachate; Evolving Technology not Demonstrated on Full-Scale for Leachate	Very Promising: EAOP has been Demonstrated on Bench- and Pilot-Scale AFFF and Leachate; Evolving Technology not Demonstrated on Full-Scale for Leachate
Co-Contaminant Concerns	Process is Resilient and Essentially not Impacted by Co-Contaminants; Other Leachate Pollutants not Impacted by FF	Process is Resilient and Essentially not Impacted by Co-Contaminants; Other Leachate Pollutants not Impacted by FF	Process is Resilient and not Impacted by Co-Contaminants; Concentrate Mgmt is Challenge	Process is Resilient and not Impacted by Co-Contaminants; Concentrate Mgmt is Challenge	GAC and IEX are Sensitive to Co-Contaminants Competing Against PFAS for Sorption	High Ammonia, Iron, Chloride, TDS, Alkalinity, Hardness and Cation/Anion not Conducive to MBR Pretreatment	Oxidation Process is Non-Selective and Potential Byproduct Formation with Co-Contaminants is a Possibility; Non-PFAS Oxidation Byproducts Unknown	Oxidation Process is Non-Selective and Potential Byproduct Formation with Co-Contaminants is a Possibility; Non-PFAS Oxidation Byproducts Unknown
Pretreatment Requirements	Bulk Up-front PFAS Removal Process that may include Filtration (if necessary)	Bulk Up-front PFAS Removal Process that may include Filtration (if necessary)	Resilient Technology that may include simple filtration or pH adjust (if necessary)	Resilient Technology that may include simple filtration or pH adjust (if necessary)	Critical Pretreatment to Attain UF Quality Feed Prior to GAC Process	Extensive Pretreatment is Necessary; Process May not be Technically Viable	PFAS Destruction Process that Does not Require Pretreatment	PFAS Destruction Process that Does not Require Pretreatment
Commercial Viability	Commercially Viable - May Need to Scale Up to Larger Unit	Commercially Viable - May Need to Scale Up to Larger Unit	Commercially Viable – May need to be Enclosed in Dedicated Bldg Rather than Mobile Connex	Commercially Viable – May need to be Enclosed in Dedicated Bldg Rather than Mobile Connex	Commercially Viable; Inefficiencies Due to Need to Treat Town Sanitary Wastewater that is Free of PFAS	MBR and GAC are Commercially Available but not Effective for Pretreating JRL Leachate and Ensuring PFAS Removal	Developing Technology on the Cusp of Commercialization; May Need to Scale Up for Dolby Leachate Volume; EAOP may be better suited for concentrates	Developing Technology on the Cusp of Commercialization; May Need to Scale Up for JRL Leachate Volume; EAOP may be better suited for concentrates
Energy Demand	Not Energy Intensive	Not Energy Intensive	Energy Intensive; 12 to 15% of O&M is Electric	Energy Intensive; 10 to 12% of O&M is Electric	Not Energy Intensive	MBR is modestly Energy Intensive	Energy Intensive; 7 to 10 % of Lease/O&M Cost is Electric	Energy Intensive; 7 to 10 % of Lease/O&M Cost is Electric
Residuals Requiring Further Management	Estimated 550 gpd of Concentrated Foamate Requires Management	Estimated 350 gpd of Concentrated Foamate Requires Management	Estimated 11,000 gpd of RO Concentrate Requires Management	Estimated 6,900 gpd of RO Concentrate Requires Management	Spent GAC or Adsorbents Need to be Replaced and Disposed; Sludge likely will contain PFAS	Inorganic Sludge, Organic WAS and Spent GAC/IEX all Need to be Managed	No Residuals Generated	No Residuals Generated
COST								
Present Worth Cost - 5 Years	$15.8 to $22 million	$7.18 to $10.4 million	$25.91 million	$16.9 million	$17.0 to $23.1 million	$20.2 million	$30.62 million	$13.5 million
Capital Cost	$7.66 million	$2.63 million	$14.548 million	$8.05 million	$13.4 to $19.5 million	$ 16.997 million	$7.618 million	$2.59 million
Lease/Service Agree/O&M Cost	$1.88 to $3.31 million/Year	$1.05 to $1.8 million/Year	$2.62 million/Year	$2.04 million/Year	$0.84 million/Year	$0.735 million/Year	$5.3 million/Year	$2.52 million/Year
PW Cost/MG of Leachate Treated	$89,100 to $124,000/MG Leachate Treated	$72,000 to $105,000/MG Leachate Treated	$146,000/MG Leachate Treated	$169,000/MG Leachate Treated	$96,000 to $130,000/MG Leachate Treated	$203,000/MG Leachate Treated	$173,000/MG Leachate Treated	$135,000/MG Leachate Treated
Operational Complexity	Simple Process, Minimal Chemicals, Not Labor Intensive, Process is Mobile	Simple Process, Minimal Chemicals, Not Labor Intensive, Process is Mobile	Reliable and Effective Process will require more labor and O&M support in comparison to EAOP and FF	Reliable and Effective Process will require more labor and O&M support in comparison to EAOP and FF	Erratic spring peak flows of 0.877 to 1.3 MGD; EMWWTP eff not ideal as tertiary feed	Extremely Complex, Labor and Energy Intensive, Significant Chemicals, Two Sludge Side Streams to Manage	Process Operations are Not Complex; Challenge will be to scale technology and coordinate 16 trailer operations in series.	Process Operations are Not Complex; Challenge will be to scale technology and coordinate 9 trailer operations in series.
Complexity of Site Development	Landfill Site Development is Complex; Requires Significant EQ Due to Erratic Spring Leachate Flows	Landfill Site Development is Complex; EQ at JRL not as Extensive as Dolby due to Less Erratic Flows at JRL	Landfill Site Development is Complex; Requires Significant EQ Due to Erratic Spring Leachate Flows	Landfill Site Development is Complex; EQ at JRL not as Extensive as Dolby due to Less Erratic Flows at JRL	Landfill Site Development is Complex due to erratic leachate and town I/I Flows	Landfill Site Development is Complex; EQ at JRL not as Extensive as Dolby due to Less Erratic Flows at JRL	Landfill Site Development is Complex; Dolby Requires Significant EQ Due to Erratic Spring Leachate Flows	Landfill Site Development is Complex; EQ at JRL not as Extensive as Dolby due to Less Erratic Flows at JRL

APPENDIX A

RESOLVES, CHAPTER 82 AND 172

SME
SEVEE & MAHER
ENGINEERS

APPROVED
JUNE 21, 2021
BY GOVERNOR

CHAPTER
82
RESOLVES

STATE OF MAINE

IN THE YEAR OF OUR LORD
TWO THOUSAND TWENTY-ONE

S.P. 64 - L.D. 129

Resolve, To Protect Consumers of Public Drinking Water by Establishing Maximum Contaminant Levels for Certain Substances and Contaminants

Mandate preamble. This measure requires one or more local units of government to expand or modify activities so as to necessitate additional expenditures from local revenues but does not provide funding for at least 90% of those expenditures. Pursuant to the Constitution of Maine, Article IX, Section 21, 2/3 of all of the members elected to each House have determined it necessary to enact this measure.

Emergency preamble. Whereas, acts and resolves of the Legislature do not become effective until 90 days after adjournment unless enacted as emergencies; and

Whereas, perfluoroalkyl and polyfluoroalkyl substances are being identified at alarming levels in well water across the State; and

Whereas, perfluoroalkyl and polyfluoroalkyl substances are increasingly associated with significant health concerns that have major consequences for the residents of this State; and

Whereas, there is currently no enforceable standard to require water systems to test and treat for perfluoroalkyl and polyfluoroalkyl substances; and

Whereas, in the judgment of the Legislature, these facts create an emergency within the meaning of the Constitution of Maine and require the following legislation as immediately necessary for the preservation of the public peace, health and safety; now, therefore, be it

Sec. 1. Definitions. Resolved: That, as used in this resolve, the following terms have the following meanings.

1. Community water system. "Community water system" has the same meaning as in the Maine Revised Statutes, Title 22, section 2660-B, subsection 2.

2. Department. "Department" means the Department of Health and Human Services.

3. Nontransient, noncommunity water system. "Nontransient, noncommunity water system" means a nontransient, noncommunity water system described in the Maine Revised Statutes, Title 22, section 2660-B, subsection 5, paragraph A that is a school or child care facility regulated as a nontransient, noncommunity water system under the federal Safe Drinking Water Act.

4. Perfluoroalkyl and polyfluoroalkyl substances. "Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS" means a perfluoroalkyl substance or polyfluoroalkyl substance that is detectable in drinking water using standard analytical methods established by the United States Environmental Protection Agency, including regulated PFAS contaminants.

5. Regulated PFAS contaminants. "Regulated PFAS contaminants" means perfluorooctanoic acid, perfluorooctane sulfonic acid, perfluorohexane sulfonic acid, perfluorononanoic acid, perfluoroheptanoic acid and perfluorodecanoic acid.

Sec. 2. Interim drinking water standard and testing requirements for perfluoroalkyl and polyfluoroalkyl substances. Resolved: That community water systems and nontransient, noncommunity water systems shall comply with the provisions of this section.

1. Initial monitoring. On or before December 31, 2022, all community water systems and nontransient, noncommunity water systems shall conduct monitoring for the level of PFAS detectable using standard laboratory methods established by the United States Environmental Protection Agency in effect at the time of sampling. Monitoring under this subsection must be conducted for all regulated PFAS contaminants and additional PFAS included in the list of analytes in the standard laboratory methods established by the United States Environmental Protection Agency in effect at the time of sampling.

2. Subsequent monitoring. After completion of initial monitoring under subsection 1, a community water system or a nontransient, noncommunity water system shall conduct continued monitoring for the presence of regulated PFAS contaminants in drinking water supplied by the water system as follows until the adoption of rules required under section 3.

A. If initial monitoring under subsection 1 detects the presence of any regulated PFAS contaminants individually or in combination at or above 20 nanograms per liter, the community water system or nontransient, noncommunity water system shall conduct continued quarterly monitoring until regulated PFAS contaminants are mitigated as described in subsection 4.

B. If initial monitoring under subsection 1 detects the presence of any regulated PFAS contaminants at or above each analyte's lowest concentration minimum reporting level as specified in the standard laboratory methods established by the United States Environmental Protection Agency in effect at the time of sampling and the level is below 20 nanograms per liter, either individually or in combination with other detected regulated PFAS contaminants, the community water system or nontransient, noncommunity water system shall conduct continued monitoring annually.

3. Reporting. Monitoring results must be reported to the department in accordance with 10-144 C.M.R. Chapter 231, Section 6.

4. Treatment; notice. If monitoring results under subsection 1 or 2 confirm the presence of any regulated PFAS contaminants individually or in combination in excess of 20 nanograms per liter, the department shall:

A. Direct the community water system or nontransient, noncommunity water system to implement treatment or other remedies to reduce the combined levels of regulated PFAS contaminants in the drinking water of the water system below 20 nanograms per liter; and

B. Direct the community water system or nontransient, noncommunity water system to issue a notice to all users of the water system to inform them of the detected PFAS concentration and potential risk to public health until the treatment under paragraph A is completed.

5. Enforcement. The department may enforce the requirements of this section under the Maine Revised Statutes, Title 22, chapter 601, subchapter 2. A person may appeal the acts or decisions of the department under this section in accordance with Title 22, chapter 601, subchapter 2-A.

Sec. 3. Maximum contaminant level for perfluoroalkyl and polyfluoroalkyl substances. Resolved: That the department shall adopt a maximum contaminant level for perfluoroalkyl and polyfluoroalkyl substances in accordance with this section. Rules adopted pursuant to this section are routine technical rules as defined in the Maine Revised Statutes, Title 5, chapter 375, subchapter 2-A.

1. Advance notice of proposed rulemaking. On or before August 1, 2023, the department shall initiate a public notice and comment process for potential rulemaking by publishing an advance notice of proposed rulemaking regarding the department's regulation of regulated PFAS contaminants.

2. Proposed rule. On or before December 31, 2023, the department shall file a proposed rule with the Secretary of State establishing a maximum contaminant level for regulated PFAS contaminants and monitoring requirements for community water systems and nontransient, noncommunity water systems.

3. Final rule. On or before June 1, 2024, the department shall file a final rule with the Secretary of State regarding the regulation of regulated PFAS contaminants. The department may adopt federal regulatory requirements established by the United States Environmental Protection Agency, including maximum contaminant levels for regulated PFAS contaminants, if the new federal requirements are the same as or more restrictive than the interim drinking water standards described in section 2. The department shall submit a report to the joint standing committee of the Legislature having jurisdiction over health and human services matters upon adoption of the final rule that includes information about the final rule, including but not limited to the maximum contaminant levels adopted. The joint standing committee of the Legislature having jurisdiction over health and human services matters may report out legislation relating to the report.

Sec. 4. Repeal of interim drinking water standard and testing requirements. Resolved: That the interim drinking water monitoring requirements for PFAS and regulated PFAS contaminants under section 2 are repealed on the effective date of the rules required under section 3.

Sec. 5. Report by the Department of Health and Human Services. Resolved: That, beginning January 1, 2022 and annually thereafter until the rules pursuant to section 3, subsection 3 are finally adopted, the Department of Health and Human Services shall report to the joint standing committee of the Legislature having jurisdiction over health and human services matters on the number of water systems tested, what levels of perfluoroalkyl and polyfluoroalkyl substances were indicated upon testing and the status of the rule-making process under this resolve. The joint standing committee of the Legislature having jurisdiction over health and human services matters may report out legislation relating to each report.

Emergency clause. In view of the emergency cited in the preamble, this legislation takes effect when approved.

CHAPTER 172

H.P. 1385 - L.D. 1875

Resolve, To Address Perfluoroalkyl and Polyfluoroalkyl Substances Pollution at State-owned Solid Waste Landfills

Emergency preamble. Whereas, acts and resolves of the Legislature do not become effective until 90 days after adjournment unless enacted as emergencies; and

Whereas, to complete the study directed by this legislation, the Department of Administrative and Financial Services, Bureau of General Services is anticipated to need to contract, consistent with the State's procurement law, with an outside entity with expertise in landfill or wastewater treatment facility engineering and design, wastewater or leachate treatment technologies or other relevant backgrounds or experience; and

Whereas, to provide adequate time for that contracting and the subsequent development of the legislative report required by this legislation, this legislation must take effect immediately; and

Whereas, in the judgment of the Legislature, these facts create an emergency within the meaning of the Constitution of Maine and require the following legislation as immediately necessary for the preservation of the public peace, health and safety; now, therefore, be it

Sec. 1. Department of Administrative and Financial Services, Bureau of General Services to study methods of treating leachate from state-owned landfills. Resolved: That, in accordance with the provisions of this section, the Department of Administrative and Financial Services, Bureau of General Services, referred to in this section as "the bureau," shall conduct a study of methods of treating leachate collected at the state-owned solid waste landfills in Old Town, known as the Juniper Ridge Landfill, and in East Millinocket, known as the Dolby Landfill, collectively referred to in this section as "the landfills," to reduce the concentration of perfluoroalkyl and polyfluoroalkyl substances in the leachate. In conducting the study under this section, the bureau shall:

1. Consider treatment technologies other than dilution that are available or under development and that could be designed and installed on site at the landfills or at an off-site treatment facility to reduce perfluoroalkyl and polyfluoroalkyl substances in the leachate to no more than the interim drinking water standard established pursuant to Resolve 2021, chapter 82. If treatment to that standard is determined by the bureau to not be feasible based on available treatment technologies, the bureau may, with input from the Department of Environmental Protection, consider options to reduce perfluoroalkyl and polyfluoroalkyl substances in the leachate to a different standard;

2. Evaluate the feasibility of, a reasonable time frame for and the anticipated associated costs to the State or to the operators of the landfills, as the case may be, of developing the capacity and necessary facilities to treat the leachate on site at the landfills or, alternatively, to transport the leachate to an off-site facility for treatment;

3. Seek input from interested parties that, in the bureau's determination, are directly affected by the current discharge into the environment of wastewater containing leachate collected at the landfills and, as necessary, consult with the Department of Environmental Protection and the operators of the landfills; and

4. As necessary, contract with individuals or businesses with expertise in landfill or wastewater treatment facility engineering and design, wastewater or leachate treatment technologies or other relevant backgrounds or experience.

As used in this section, "perfluoroalkyl and polyfluoroalkyl substances" has the same meaning as in the Maine Revised Statutes, Title 32, section 1732, subsection 5-A.

Sec. 2. Department of Administrative and Financial Services, Bureau of General Services; report. Resolved: That, on or before January 15, 2023, the Department of Administrative and Financial Services, Bureau of General Services shall submit to the joint standing committee of the Legislature having jurisdiction over environment and natural resources matters a report containing its findings and recommendations, including any suggested legislation, resulting from the study conducted under section 1. After receiving the report, the joint standing committee may report out legislation to implement any such recommendations to the 131st Legislature.

Emergency clause. In view of the emergency

[redacted]

APPENDIX B

DOLBY LANDFILL AND JRL SITE VISIT NOTES

ANALYSIS FOR TREATING PFAS FROM STATE OWNED LANDFILLS
SITE RECONNAISSANCE MEETING NOTES
April 25 and 26, 2022

BACKGROUND

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are a group of man-made carbon-fluorine chemicals produced since the 1940s. They have been referenced as "forever chemicals" due to the strength of the carbon-fluorine bond that is not susceptible to degrading naturally or easily within typical treatment processes. PFAS have been detected in surface waters, groundwater, drinking water, wastewater treatment plant (WWTP) effluents, and landfill leachates. Over the past five years the United States Environmental Protection Agency (USEPA) has identified landfill leachates as a potentially significant source of PFAS to the environment.

The State of Maine Environmental and Natural Resources committee passed LD 1875 "to address PFAS Pollution at State-owned Solid Waste Landfills." LD 1875 includes language relative to the Bureau of General Services (BGS) completing a study of methods for treating leachate collected at the State-owned landfills. Sevee & Maher Engineers and Crawford Engineers (i.e., the SME Team) were contracted by BGS to conduct a study (i.e., the Study) to identify and assess treatment alternatives for reducing the concentration of PFAS in leachates that discharge from the State-owned solid waste landfills in East Millinocket (Dolby landfill) and Old Town (Juniper Ridge landfill).

Currently the leachate from the Dolby landfill flows by gravity to a lined leachate storage pond and then is pumped roughly 3.7-miles to the East Millinocket wastewater treatment plant (EMWWTP) where the leachate is combined with sanitary wastewater from the town of East Millinocket. The combined sanitary wastewater and leachate is treated via an extended aeration process and the treated effluent is discharged to the Penobscot River.

Leachate from the Juniper Ridge Landfill (JRL) is pumped from various cells to a 0.912 million gallon (MG) capacity above ground storage tank (AST) adjacent to the JRL site. Leachate is hauled from the AST to the Nine Dragons secondary wastewater treatment plant (WWTP) in Old Town by tanker truck and blended with approximately 24 million gallons per day (mgd) of pulp and paper wastewater. The secondary treated effluent from Nine Dragons is discharged to the Penobscot River.

The following Site Reconnaissance Meeting Notes summarize observations from the site visits to the Dolby landfill site, the JRL site and the EMWWTP that occurred on April 25th and 26th, 2022. In addition to conducting tours of the respective facilities, the SME Team also identified and evaluated potential locations for collecting leachate samples in support of the subject Study.

DOLBY LANDFILL AND E. MILLINOCKET WASTEWATER TREATMENT PLANT

Both the Dolby landfill and the EMWWTP sites were visited on April 25, 2022 and below are observations. The operators at the Dolby landfill (Dick Angotti and Jim Goodwin) and EMWWTP (Dave Hebert, Blaine McLaughlin and Greg Hawksley) coordinated site tours, answered question and provided support documentation for the respective facilities.

Dolby Landfill Overview. The Dolby Landfill facility consists of three landfill sites (Dolby I, Dolby II, and Dolby III) that are located on the east side of Route 157, approximately 2.5 miles northwest of East Millinocket.

The Dolby I landfill received a license from MEDEP in 1975 and occupies about 23 acres southwest of Dolby II and III. Dolby I is an unlined landfill and any leachate over the active operating and since closed years was managed by natural attenuation. The principal waste streams deposited at Dolby I were wastewater sludge, woodroom/woodyard waste, wood ash, and general rubbish from the Millinocket and East Millinocket mills. Waste was hauled to Dolby I between 1975 and 1979 and a final soil cover was placed over Dolby I in 1980-81. No leachate is collected from Dolby I and stormwater is primarily drained to the east and south away from Dolby II and III.

Dolby II is immediately east and upslope of Dolby III. It was licensed by MEDEP in 1978 and occupies about 75 acres. Dolby II is an unlined landfill. The principal waste streams delivered to Dolby II were woodroom/woodyard waste, wastewater sludge, wood ash, general rubbish from the Millinocket and E. Millinocket mills, and municipal solid waste (MSW) from the towns of Millinocket and E. Millinocket. Waste placement at Dolby II occurred from 1979 to 1986. A final soil cover was placed over Dolby II in 1987. Leachate and groundwater from Dolby II flows by gravity toward Dolby III and eventually to the leachate collection system, storage pond and pumping station west of Dolby III.

Construction of Dolby III commenced in 1984. Dolby III occupies about 73 acres and has been operated in stages. Dolby III is an unlined landfill with a series of leachate collection pipelines that were installed originally to dewater the site during construction and now serve as an active leachate collection network. The original waste streams at Dolby III were wastewater sludge, woodroom/woodyard waste, wood ash, rubbish from the Millinocket and E. Millinocket mills and MSW from the local communities. The disposal of MSW was discontinued in 1993 due to a change in solid waste regulations. Dolby III essentially stopped receiving waste in approximately 2012, when papermaking operations in Millinocket and East Millinocket were terminated. Dolby III was initially closed with a soil cover that occurred in progressive stages. Beginning in 2016 the Dolby III cover has been in the process of being upgraded by installation of a geomembrane barrier layer. As of the end of 2022 approximately 30-acres of geomembrane will have been installed. Leachate from Dolby III flows by gravity and combines with leachate from Dolby II, and eventually is stored in the leachate holding pond located immediately west of Dolby III.

The Dolby landfill facility is operated and maintained by SME pursuant to contracts awarded by the state beginning in 2011.

Dolby Leachate Collection System. Dolby I does not include a leachate collection system and the landfill was covered in 1981. Any leachate generated is allowed to infiltrate beneath the site and was managed by natural attenuation. As such, there is no leachate from Dolby I that contributes to the composite leachate collected from the Dolby Landfill facility.

Dolby II and III are both unlined landfills. Leachate and groundwater from beneath Dolby II drains to Dolby III. Dolby III is equipped with a partial leachate collection network that was originally installed to drain groundwater from the site during construction. The groundwater drains were left in-place after construction and now provide active groundwater and leachate drainage. The network of leachate collection pipelines drain by gravity to manhole CB-1 on the west side of the landfill site. The combined leachate from Dolby II/III then flows to a leachate holding pond that is double-lined with high-density polyethylene (HDPE) and has a maximum holding volume of about 5-MG. Adjacent to the leachate holding pond is a pump station equipped with two 35-hp pumps that operate in a lead-lag arrangement. Each pump is capable of pumping about 600 gallons per minute (gpm) while the combined pumping capacity if both pumps are operated is about 750-gpm. During the site visit the average leachate flow was about 400-gpm. The pumps are operated based on the water level in the leachate storage pond. Leachate flow is monitored via a Foxboro IMT 25 magnetic flow meter and the depth of the pond is measured via an ultrasonic level recorder located in the pump station's wet well. The leachate collection and pumping system do not include supervisory control and data acquisition (SCADA), but emergency alarms for loss of power, pump failure, and high levels in the wet well are monitored daily during periods of high leachate flow.

The combined leachate from Dolby II and III is pumped via an 8-inch diameter force main to an apex approximately 1.2 miles south of the leachate pond and then flows by gravity via an 10-inch diameter sewer to the EMWWTP. The total length of the force main and gravity sewer is roughly 3.7-miles. Figure 1 shows the location of the leachate collection system and the route of the leachate pipeline from Dolby to the EMWWTP. The landfill operation staff noted that the leachate forms encrustation and scale builds-up on the walls of the force main and sewer resulting in increased pump pressures and reduced flows. Localized sections of the leachate pipeline are cleaned every year and the entire pipeline is flushed and cleaned about every three years.

<u>Dolby Leachate Volume and Quality.</u> Over the past 10-years the volume of leachate from Dolby II/III has averaged about 60 million gallons per year (MG/yr) or roughly 164,000 gpd. Leachate generation volumes vary seasonally based primarily on the quantity of precipitation and groundwater elevations. In the spring, when leachate volumes are higher, the pumps may run 24-hours per day, 7-days per week while during drier months the pumps cycle much less frequently. SME will summarize the volume of Dolby leachate over the past three years and project the leachate volume reduction as more phases of Dolby III receive upgraded cover. In addition, the effectiveness of the 5-MG leachate pond to attenuate peak flows will be projected and average annual flows, peak monthly flows and maximum day flows will be calculated in order to size subsequent PFAS treatment processes.

Leachate quality data for Dolby II/III from approximately 2018 – 2021 has been collected and will be summarized to present historical landfill leachate quality. In addition, the SME Team, as part of the subject study, will collect two rounds of leachate samples and analyze the leachate for conventional pollutants as well as PFAS. Further, specific to the characterization of PFAS in leachate, the Solid Waste Division (SWD) of MEDEP is collecting samples from all landfills within the State of Maine over a three-year period and analyzing for 28 individual PFAS compounds. The SME team will analyze leachate samples for the same 28 PFAS compounds. To date the first round sampling by the MEDEP SWD has been completed. The composite of the six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA) regulated in Maine drinking water from Dolby was 351 nanograms per liter (ng/l or parts per trillion, ppt), greater than the maximum contaminant level (MCL) of 20 ng/l set by MEDEP in drinking water.

A few other observations regarding the Dolby leachate quality include the leachate appears very dilute based on visual observations (see Figure 2) which is confirmed by the relatively low conductivity of the leachate (typically between less than 400 to 500 umhos/cm). When observed on April 25 the leachate was “fresh” with no noxious odors such as sulfide or ammonia that often are associated with landfill leachates.

Current Dolby Leachate Treatment. Dolby landfill leachate is pumped from the leachate storage pond approximately 3.7-miles to the EMWWTP, combined with sanitary wastewater from the town of E. Millinocket, and then treated via an extended aeration process and discharged by gravity to the Penobscot River. Flow data for the past 27 months has been provided by EMWWTP operators and will be evaluated as part of the subject Study. On average, it is estimated that the Dolby leachate and sanitary flow from E. Millinocket are about 164,000 gpd and 341,000 gpd, respectively (total combined flow is roughly 505,000 gpd).

Figure 3 presents a simplified flow schematic that shows how the leachate and sanitary flows combine and the subsequent treatment train at the EMWWTP. The Dolby leachate is not pretreated prior to combining with the E. Millinocket sanitary wastewater at sanitary manhole 106B (SMH-106B). The combined flow is treated by mechanical screens, a vortex grit removal process, an extended aeration process, disinfected with sodium hypochlorite and is finally dechlorinated via sodium bisulfite. The WWTP process includes flow monitoring, automatic flow paced samplers, continuous monitoring for dissolved oxygen (DO) and chlorine residual as well as a SCADA system. The EMWWTP was completely upgraded in 2019 after the Katahdin Paper Mill (formerly GNP) closed and the former GNP WWTP was abandoned. Unit processes and monitoring locations are described below in the order of the treatment process.

Mechanical Screens. Mechanical screens (Duperon Flexrake) are located in the Screenings Room of the headworks building. The screens have a bar spacing of 0.5-inches and serve to collect and remove large solids from the wastewater. Screenings are removed automatically and fed to a screenings wash press for washing and compaction. The dewatered screenings are stored in a dumpster and periodically disposed off-site.

Vortex Grit Chamber. A vortex grit removal unit (manufactured by Envirodyne) is located downstream from the mechanical screens in the headworks building. Vortex grit removal uses centrifugal forces to separate denser grit from lower specific gravity organic solids and the wastewater flow. The separated grit slurry is pumped to a grit classifier that recirculates about 90 percent of the flow back to the wastewater stream. The separated and washed grit is dumped into a grit cart that is emptied and disposed off-site roughly once per week.

Headworks Bypass and Bar Screen. A bypass channel with a manual bar rack allows flow to be diverted around the headworks (mechanical screens and grit removal) in the event the screens or grit removal operations need to be off-line. The manual bar rack is constructed of aluminum with a bar spacing of 0.5-inches.

Influent Sampling Station and Flow Monitoring. Influent wastewater is sampled by means of an ISCO flow-paced automatic sampler located between the mechanical screens and grit chamber. The sampler is located in the northern corner of the electrical room within the headworks building. Composite samples are collected three times per week (Monday, Wednesday and Friday) and are flow-paced over a 24-hour period.

Influent flow monitoring is accomplished using a six-inch Parshall flume and ultrasonic level sensor located just upstream from the throat of the flume. This set-up is designed for flows between 0.035 and 2.5 mgd.

Aerated Lagoon System. As part of the 2019 EMWWTP upgrade the then existing secondary lagoon as part of the former GNP treatment facility was fully reconstructed and utilized for secondary treatment. Reconstruction included reconfiguring and lining the original lagoon, separating the new lagoon into three cells: the first cell is approximately 50 percent of the lagoon capacity (8.6 MG) and cells 2 and 3 are each about 25 percent of the lagoon volume (each 4.3 MG) for a combined volume of 17.2 MG. Cell 1 is separated from cells 2 and 3 by a lined earthen berm that was constructed lengthwise. Cells 2 and 3 are separated by a HDPE baffle curtain. Cell 1 is about 15-feet in depth and cells 2 and 3 are about 14.5-feet deep.

The new lagoons utilize a partial mix, extended aeration process with long solids retention times to remove biodegradable organics. Sedimentation of solids is accomplished in the downstream areas of the lagoons where there is limited aeration. Settled sludge is not actively removed from the process similar to a conventional activated sludge process but rather is allowed to accumulate within the cells and then dredged, dewatered and disposed from the lagoons about every 20 to 30 years.

Each lagoon is equipped with fine bubble tube diffusers (48 submerged tube assemblies) and the total design air flow is 434 standard cubic feet per minute (SCFM). Three positive displacement blowers (each 20-hp) equipped with variable frequency drives (VFDs) provide the necessary aeration to the diffusers. The blowers are located in a dedicated blower building. Under normal operations only one blower is necessary.

Disinfection. Disinfection is required at the EMWWTP from May 15th to October 1st each year. Sodium hypochlorite (NaOCl) is dosed at the head end of the chlorine contact basin and then flows in a serpentine path through one of two channels to provide the necessary contact time. Each channel is 3-feet wide by 12-feet deep by 130-feet long, which allows a contact time of 20-minutes at peak hourly flow and 148 minutes at average design flow. NaOCl is stored in a bulk fiberglass (FRP) tank in the Chemical Storage building and pumped to the contact tank using two chemical metering pumps that are flow-paced based on the effluent flow meter.

Effluent Flow Monitoring/Sampling Station. Both chlorine contact channels are equipped with ultrasonic level transducers to monitor flow and depth before passing over weirs into the dechlorination chamber.

An effluent sampler (ISCO) is housed adjacent to the downstream end of the chlorine contact tank. Similar to the influent sampler, the effluent sampler collects flow-paced composites and the sampler is refrigerated.

Dechlorination. Sodium bisulfite (NaHSO3) is pumped from the Chemical Storage building to the downstream end of the chlorine contact tank through a diffuser to ensure good mixing and proper dechlorination.

Support Facilities. Support facilities at the EMWWTP include: a process control, office, electrical room and laboratory building; a garage and tool room; standby generator; and the Allan Bradley Factory Talk SCADA software. EMWWTP does not include a plant water system or odor control facilities.

Preliminary Dolby Leachate Treatment Options. During the site reconnaissance on April 25th two options were identified for locating a treatment facility to remove PFAS from the Dolby leachate.

Construct a Leachate Treatment System at Dolby. This option would locate a dedicated PFAS treatment facility at the Dolby site. A number of potential locations could be considered although the undeveloped Site Trailer Location shown on Figure 1 appears most suited at this time. There is more than sufficient area to house a treatment plant at this location and electricity is already available onsite.

Situating a treatment plant at Dolby will likely require either a “gross PFAS pretreatment” approach such as Foam Fractionation (FF) with subsequent discharge to EMWWTP or constructing a dedicated PFAS treatment system (independent of EMWWTP) inclusive of secondary biological treatment and tertiary PFAS removal followed by direct discharge to the Penobscot River. The second option would likely require a secondary biological process to comply with pollutant limits established for biochemical oxygen demand (BOD5), total suspended solids (TSS), ammonia, pH, zinc and a number of toxic organics as outlined in the Landfill Point Source Development document for direct dischargers from non-hazardous landfills (EPA-821-R-97-022). Depending on the characteristics of the leachate other pretreatment such as oxidation, pH adjustment, coagulation and precipitation may be required and it may be necessary to add nutrients such as nitrogen and phosphorus to balance the carbon to nitrogen to phosphorus ratio for optimum biological treatment. A tertiary PFAS treatment train (such as GAC adsorption and/or ion exchange, IEX) would be located downstream from the secondary biological process and it is possible that an odor control process would need to be installed to control odors such as sulfides and ammonia that are common to landfill leachates. Depending on the ultimate PFAS treatment process, there may be a number of side streams and/or sludge that would also need to be managed.

The final treated effluent could be discharged one of two ways. First, if the “gross PFAS pretreatment” is implemented the effluent from the FF or equivalent technology would simply be connected to the existing pipeline from Dolby to the EMWWTP. In contrast, if a dedicated PFAS treatment facility is constructed at Dolby, the discharge scenario would be to pump the treated effluent into the existing 3.7-mile long pipeline that already extends to the EMWWTP and to construct a bypass around the treatment processes and tie-in to the existing outfall to the Penobscot River.

Construct a PFAS Polishing System at the EMWWTP. In this situation the EMWWTP would continue to provide secondary biological treatment of the combined leachate from Dolby and the sanitary wastewater from the Town of E. Millinocket. The treated effluent currently meets the National Pollution Discharge Elimination System (NPDES) requirements for conventional pollutants such as BOD5, TSS, pH and E. coli to discharge to the Penobscot River. In addition, the secondary biological process would likely yield a sufficiently pretreated wastewater that could be treated by a process such as GAC adsorption and/or IEX without the need for "leachate pretreatment."

In contrast to the dedicated leachate treatment system at Dolby to treat only Dolby leachate, the PFAS polishing treatment system for this option must be designed to handle the combined leachate and sanitary wastewater volume (roughly three times the volume of treating for leachate only). However, the existing infrastructure at this site would be a significant benefit and would eliminate the need for a treatment process for BOD5, TSS, pH and ammonia removal at the Dolby site. There is more than ample room in the vicinity of the chlorine contact tank and outfall structure to locate a PFAS treatment train. Further, there is already electricity at the site, the PFAS treatment operation could easily be integrated into the existing SCADA, and there should be synergies in arranging for the EMWWTP operators to eventually operate the PFAS treatment unit operation.

JUNIPER RIDGE LANDFILL AND NINE DRAGONS WWTP

Leachate from the JRL site is collected via a series of leachate collection drains, pumped via four leachate pump stations to a 0.912 MG AST, hauled by tanker truck approximately seven miles to the Nine Dragon secondary WWTP in Old Town, combined with about 24 mgd of pulp and paper wastewater, and then treated and discharged to the Penobscot River. The JRL site was visited on April 25 and observations are presented below. Management from Nine Dragons were not willing to allow a site tour and/or sampling of the influent and effluent from the Nine Dragon WWTP. JRL is owned by the State of Maine BGS and is operated by NEWSME, a subsidiary of New England Waste Services. The site engineer for the JRL operation (Jeremy Labbe) coordinated the site tour, answered questions and provided support documentation for the JRL facilities.

Juniper Ridge Landfill Overview. JRL was originally owned and operated by Fort James Operating Company (Fort James) and subsequently by Georgia-Pacific (GP) between December 1996 and February 2004. In 1989, the Maine Legislature banned permitting of new commercial solid waste disposal facilities and placed the responsibility for providing future disposal capacity on the State itself. Subsequently, in 2003 the Legislature directed the State to acquire the JRL to address the solid waste disposal needs of Maine residents and businesses and in February 2004 the JRL was sold to the State of Maine.

JRL was originally permitted for the disposal of pulp and papermaking residuals from the Fort James/GP Old Town mill (primarily wastewater treatment plant sludge), bottom ash from Lincoln Pulp and Paper, and burn pile ash from the City of Old Town transfer station. In addition, the landfill is currently permitted to accept residues from waste-to-energy facilities (i.e., by-pass municipal solid waste-MSW), construction and demolition (C&D) debris, and other non-hazardous wastes generated within the State of Maine.

JRL includes the original 68-acre landfill footprint (cells 1 – 10) and an approved 54-acre expansion with seven cells (cells 11 – 17). Cell 11, 12, and 13 were constructed in 2018, 2020 and 2021, respectively, and cells 14 – 17 are yet to be constructed. JRL has been designed and constructed as a secure waste disposal facility in that the groundwater beneath and adjacent to the site is protected by a composite liner and leachate collection system (for the original JRL cells) and a double lined system with leak detection was installed for the 2017 approved expansion.

JRL's permitted footprint including the 2017 expansion is now approximately 122-acres. The existing landfill infrastructure also includes a 2-mile long access road, a maintenance/administration building, several storage buildings, a dual scale house, a former leachate storage pond now used for stormwater detention, a 0.912 MG leachate AST, four leachate pump stations, a leachate tanker truck loading rack, a water hauling truck loading rack, multiple detention and sedimentation ponds, a construction materials laydown area, a landfill gas flare, a sulfide gas scrubbing system, and a perimeter access road.

Juniper Ridge Leachate Collection System. The original landfill cells (1 – 10) were constructed with underdrain systems to relieve upward groundwater pressures as appropriate. The cells have a composite liner system consisting of an 80-mil HDPE membrane overlying a geocomposite clay liner and two-feet of low permeability soil. The cells also contain a leachate collection system consisting of a 12-inch layer of granular material, geocomposite drainage net, and a piping network consisting of 6- and 8-inch diameter collection laterals spaced at about 100- to 200-feet that connect to 8-inch and 12-inch diameter header pipes. Only temporary cover has been placed over the sides of cells 1 – 10 and cells 1, 2, 5 and 6 have temporary cover on top of the landfill cells.

Cells 11 through 17 are/will be constructed with two liners (primary and secondary), a leak detection system, leachate and gas collection systems, and intermediate and eventually final cover. Under the entire expansion an imported soil layer of compacted clay serves to provide a uniform, low hydraulic conductivity layer beneath the secondary liner. A granular underdrain collection system is installed beneath about 12.7 acres of the expansion where the landfill base is located below the site's water table. The leachate collection design is similar to that of cells 1 – 10. Cells 11 – 13 are currently operating and uncovered.

There are four leachate pump stations (PS 4, 5, 8 and 13) that are designed and constructed to handle leachate from one or more cells, and a fifth pump station (PS 14) is scheduled to be brought on-line in 2022. Each pump station transfers the leachate to a 921,000 gallon AST for temporary storage prior to tanker trucking the leachate to Nine Dragons for treatment and discharge. A fifth leachate pump station will constructed at JRL in the next several years as the permitted landfill cells become fully developed.

Juniper Ridge Leachate Volume and Quality. During 2021 the total quantity of leachate sent off-site was about 15.2 MG/year or roughly 42,000 gpd on average. Average volumes of leachate range from 1.6 MG/month to 0.886 MG/month. The operator estimates anywhere from 8 to 10 tanker truckloads per day 5 days per week of leachate are taken to Nine Dragons.

SME will be summarizing the volume of JRL leachate over the past three years and projecting the leachate volume reduction as cells are covered and closed. In addition, the effectiveness of the 0.921-MG leachate AST to attenuate peak flows will be projected and average annual flows, peak monthly flows and maximum day flows determined in order to size subsequent PFAS treatment processes. The JRL average leachate flow (0.042 mgd) is less than 0.2% of the influent Nine Dragons flow (estimated at 24 mgd).

Leachate quality data for JRL from approximately 2018 – 2021 has been collected and will be summarized to present historical landfill leachate quality. In addition, the SME Team, as part of the subject study, will collect two rounds of samples and analyze the leachate for conventional pollutants as well as PFAS. Further, specific to the characterization of PFAS in leachate, the SWD of MEDEP is collecting samples from all landfills within the State of Maine over a three-year period and analyzing for 28 individual PFAS compounds. The SME team will be analyzing leachate samples for the same 28 PFAS compounds. To date the first round of sampling by the MEDEP SWD has been completed. The composite of the six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA regulated in Maine drinking water) from JRL was 410 ng/l or ppt, which is greater than the maximum contaminant level (MCL) of 20 ng/l set by MEDEP for drinking water.

A few other preliminary observations regarding the JRL leachate quality include the leachate appears concentrated and opaque based on visual observations (see Figure 2). That condition is confirmed by the relatively high conductivity of the leachate (typically between 11,300 to 37,900 umhos/cm). The leachate when observed on April 25 was tending anaerobic with notable sulfide odors that are often associated with landfill leachates. A preliminary review of the historical JRL leachate quality indicates a very concentrated leachate with high organic content, high ammonia, positive occurrences for alpha terpineol, benzoic acid, and phenol, and excessive levels of cations and anions.

<u>Current Juniper Ridge Leachate Treatment.</u> Leachate generated at JRL is collected, stored, and then hauled by tanker trucks to the Nine Dragons WWTP in Old Town for treatment. JRL also maintains an Industrial Wastewater Discharge Permit with the City of Brewer water pollution control facility (WPCF) as a backup disposal site.

Figure 4 presents a simplified flow schematic that shows how the JRL leachate and Nine Dragons influent flows combine and the subsequent treatment train at the Nine Dragon WWTP. The JRL leachate is NOT pretreated prior to combining with the Nine Dragons influent at the aerated lagoon receiving station.

Only limited information is available on the Nine Dragons treatment process. It appears combined flows (roughly 24 mgd) are treated by mechanical screens, primary clarifiers (two, each 150-feet in diameter), a 50 MG capacity aeration basin, and secondary clarifiers (two, each 170-feet in diameter). Treated effluent is discharged to the Penobscot River. Primary and waste activated sludge are blended and dewatered and then hauled off-site (to JRL).

<u>Preliminary Juniper Ridge Leachate Treatment Options.</u> Initially it was projected that the JRL leachate could be treated at a dedicated leachate facility located adjacent to the 0.921 AST at JRL and the treated effluent discharged directly to the Penobscot River (or waters connecting to the Penobscot River) or the effluent could continue be trucked to the Nine Dragons WWTP or a pipeline to Nine Dragons could be installed. During the site reconnaissance visit it became clear that the option to construct a pipeline seven miles from JRL to Nine Dragons (Figure 5) is not feasible. Further, (from discussions with MEDEP) it is highly unlikely that a permit for a new discharge outfall to the Penobscot River could be obtained.

The backup option of hauling the leachate from JRL to Nine Dragons and then treating the ENTIRE 24-mgd of combined papermaking and JRL leachate for PFAS removal was dismissed as not practical.

At this time the primary JRL leachate treatment option is to design and construct a dedicated leachate treatment adjacent to the AST at the JRL site. Similar to the dedicated leachate treatment system for consideration at the Dolby site, the leachate at JRL could potentially be treated by a "gross PFAS pretreatment" such as FF and then hauled to Nine Dragons for final treatment of other parameters not treated during the gross PFAS pretreatment process or alternatively an advanced tertiary treatment train could be constructed at JRL that would require pretreatment (such as oxidation, pH adjustment, coagulation and precipitation), secondary biological treatment and tertiary PFAS treatment (such as GAC and/or IEX). Depending on the ultimate PFAS treatment process, there may be a number of side streams and/or sludge that will also need to be managed if full treatment occurs at JRL. The final treated effluent could be trucked to a treatment facility such as Nine Dragons or the City of Brewer WWTP, which both have licensed effluent discharges to the Penobscot River. These options will need to be further developed and evaluated.

IDENTIFIED POTENTIAL SAMPLE LOCATIONS

As part of the site reconnaissance visit, potential sample locations at the Dolby landfill, EMWWTP, JRL and Nine Dragon WWTP were identified and evaluated by the SME team. Sampling episodes are tentatively scheduled for May 2022 (spring, high groundwater and high leachate volume conditions) and June/July 2022 (summer, low groundwater and low leachate volume conditions). Sample locations include:

Dolby Leachate at Manhole CB-1. This sample represents "fresh" leachate that is flowing from the Dolby II and Dolby III landfills. Samples will be collected as a grab sample and will be analyzed for conventional pollutants (BOD5, total organic carbon (TOC), TSS, ammonia and pH), zinc, regulated toxic organics, anions and cations, a number of non-conventional pollutants and for the 28 PFAS compounds identified by MDEP for testing.

Dolby Leachate from the Effluent of the Leachate Pond. This sample represents the effluent from the leachate holding pond that flows to the EMWWTP. This sample is representative of the composite leachate that is discharged from the Dolby site and can be diluted with precipitation and snow melt. This sample will be collected as a grab sample and analyzed for the same parameters listed above.

East Millinocket Influent Sanitary Sample. A sample of the sanitary wastewater (prior to combining with the Dolby leachate) will be collected immediately upstream of SMH-106B. This will represent the contribution of flow and pollutant loadings from the Town of E. Millinocket only. This sample will be collected as a grab sample and analyzed for the same parameters listed above.

EMWWTP Influent and Effluent Samples. SME will coordinate with EMWWTP operators to obtain sample aliquots from the one of the three weekly 24-hour influent and effluent composite samples collected by the EM staff for NPDES reporting. Both locations have ISCO automatic, flow-paced samplers. Samples will be analyzed for the same parameters listed above.

EMWWTP Secondary Sludge. Initially it was planned to collect a biological sludge sample from the secondary treatment process in an effort to characterize the tendency of PFAS to partition to the sludge stream. However, the extended aeration process allows sludge to accumulate within the aeration lagoon for between 20 and 30-years and the operators stated there was no means to collect such a sample. As such, no sludge sample will be collected from the EMWWTP lagoon.

JRL Leachate. Leachate at JRL is pumped to a 0.912 MG capacity holding tank and then hauled by tanker truck to the Nine Dragons WWTP. Leachate samples will be collected as the leachate is pumped from the storage tank to the tanker truck and represents leachate being transported from JRL. This sample will be collected as a grab sample and analyzed for the same parameters listed above. The leachate in the holding tank is a composite of the leachate pumped by the four existing pump stations associated with the JRL waste cells.

Nine Dragons WWTP Samples. Initially it was planned to collect influent, effluent and sludge samples from the Nine Dragons activated sludge treatment process in Old Town where the JRL leachate is hauled and treated. However, the management of Nine Dragons was not receptive to The SME team conducting a site visit or sampling at the WWTP because LD 1875 had not been enacted. No samples are therefore projected to be collected from the Nine Dragons WWTP.

NOTABLE PRELIMINARY OBSERVATIONS FROM SITE RECONNAISSANCE VISIT

A number of salient observations were recorded during the site reconnaissance visit. These include:

- Leachate samples from Dolby and JRL were visually very different from one another. The Dolby leachate was clear and dilute while the JRL leachate was a dark opaque color and concentrated. Further, the Dolby leachate was “fresh” without obvious odors for sulfides or ammonia, while the JRL leachate appeared more anaerobic with obvious sulfide odors.

  Further historical leachate quality data from 2018 to 2021 was gathered for both Dolby and JRL and briefly reviewed. The leachate quality between Dolby and JRL is strikingly different. JRL leachate has a very high organic content, high ammonia levels, positive occurrences for toxic organics that will need to be treated, and excessive levels of cations and anions that will be competing for PFAS removal via carbon adsorption or ion exchange. In contrast, the Dolby leachate is dilute for all of the compounds referenced above. These observations highlight the point that leachates are not homogenous and may vary significantly in appearance and quality.

- Preliminary flow data was collected and reviewed for the Dolby and JRL leachates and the respective WWTPs that currently receive these leachates. The Dolby leachate is estimated to average about 164,000 gpd and represents about 33 percent of the total influent flow (505,000 gpd) to the EMWWTP. In contrast, the JRL leachate flow averages about 42,000 gpd and represents less than 0.2 percent of the estimated influent flow to Nine Dragons (24,000,000 gpd).

- Dolby leachate infrastructure currently includes a 5 MG leachate storage pond, pump station, 3.7-mile long pipeline from Dolby to the EMWWTP, the leachate is then treated along with sanitary wastewater from East Millinocket at the EMWWTP, and the treated effluent is discharged to the Penobscot River. The option of constructing a tertiary PFAS treatment process at the tail end of the existing secondary treatment at EMWWTP is very attractive, particularly if the secondary biological process provides some effective pretreatment for PFAS removal. This option negates the need for constructing a dedicated pretreatment, secondary biological and tertiary PFAS removal process at the Dolby site. The concept of constructing a “gross PFAS pretreatment “ system at Dolby with discharge to EMWWTP will also be evaluated.

- Although Nine Dragons was not willing to allow a tour and/or sampling of their secondary activated sludge process, a number of alternate routes for constructing a pipeline from JRL to Nine Dragons were explored. In general, the routes are all about 7-miles in length with no simple pathway. Further, if a PFAS treatment system were installed at JRL it is extremely unlikely that a new outfall to the Penobscot (that would be closer to JRL) could be permitted.

- It is not feasible to continue to haul the JRL leachate to Nine Dragons and subsequently treat the ENTIRE Nine Dragons wastewater influent flow of roughly 24-mgd (of which only 0.042 mgd is JRL leachate on average) for PFAS (in such a scenario it is possible that the primary and waste activated sludge at Nine Dragons could also contain PFAS and require treatment or additional management).

- The most likely option for removing PFAS from the JRL leachate will include a “gross PFAS pretreatment” at a site adjacent to the 0.921 MG storage tank JRL and then to haul the pretreated leachate to Nine Dragons for secondary biological treatment.

Attachments:

Figure 1 – Overview of Dolby Landfill and Pipeline Route to EMWWTP
Figure 2 – Photograph of Dolby and JRL Leachates
Figure 3 – Simplified Flow Schematic of Dolby Leachate Infrastructure and EMWWTP
Figure 4 – Simplified Flow Schematic of JRL Leachate Infrastructure and Current Nine Dragon WWTP
Figure 5 – Overview of JRL and Pipeline to Nine Dragons WWTP

NOTES

1. BASE MAP FROM GOOGLE EARTH PHOTO DATED 8/2019.
2. EXISTING PROPERTY BOUNDARY FROM PLAN ENTITLED "BOUNDARY SURVEY OF A PORTION OF THE KATAHDIN PAPER COMPANY LLC PROPERTY, EAST MILLINOCKET, MAINE, VOLUME 8702, PAGE 146 FOR KATAHDIN FOREST MANAGEMENT" PREPARED BY PLIGSA & DAY LAND SURVEYORS, DATED MAY 31, 2011.
3. MANHOLE PIPE LOCATIONS FROM SQUAW BAY CORPORATION DRAWING DATED 4/25/95. LOCATIONS ARE APPROXIMATE.

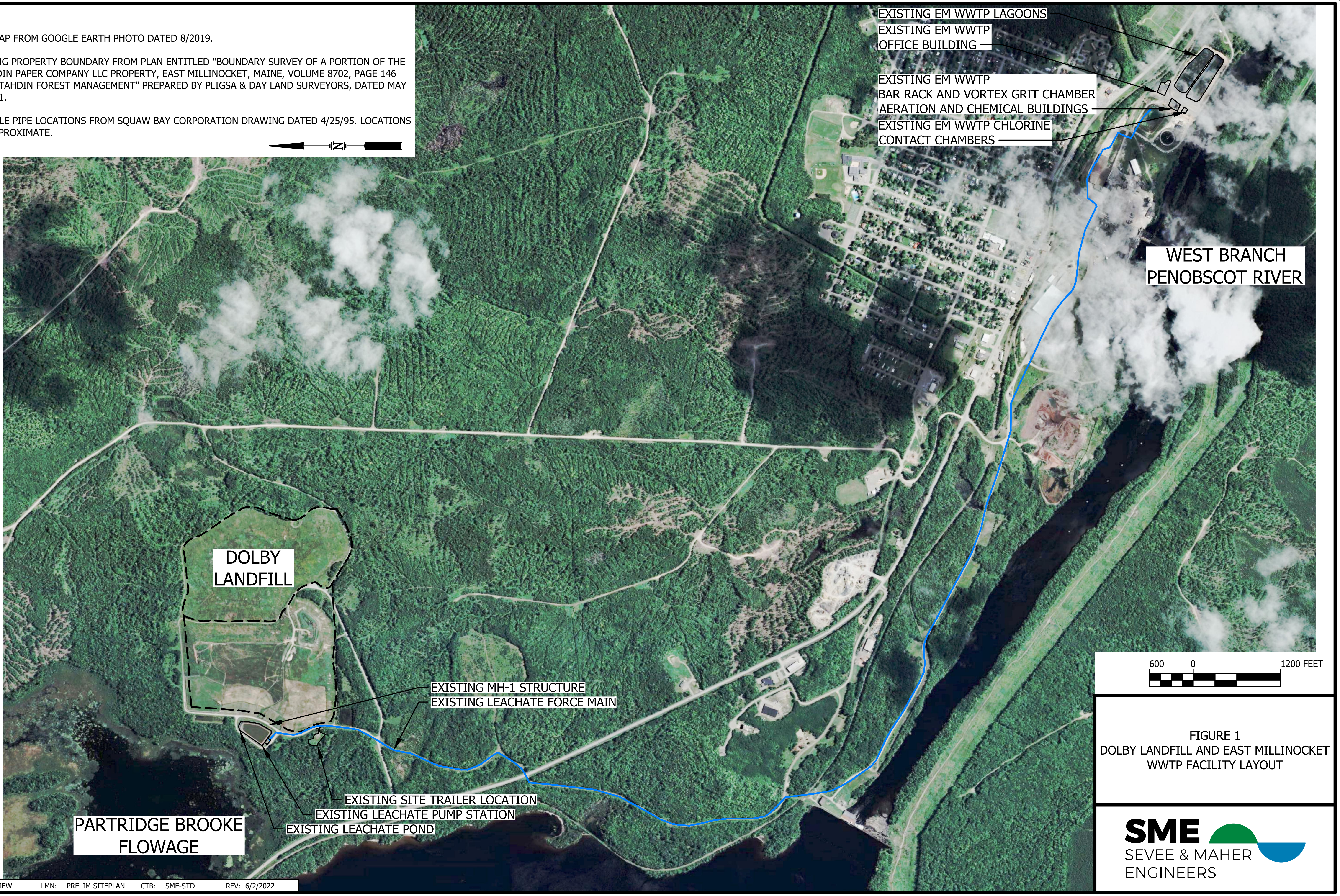

FIGURE 1
DOLBY LANDFILL AND EAST MILLINOCKET
WWTP FACILITY LAYOUT

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: PRELIM SITEPLAN CTB: SME-STD REV: 6/2/2022

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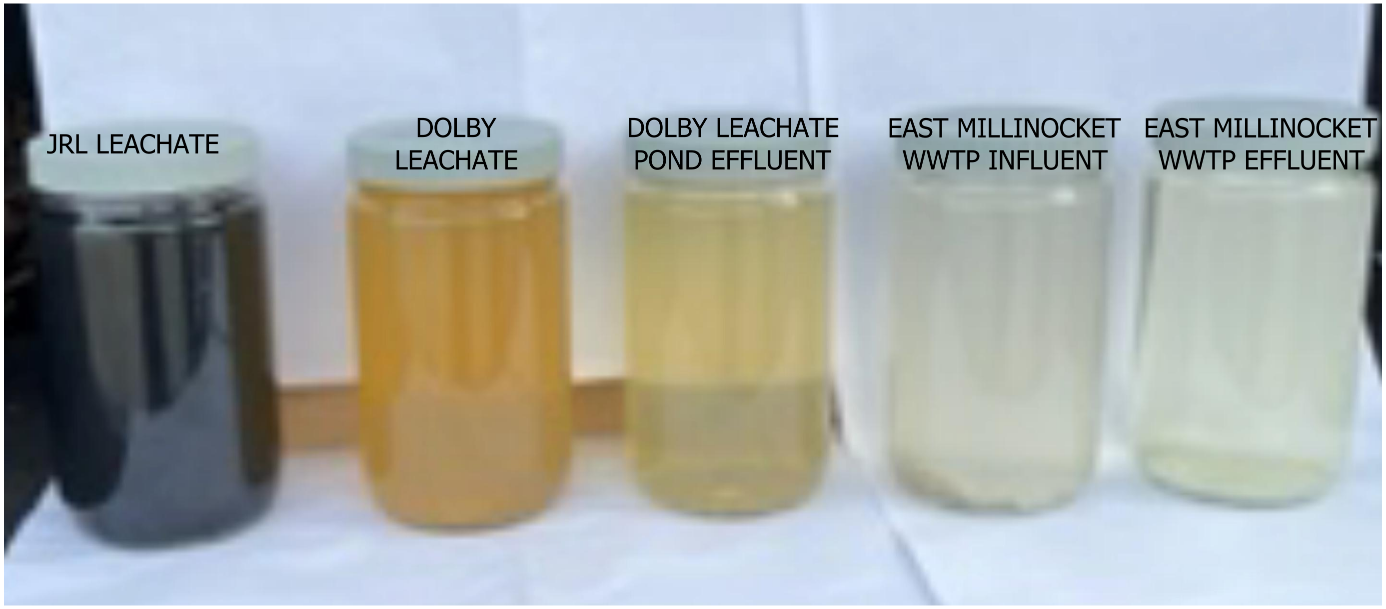


FIGURE 2
PHOTOGRAPH OF DOLBY
AND JRL LEACHATES

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 6/2/2022

\\Nserver\cfs\Kpc\Dol\PFAS\ACAD\SCHEMATICS.dwg, FIG 2 SAMPLES, 6/2/2022 12:48:32 PM, jrl

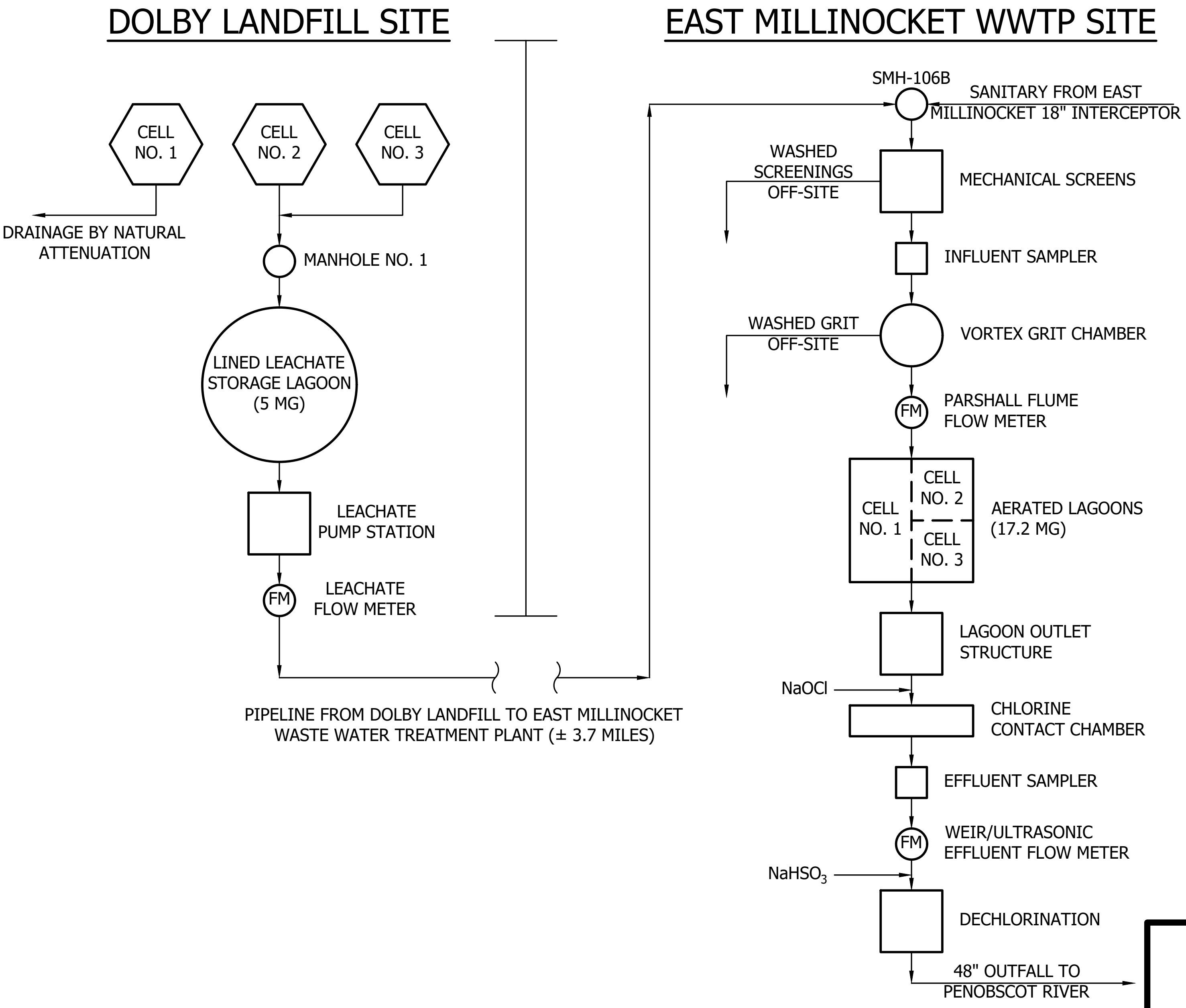


FIGURE 3
DOLBY LANDFILL AND EAST
MILLINOCKET WASTE WATER
TREATMENT PLANT

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 6/2/2022

\\Nserver\cfs\Kpc\Dol\PFAS\ACAD\SCHEMATICS.dwg, FIG 3 DOLBY, 6/2/2022 12:48:36 PM, jrl

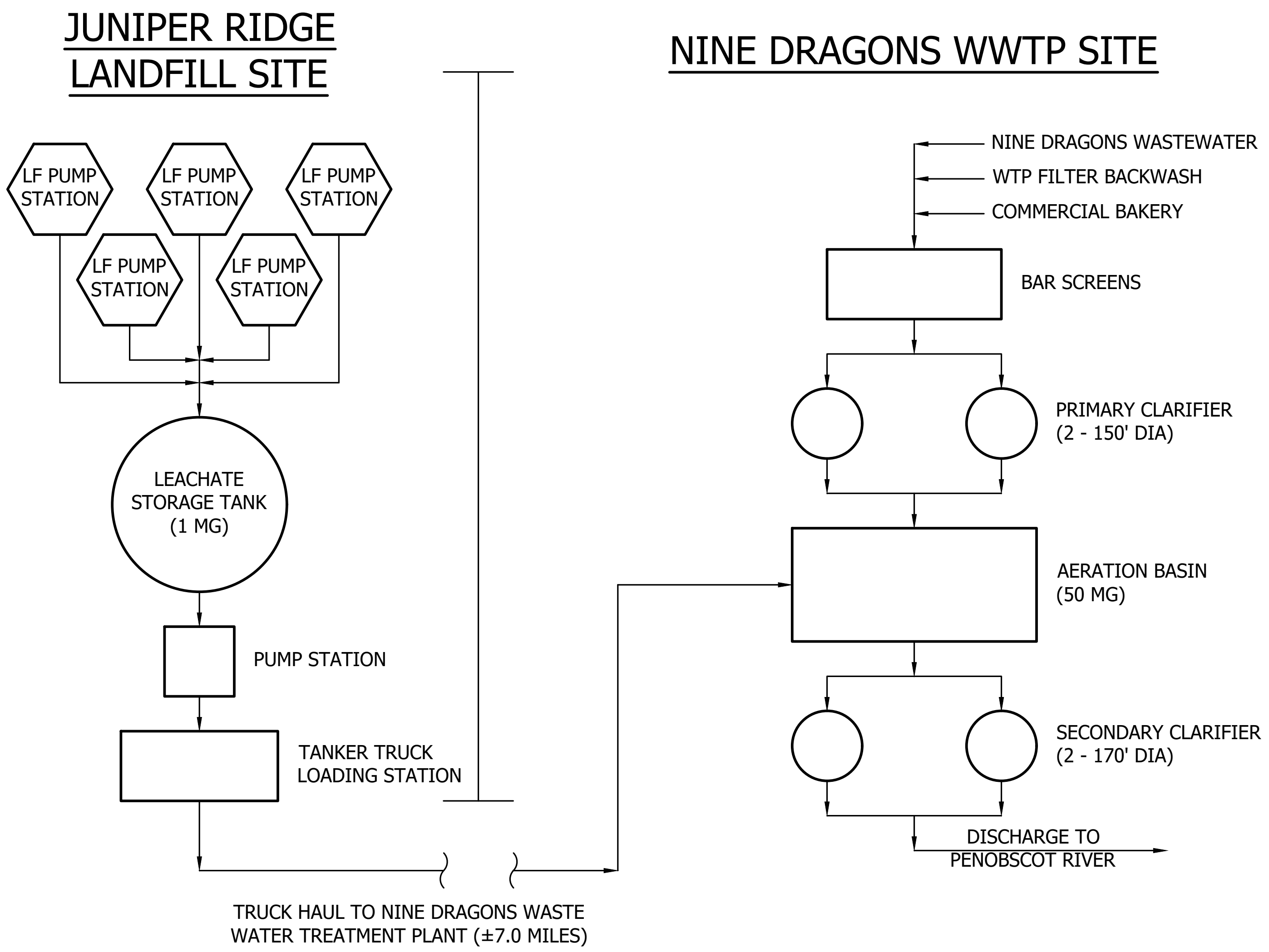


FIGURE 4
JUNIPER RIDGE LANDFILL
AND NINE DRAGONS WASTE
WATER TREATMENT PLANT

SME
SEVEE & MAHER
ENGINEERS

DWG: SCHEMATICS LMN: LMN CTB: SME-STD REV: 6/2/2022

\\Nserver\cfs\Kpc\Dol\PFAS\ACAD\SCHEMATICS.dwg, FIG 4 JRL, 6/2/2022 12:48:41 PM, jrl

FIGURE 5
JUNIPER RIDGE LANDFILL AND NINE DRAGONS WWTP FACILITY LAYOUT

SME
SEVEE & MAHER ENGINEERS

DWG: SITEOVERVIEW LMN: PRELIM SITEPLAN CTB: SME-STD REV: 6/2/2022

\\Nserver\cfs\Kpc\Do\PFAS\ACAD\SITEOVERVIEW.dwg, FIG 5 JRL, 6/2/2022 12:51:05 PM, jrl

APPENDIX C

DOLBY, JRL AND EAST MILLINOCKET WWTP SITE PHOTOS

SME
SEVEE & MAHER
ENGINEERS

Dolby Photos

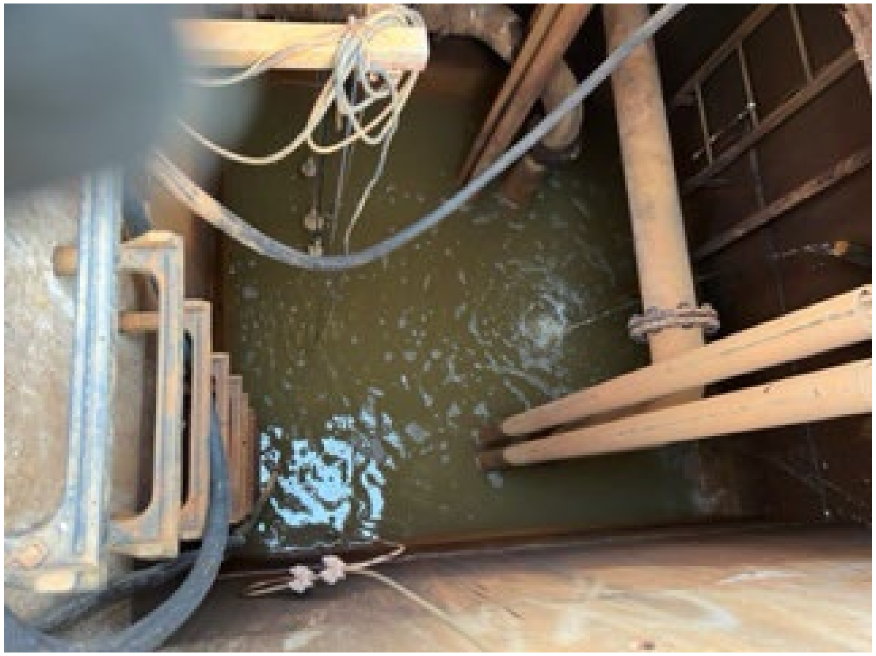
CB #3 at Dolby Landfill

Leachate Lagoon at Pumpstation at Dolby Landfill

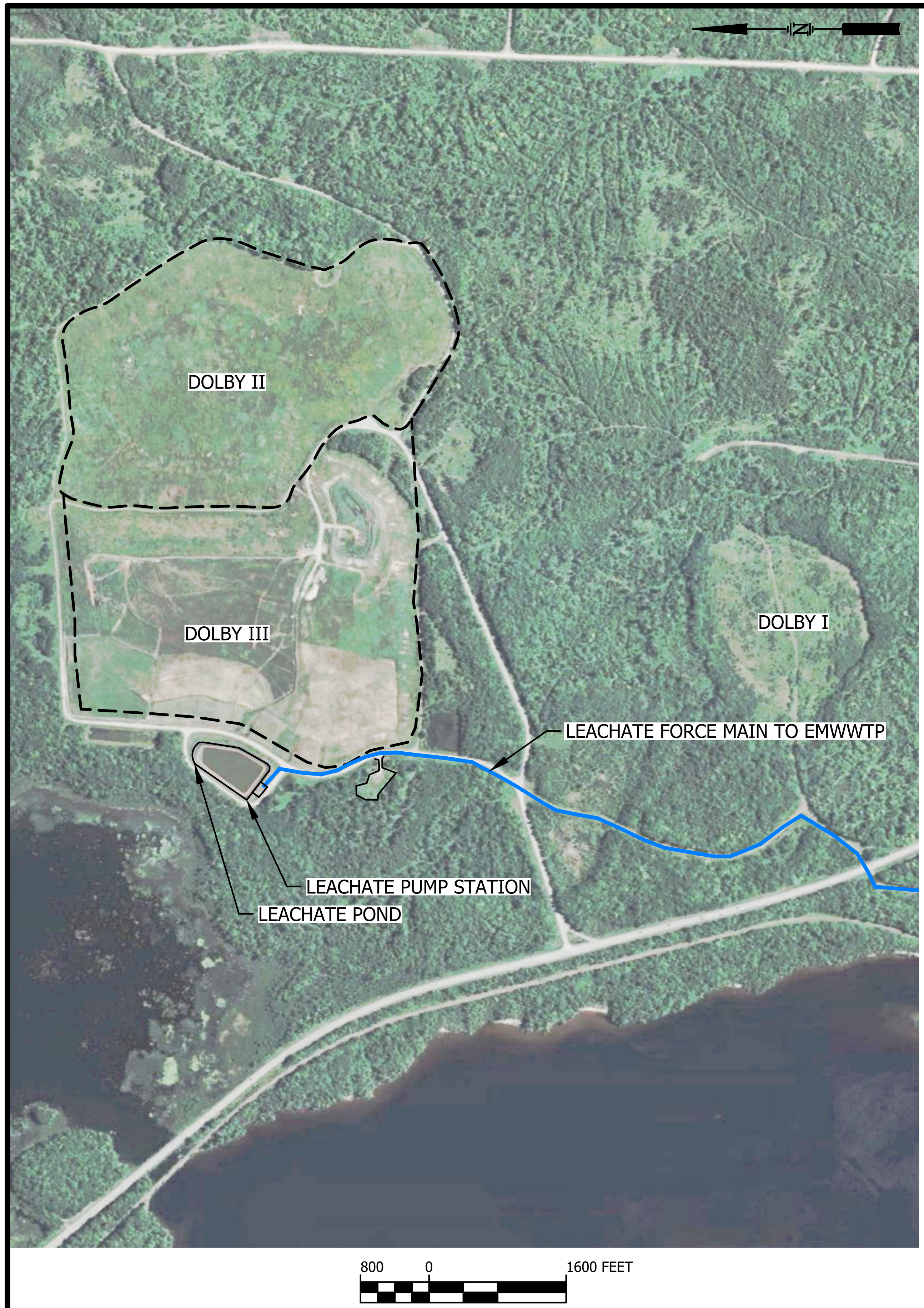
Dolby Photos

Leachate Pumpstation Control Panel

Potential Site 3



Pumpstation Wet Well



LANDFILL PLAN

LEACHATE PIPED 3.7 MILES TO TREATMENT PLANT EMWWTP

LEACHATE POND AND PUMP STATION

DOLBY LANDFILL
LEACHATE TO EMWWTP

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: PRELIM SITEPLAN CTB: SME-STD REV: 9/19/2022

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EMWWTP PHOTOS

Aerated Lagoon 2

Aerated Lagoon 3

Mechanical Screens

Vortex Grit Unit

Washed Grit

Washed Screenings

Blowers for AB

NaHSO3 and NAOCl Tanks

Cl2 Contact Tank

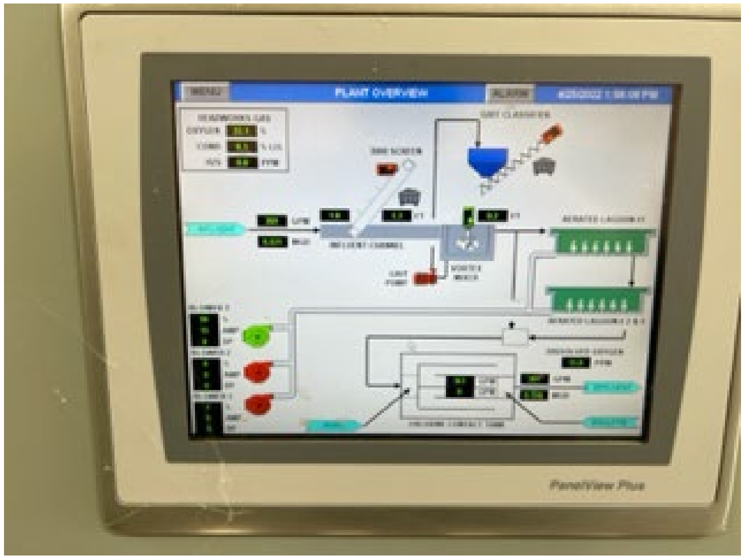
Effluent Sampler

EMWWTP PHOTOS

Disinfected Effluent

Potential Site 1

EMWWTP PHOTOS



SCADA Screen

EMWWTP Site Map

JRL PHOTOS

Generator

Leachate Storage Tank

JRL PHOTOS

Truck Loading Station

JRL Site

LANDFILL PLAN

LEACHATE TRUCKED 7 MILES TO TREATMENT PLANT

LEACHATE LOADING RACK AND TANK

JUNIPER RIDGE LANDFILL
LEACHATE TO NDWWTP

SME
SEVEE & MAHER
ENGINEERS

DWG: SITEOVERVIEW LMN: PRELIM SITEPLAN CTB: SME-STD REV: 6/2/2022

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APPENDIX D

FOAM FRACTIONATION LABORATORY BENCH-SCALE STUDIES

APPENDIX D-1

TECHNICAL MEMO SUMMARIZING FOAM FRACTIONATION BENCH SCALE TESTING RESULTS

SME
SEVEE & MAHER
ENGINEERS

TECHNICAL MEMORANDUM NO. 6
FOAM FRACTIONATION LABORATORY BENCH SCALE RESULTS
September 26, 2022

OVERVIEW

LD 1875 stipulates the Bureau of General Services (BGS) conduct a Study to assess the feasibility to reduce per- and polyfluoroalkyl substances (PFAS) associated with leachate that is generated by the Dolby Landfill and the Juniper Ridge Landfill (JRL). The Study included a technology review to screen potential treatment processes for removing PFAS from leachate. Foam fractionation (FF) was identified as a developing technology that has been successfully implemented in the clean-up of aqueous film-forming foam (AFFF) used for fire suppression, landfill leachate, and other sites where the release of high concentrations of PFAS has occurred.

Two experienced technology vendors (Sanexen and ECT2) that provide FF for PFAS treatment agreed to demonstrate the viability of FF by conducting bench-scale laboratory treatability testing of leachate from Dolby and JRL. This technical memorandum provides a summary of the procedures and results from the bench-scale laboratory treatability simulations. Copies of the specific bench scale testing reports prepared by Sanexen and ECT2 are included as attachments to this memorandum.

FOAM FRACTIONATION TECHNOLOGY

FF is a remediation technology that has been newly developed for treatment of PFAS contaminated drinking water, wastewater, leachate and high concentrated PFAS wastes from releases such as AFFF activities. Although the application of FF to reduce PFAS pollution is relatively new, the technology has been employed for years in the separation of proteins (such as fish wastes in aquariums). The FF process is simple, has few moving parts, and is relatively inexpensive to construct and operate in comparison to other PFAS technologies that may require significant pretreatment. FF takes advantage of the high surface activity imparted by the chain of fluorocarbon molecules that comprise various PFAS and the affinity those molecule(s) have to adsorb onto the surface of air bubbles. PFAS species with longer molecular chains benefit from higher adsorption coefficients and are easier to remove using FF as compared to shorter-chain species that exhibit lower adsorption coefficients.

The FF process is similar to a counter-current air stripper or dissolved air flotation (DAF) technology. A vessel (i.e., fractionator) containing a water column is equipped with a bubbler at its base. Air bubbles are injected into the base of the water column. The bubbles move upward though the water column and PFAS molecules contained in the water attach themselves to the air/water interface (i.e., film) forming the bubbles. The bubbles float to the top of the water column and form a layer of foam (i.e., foamate) that accumulates at the top of the fractionator. The foamate is vacuumed off the top of the fractionator for further treatment, direct destruction, or consolidation. The hydrophobic (i.e., not wanting to mix with water) nature of PFAS makes those compounds prone to accumulation on the surface of liquid-gas bubble interfaces.

As bubbling progresses, treated water (i.e., raffinate) flows to the bottom of the fractionator and is relatively free of PFAS. The raffinate can be diverted to a subsequent fractionator for further PFAS removal, be directly discharged, or be further treated using adsorption technologies such as granular activated carbon (GAC) or ion exchange (IEX), depending on the PFAS clean-up goals. In general, FF results in about 95% raffinate (mostly clean of PFAS) by volume treated and about 5% foamate requiring further PFAS consolidation and/or treatment.

In contrast to treating potable water containing PFAS using technologies such as GAC or IEX adsorption, FF is viewed as a highly effective "upfront bulk" PFAS removal method that is well suited for treating complex wastewaters such as landfill leachates, which are not conducive to adsorptive treatment due to the abundance of other non-PFAS pollutants in the wastewater/leachate that are attracted to adsorptive media.

DOLBY AND JUNIPER RIDGE LANDFILL BACKGROUND

Dolby is a closed, unlined landfill about 171 acres in area. Groundwater and leachate combine within the landfill drainage system. The groundwater tends to dilute the leachate that percolates through the waste placed in the landfill. Final soil cover is installed on Dolby II and geomembrane cover is in-place over about half of Dolby III, the other half will receive final cover over the next three years. The Dolby I landfill is an attenuation facility that does not include leachate collection. Leachate from the Dolby II and Dolby III landfills flows to a 2 MG (working capacity) storage pond and then is pumped to the East Millinocket wastewater treatment plant (EMWWTP) for processing along with sanitary wastewater from the town. Current leachate flows are about 127,000 gpd and once final geomembrane cover is completed for Dolby III it is projected leachate flows will decrease to about 88,500 gpd.

JRL is an active, double-lined landfill about 112 acres in area that is projected to continue development to 120 acres through about 2040. Active cells are operated and maintained with temporary geomembrane cover to reduce precipitation infiltration. . Final geomembrane cover will be installed progressively over JRL from 2023 to about 2040. Leachate collected from JRL is piped to a 0.92 MG capacity above ground storage tank and then trucked by tankers about 7 miles to the Nine Dragons WWTP (NDWWTP) for treatment along with over 20 mgd of industrial wastewater. Current average leachate flows are about 42,000 gpd and once final geomembrane cover is installed it is projected leachate flows will decrease substantially to about 10,000 gpd after about 2040.

Table 1 presents a summary of the general characteristics of the Dolby Landfill and JRL.

TABLE 1. OVERVIEW OF DOLBY LANDFILL AND JRL

DOLBY LANDFILL

- Landfill is CLOSED, covers 151 acres
- Received waste from 1975 - 2012
- LF is unlined (receives groundwater)
- Roughly 75% of LF covered with soil and 25% with final geomembrane
- Current Avg leachate flow = 127,000 gpd; flow in 2025 est. = 88,500 gpd
- Leachate is treated at EMWWTP (Qd = 2.0 mgd); discharged to Penobscot
- Dolby leachate blends with EMWWTP sanitary flows (343,000 gpd)
- Other than storage, no pretreatment

JUNIPER RIDGE LANDFILL

- Landfill is ACTIVE; today covers 112 acres; final build-out 120 acres
- Began receiving waste in 1980s
- LF is double-lined (no groundwater inflow to leachate collection system)
- Currently 55 acres with intermediate geomembrane cover
- Current Avg leachate flow = 42,000 gpd; flow in 2042 est. = 10,000 gpd
- Leachate is hauled by tank truck to the NDWWTP (Qd = 24 mgd) and discharges to Penobscot
- JRL leachate blends with Nine Dragon's industrial flows (>20 mgd)
- Other than storage, no pretreatment

LANDFILL LEACHATE CHARACTERIZATION

Table 2 presents the analytical results from samples collected by Sevee & Maher Engineers (SME) personnel on June 15, 2022 and analyzed by Alpha Analytics Laboratory. The leachate quality data presented in Table 2 represents the quality of the leachate samples that were provided to Sanexen and ECT2 for bench-scale PFAS treatability testing.

CLEANUP GOALS

The cleanup goals established for the subject Study, including the laboratory bench-scale treatability testing, is to reduce the concentration of six specific PFAS compounds to less than the maximum contaminant level (MCL) for drinking water in Maine (i.e., the sum of six) to below the current MCL of 20 ng/l. The six Maine regulated PFAS include: perfluorooctanic acid (PFOA), perfluoroctanesulfonic (PFOS), perfluoroheptanoic acid (PFHpA), perflluorononanoic acid (PFNA), perfluorohexanesulfonic (PFHxS) and perfluorodecanoic acid (PFDA).

SAMPLING, TESTING AND BENCH-SCALE PROCEDURES

Raw leachate samples were collected by Sevee & Maher Engineers (SME) personnel from both Dolby and JRL on June 15, 2022. At Dolby, the leachate was collected from the leachate pond's pump station wet well, which connects to the leachate pond. The pump station pumps leachate approximately 3.2 miles to the EMWWTP. Identical sample aliquots of leacahte were sent to Alpha Analytical Laboratory (subcontractor to SME) and to Sanexen (ECT2 did not conduct treatability analysis on Dolby leachate). At JRL the leachate was collected from the 0.92 MG storage tank via the tank truck loading station. A pre-cleaned 275-gallon tote was filled with leachate and then identical aliquots were sent to Alpha Analytical Laboratory, Sanexen and ECT2. The sampling locations and procedures were consistent with previous sampling episodes conducted for this Study and are representative of the leachate from each landfill.

SME provided leachate characterization data (both conventional water quality and PFAS results) from a previous sampling episode in May 2022 at both Dolby and JRL to Sanexen and ECT2 in order to provide guidance on the anticipated quality of the leachate. For the specific samples collected on June 15th, Alpha Analytical analyzed the raw leachate from both Dolby and JRL for PFAS but did not analyze any of the bench scale treatability effluent samples. Sanexen performed both raw and treated effluent PFAS testing on both Dolby and JRL leachate samples using an in-house laboratory. ECT2 analyzed both raw and treated effluent for PFAS from only JRL; ECT2 used an independent laboratory for analysis of the raw and treated effluent. All three laboratories tested the raw JRL leachate for PFAS while Alpha Analytical and Sanexen also tested the raw leachate from Dolby. Analytical results were not shared with either vendor until after the Bench Scale Treatability Reports were submitted.

There are currently no USEPA-certified methods for analysis of PFAS in media other than drinking water. The analytical methods used by each of the three laboratories varied and are briefly outlined below.

- The method used by Alpha Analytical for leachate is based on USEPA Method 537 Version 1.1, solid phase extraction and liquid chromatograph (LC) /mass spectrographic (MS) methods that use isotope dilution for QA/QC adjustments to compensate for matrix interferences. Alpha's methods were designed in compliance with the Department of Defense Quality Systems Manual 5.2. Although complex matrices such as landfill leachate can result in detection limits and surrogate recoveries outside the limits of the laboratory method, that was not the case for the Dolby and JRL leachate samples analyzed by Alpha. A total of 28 PFAS were tested and reported by Alpha for the sampling episode.

- Sanexen conducted PFAS analyses with their LC-MS/MS system using a modified USEPA Method 533 and a modified USEPA Method 8327. A total of 25 PFAS were monitored throughout the treatability testing. For Quality Control (QC) purposes, an isotopic internal standard was added to each sample. The results were adjusted according to the recovery percentages of that standard to ensure that any matrix interference or any loss of analytes through the analytical testing process were accounted for. Each sample batch included a blank and a standard to confirm that the analytical instrument was operating properly at the time of the analysis. A blank run was also added to the end of the batch to ensure that no analyte or contaminant was carried over from one analysis to the next analysis. The acceptable ranges for those controls were the same as those listed in the EPA methods. For this Study, dilutions were done on the final extract and the results compared to ensure that the results fell within an acceptable statistical range with respect to one another. Results for PFAS compounds that have an undefined, branched and/or linear form that could clearly be identified from the analysis were reported as the sum of those isomers.

- ECT2 used a commercial laboratory for PFAS analyses. The analytical methodology incorporated was isotope dilution for non-potable water by Method EU-047, which is a variation of the draft USEPA Method 1633 proposed for matrices similar to leachate. Throughout the ECT2 bench-scale study the laboratory applied standard QA/QC procedures. A total of 25 PFAS were monitored throughout the ECT2 treatability testing.

Table 3 provides a comparison of the raw leachate analytical results from the three laboratories that participated in the testing. Each laboratory used isotope dilution but incorporated different variations of the USEPA procedures for analyzing PFAS in drinking water. The complex nature of leachate often results in elevated analytical detection limits due to other compound interferences within the leachate matrices and/or poor surrogate recoveries (to check the efficiency of the sample extraction method). This was not the case however for the PFAS analyses completed by the three analytical laboratories. Further, the comparability between laboratories was good (typically between -19% to 6% for ECT2 compared to Alpha for the sum of six and 27% to 46% for Sanexen compared to Alpha for the sum of six) considering the complex leachate matrix. The data in Table 3 does not indicate a bias or other interferences as a concern between the laboratories. Further, it should be recognized that primary objectives of the bench-scale treatability studies performed by Sanexen and ECT2 were to assess the relative difference between the raw and treated leachate and if assess if the FF treatment process was able to provide a treated effluent with the sum of six PFAS near or below the MCL of 20 ng/l. The PFAS data in Table 3 demonstrates successful PFAS reduction.

RESULTS

Detailed results from the bench scale treatability trials are attached to this Technical Memorandum. Below is a brief summary of the bench scale treatability procedures and their reported results.

Sanexen. Leachate samples from both Dolby and JRL were processed in a 12-liter miniaturized proprietary process FF column that closely replicates Sanexen's commercial scale FF process. For the Dolby leachate insufficient foam was generated when aerated without a surfactant. Sanexen dosed the leachate with a surfactant to generate an adequate volume of foam necessary for processing. This mixture was treated by FF in a batch mode over about a 30-minute period. The resulting FF-treated leachate was filtered using a specialized ion exchange (IEX) resin as a potential polishing process. Results from the bench scale testing demonstrated that the Dolby sum of six compounds was reduced from about 285 ng/l to less than 86 ng/l (>70 % removal) by FF by itself, and IEX polishing further reduced the sum of six PFAS to <24 ng/l, essentially meeting the State of Maine MCL of 20 ng/l. FF performed well on the sum of six compounds with the exception of PFHpA and PFHxS that were only reduced by 4 and 38 %, respectively. Sanexen personnel indicated the FF unit operation could be optimized for more effective PFAS reduction and recommended performing field-scale pilot testing of the leachate using FF to allow further evaluation of various air to water ratios, longer reaction times, various recycling ratios, utilizing several FF reactors in series, assessing other surfactants, and generally providing a better understanding of operational parameters. Sanexen is confident that through the use of a more specific IEX unit or an alternate filtration media coupled with FF the Dolby leachate can reliably be treated to consistently reduce the sum of six PFAS to below the 20 ng/l MCL.

For the JRL leachate, initial testing indicated that foam was easily generated with no surfactant being added. As such, no surfactant was dosed into the leachate as part of the bench-scale treatability testing. Similar to Dolby, the JRL leachate was treated in a 12-liter FF reactor in a batch mode for about 30-minutes. The FF process by itself was capable of reducing the sum of six PFAS from about 3,664 ng/l to less than 133 ng/l, representing a 96 percent PFAS reduction by weight. It is notable that the reduction for PFHpA and PFHxS in the JRL leachate was significantly better than the reduction for those same compounds in the Dolby leachate. The IEX polishing step for the JRL leachate reduced the sum of six PFAS to <32 ng/l. Although the bench-scale treatment did not provide an effluent below the goal of 20 ng/l, Sanexen is confident that operational optimization using FF and IEX will consistently reduce the sum of six PFAS to below the 20 ng/l MCL .

ECT2. Leachate samples from JRL were processed in a 3-gallon FF reactor. ECT2 employed a strategy to enhance the viability of FF by incorporating a surfactant, referred to as a boosting agent. As part of the bench scale study a total of 11 separate batch FF treatment runs were conducted with various boosting agents dosed at varying concentrations. One of the FF treatment runs was conducted with no boosting agent. Each batch run was conducted for 30 minutes to an hour, depending on the amount of boosting agent added.

The treated raffinate from the 11 trial runs showed removal for the sum of six PFAS to range from 98.1 percent to 99.8 percent. The raw JRL leachate had influent levels for the sum of six at 2,419 ng/l and five of the 11 runs had sum of six PFAS levels below the State of Maine drinking water MCL of 20 ng/l. The PFAS compound with the highest influent and effluent concentration through most runs was PFOA, although treated raffinate concentrations for PFOA were typically below 10 ng/l. Total PFAS removals were also very good, achieving about 80 percent in one trial. In summary, FF alone was able to achieve extremely high removals (+99 percent) for the sum of six PFAS and the treated raffinate samples were less than 20 ng/l for the sum of six PFAS compounds.

CONCLUSIONS

Leachate from the Dolby Landfill was sampled, analyzed for PFAS and a number of other water quality parameters (Alpha Analytics), and was provided to Sanexen for bench scale treatability testing using FF and IEX polishing. Leachate from JRL was similarly sampled, analyzed for PFAS and other water quality parameters (by Alpha Analytics) and was provided to both Sanexen and ECT2 for bench-scale treatability testing. Conclusions include:

- Leachate from Dolby is generally dilute due to the landfill being unlined and groundwater up-flow into the leachate collection network. The Dolby leachate was fairly clean with a neutral pH, low in conventional pollutants such as BOD5, TSS, and ammonia and the PFAS concentrations were relatively low (raw sum of six was 285 ng/l) in comparison to other landfills.

- Dolby bench scale treatability testing by Sanexen included FF and IEX polishing as unit operations. The results demonstrated that the FF process is capable of removing the sum of six PFAS from 285 ng/l to less than 86 ng/l. PFAS reduction for PFHpA and PFHxS via FF was modest while the other four PFAS reductions were very good. When IEX was incorporated as a "polishing" step, the final treated effluent PFAS concentrations approached the State of Maine PFAS MCL of 20 ng/l.

- The JRL bench-scale treatability testing by Sanexen included FF and IEX polishing similar to the Dolby testing. The FF process by itself was capable of reducing the sum of six PFAS from about 3,664 ng/l to less than 133 ng/l, representing a 96 percent PFAS reduction by weight. Reduction for PFHpA and PFHxS in the JRL leachate was significantly better than the reduction for those compounds in the Dolby leachate. The IEX polishing step reduced the level of the sum of six PFAS to <32 ng/l. Similar to Dolby, although the bench scale treatability did not yield an effluent below the goal of 20 ng/l, Sanexen is confident that operational optimization will result in the FF and IEX process consistently reducing the sum of six PFAS to below the MCL of 20 ng/l for the JRL leachate.

- The JRL bench scale treatability testing by ECT2 focused solely on the effectiveness of FF using various boosters to encourage foam formation. The treated raffinate from the 11 trial runs show removal of the sum of six PFAS from 98.1 percent to 99.8 percent and five of the 11 runs had sum of six PFAS levels below the State of Maine drinking water MCL of 20 ng/l. The PFAS compound with the highest influent and effluent concentration for most runs was PFOA, although treated raffinate concentrations for PFOA were typically below 10 ng/l. In summary, FF (with surfactants) was able to achieve extremely high removals (+99 percent) for the sum of six PFAS with the treated raffinate containing less than the 20 ng/l MCL for the sum of six PFAS compounds.

- The bench scale treatability results from both Sanexen and ECT2 demonstrate that FF is effective at reducing PFAS concentrations SPECIFICALLY FROM DOLBY AND JRL LEACHATE to near or below the 20 ng/l PFAS MCL for drinking water in the State of Maine. The application of FF if used as an "upfront bulk" PFAS removal process should allow both leachates to be pretreated to reduce PFAS below the Maine drinking water MCL and allow both the Dolby and JRL leachate to continue to be treated for conventional parameters (e.g., BOD5, TSS, and ammonia) at the EMWWTP and the NDWWTP, respectively.

- The bench-scale treatability results from both Sanexen and ECT2 are very promising. It is recommended consideration be given to conducting a continuous flow pilot test at the JRL site and potentially at the Dolby site.

Field-scale pilot testing will allow better understanding of operational parameters necessary for successful PFAS treatment and move from the feasibility testing phase to the full-scale design and implementation phases. .

ATTACHMENTS

Sanexen Bench Testing Report – Dolby Landfill
Sanexen Bench Testing Report – Juniper Ridge Landfill
ECT2 Bench Testing Report – Juniper Ridge Landfill

TABLE 2. ANALYTICAL RESULTS - DOLBY AND JUNIPER RIDGE LANDFILLS LEACHATE (1)

Parameter/Pollutant	Acronym Name	Units	Dolby (4) BGS #2 15-Jun-22	JRL (5) BGS #2 15-Jun-22
2. LEACHATE/WASTEWATER QUALITY				
A. Conventional/Nutrients				
Biochemical Oxygen Demand	BOD5	mg/l	<2.0	110
Total Organic Carbon	TOC	mg/l	22.5	482
Total Suspended Solids	TSS	mg/l	<5.0	40
Ammonia as Nitrogen	NH3-N	mg/l	9.85	678
pH	-	su	7.7	7.5
B. Toxic Metals				
Arsenic	As	mg/l	<0.005	0.406
Zinc	Zn	mg/l	<0.05	<0.1
C. Toxic Organics				
Semi-Volatile Organics	SVOCs			
Alpha Terpineol	-	ug/l	<5	23.5
Benzoic Acid	-	ug/l	<50	<200
p-Cresol	-	ug/l	<5	63
Phenol	-	ug/l	<5	<20
Total Volatile Organic Compounds	VOCs	ug/l	ND	740
D. Anions/Cations				
Barium	Ba	mg/l	0.063	1.16
Bromide	Br	mg/l	0.151	NS
Calcium	Ca	mg/l	111	244
Magnesium	Mg	mg/l	77.6	201
Potassium	K	mg/l	77.4	1130
Sodium	Na	mg/l	28.9	2570
Strontium	St	mg/l	0.639	2.93
Bicarbonate	HCO3	mg/l	760	3570
Chloride	Cl	mg/l	28	5800
Fluoride	F	mg/l	<0.2	0.26
Nitrite/Nitrate	NO2/NO3	mg/l	0.27	1.9
Sulfate	SO4	mg/l	28	120
E. Other Non-Conventional Parameters				
Alkalinity as CaCO3	-	mg/l	760	3570
Hardness as CaCO3	-	mg/l	597	1440
Iron	Fe	mg/l	1.27	8.34
Manganese	Mn	mg/l	1.03	2.25
Total Dissolved Solids	TDS	mg/l	910	12000
Conductivity	-	umhos/cm	1500	24000
Perchlorate	NaClO4	ug/l	<0.05	0.067
Total Phosphorus	TP	mg/l	0.027	3.83
Surfactants	MBAS	mg/l	0.07	1.41
F. Six State of Maine Regulated PFAS				
Perfluorooctanesulfonic	PFOS	ng/l	52.6	108
Perfluorooctanic Acid	PFOA	ng/l	90.4	1190
Perfluoroheptanoic Acid	PFHpA	ng/l	41.5	677
Perfluorononanoic Acid	PFNA	ng/l	16	54.8
Perfluorohexanesulfonic	PFHxS	ng/l	2.5	390
Perfluorodecanoic Acid	PFDA	ng/l	<1.86	23.4
Sum of Six Regulated Compounds (2)			203	2443

	Acronym Name	Units	Dolby (4) BGS #2 15-Jun-22	JRL (5) BGS #2 15-Jun-22
G. Other Unregulated PFAS				
Perfluorobutanesulfonic Acid	PFBS	ng/l	<1.86	2560
Perfluorobutanoic Acid	PFBA	ng/l	27.8	1970
Perfluorodecanesulfonic Acid	PFDS	ng/l	<1.86	<20
Perfluorododeanoic Acid	PFDoDA	ng/l	<1.86	<20
Perfluoroheptanesulfonic Acid	PFHpS	ng/l	<1.86	<20
Perfluorohexadecanoic Acid	PFHxDA	ng/l	<3.71	<40
Perfluorohexanoic Acid	PFHxA	ng/l	42.5	2250
Perfluorononanesulfonic Acid	PFNS	ng/l	<1.86	<20
Perfluorooctadecanoic Acid	PFODA	ng/l	<3.71	<40
Perfluorooctanesulfonamide	PFOSA	ng/l	<1.86	<20
Perfluoropentanesulfonic Acid	PFPeS	ng/l	<1.86	51.7
Perfluoropentanoic Acid	PFPeA	ng/l	38.3	1260
Perfluorotetradecanoic Acid	PFTA	ng/l	<1.86	<20
Perfluorotridecanoic Acid	PFTrDA	ng/l	<1.86	<20
Perfluoroundecanoic Acid	PFUnA	ng/l	<1.86	<20
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	ng/l	<1.86	<20
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	ng/l	<1.86	<20
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	ng/l	<1.86	384
2,3,3,3-Tetrafluoro-2-[1,1,2,2,3,3,3-Heptaflluoropropoxy]-Propanoic Acid	HFPO-DA	ng/l	<46.4	<500
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	ng/l	<1.86	<20
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	ng/l	<1.86	88.1
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	ng/l	<1.86	23.4
Sum of All PFAS Compounds (3)		ng/l	312	11030

(1) - Database includes sampling funded by BGS for State-Owned landfill leachates on June 15, 2022

(2) - PFAS values are State of Maine MCLs established June 21, 2021 for six PFAS analytes combined in drinking water. MCL = 20 ng/l

(3) - Values less than the analytical detection limit are assumed as zero when calculating the sum and averages

(4) - Dolby leachate samples collected as grab from leachate pond wet well

(5) - JRL leachate samples collected from tanker truck loading station

TABLE 3. COMPARISON OF ALPHA ANALYTICAL, ECT2 AND SANEXEN PFAS ANALYTICAL RESULTS FOR JRL AND DOLBY LANDFILL LEACHATE

Parameter/Pollutant	Acronym Name	Units	ALPHA JRL (3) 6/15/22	ECT2 JRL (4) 6/15/22	% Difference	ALPHA JRL (3) 6/15/22	Sanexen JRL (5) 6/15/22	% Difference	ALPHA DOLBY (4) 6/15/22	Sanexen DOLBY (5) 6/15/22	% Difference
Per- and Polyfluoralkyl Substances											
a. Six State of Maine Regulated PFAS (2)											
Perfluorooctanesulfonic	PFOS	ng/l	108	115	6%	108	200	46%	52.6	81	35%
Perfluorooctanic Acid	PFOA	ng/l	1190	1166	-2%	1190	1630	27%	90.4	123	27%
Perfluoroheptanoic Acid	PFHpA	ng/l	677	723	6%	677	1200	44%	41.5	48	14%
Perfluorononanoic Acid	PFNA	ng/l	54.8	58.5	6%	54.8	95	42%	16	21	24%
Perfluorohexanesulfonic	PFHxS	ng/l	390	337	-16%	390	500	22%	2.5	8	69%
Perfluorodecanoic Acid	PFDA	ng/l	23.4	19.7	-19%	23.4	39	40%	<1.86	<DL	NA
Sum of Six Regulated Compounds (1)		ng/l	2443	2419	-1%	2443	3664	33%	203	281	28%
Percent Removal Total PFAS											
b. Other Unregulated PFAS											
Perfluorobutanesulfonic Acid	PFBS	ng/l	2560	1944	-32%	2560	3000	15%	<1.86	15	88%
Perfluorobutanoic Acid	PFBA	ng/l	1970	1503	-31%	1970	1800	-9%	27.8	40	31%
Perfluorodecanesulfonic Acid	PFDS	ng/l	<20	<2.4	NA	<20	NT	NA	<1.86	NT	NA
Perfluorododeanoic Acid	PFDoA	ng/l	<20	1.47	NA	<20	<DL	NA	<1.86	<DL	NA
Perfluoroheptanesulfonic Acid	PFHpS	ng/l	<20	3.68	NA	<20	<DL	NA	<1.86	<DL	NA
Perfluorohexadecanoic Acid	PFHxDA	ng/l	<40	NT	NA	<40	NT	NA	<3.71	NT	NA
Perfluorohexanoic Acid	PFHxA	ng/l	2250	2735	18%	2250	2800	20%	42.5	60	29%
Perfluorononanesulfonic Acid	PFNS	ng/l	<20	<1.08	NA	<20	NT	NA	<1.86	NT	NA
Perfluorooctadecanoic Acid	PFODA	ng/l	<40	1.47	NA	<40	NT	NA	<3.71	NT	NA
Perfluorooctanesulfonamide	PFOSA	ng/l	<20	2	NA	<20	NT	NA	<1.86	NT	NA
Perfluoropentanesulfonic Acid	PFPeS	ng/l	51.7	61.7	16%	51.7	80	35%	<1.86	<DL	NA
Perfluoropentanoic Acid	PFPeA	ng/l	1260	1507	16%	1260	1430	12%	38.3	4	-858%
Perfluorotetradecanoic Acid	PFTA	ng/l	<20	<1.89	NA	<20	NT	NA	<1.86	NT	NA
Perfluorotridecanoic Acid	PFTrDA	ng/l	<20	<1.89	NA	<20	NT	NA	<1.86	NT	NA
Perfluoroundecanoic Acid	PFUnA	ng/l	<20	1.47	NA	<20	<DL	NA	<1.86	<DL	NA
1H, 1H, 2H, 2H-Perfluorodecanesulfonic Acid	8:2FTS	ng/l	<20	14	NA	<20	25	NA	<1.86	<DL	NA
1H, 1H, 2H, 2H-Perfluorohexanesulfonic Acid	4:2FTS	ng/l	<20	<1.48	NA	<20	<DL	NA	<1.86	<DL	NA
1H, 1H, 2H, 2H-Perfluorooctanesulfonic Acid	6:2FTS	ng/l	384	338	-14%	384	400	4%	<1.86	17	89%
2,3,3,3-Tetraflluoro-2-[1,1,2,2,3,3,3-Heptaflluoropropoxy]-Propanoic Acid	HFPO-DA	ng/l	<500	<1.48	NA	<500	<DL	NA	<46.4	<DL	NA
4,8-Dioxa-3h-Perfluorononanoic Acid	ADONA	ng/l	<20	NT	NA	<20	<DL	NA	<1.86	<DL	NA
N-Methyl Perfluorooctanesulfonamidoacetic Acid	NMeFOSAA	ng/l	88.1	56.1	NA	88.1	NT	NA	<1.86	NT	NA
N-Ethyl Perfluorooctanesulfonamidoacetic Acid	NEtFOSAA	ng/l	23.4	13.2	NA	23.4	NT	NA	<1.86	NT	NA
Perfluoro-3-Methoxypropanoic Acid	PFMPA	ng/l	NT	NT	NA	NT	<DL	NA	NT	<DL	NA
Perfluoro-4-Methoxypropanoic Acid	PFMBA	ng/l	NT	NT	NA	NT	<DL	NA	NT	<DL	NA
Perfluoro(2-Ethoxyethane)Sulfonic Acid	PFEESA	ng/l	NT	NT	NA	NT	<DL	NA	NT	<DL	NA
Nonafluoro-3,6-Dioxaheptanoic Acid	NFDHA	ng/l	NT	NT	NA	NT	<DL	NA	NT	<DL	NA

9-Chlorohexadecafluoro-3-Oxanone-1-Sulfonic Acid	SCI-PF3ONS	ng/l	NT	NT	NA	NT	<DL	NA	NT	<DL	NA
11-Chloroeiosafluoro-3-Oxaundecane-1-Sulfonic Acid	11Cl-FP3OUdS	ng/l	NT	NT	NA	NT	<DL	NA	NT	<DL	NA
Sum of All PFAS Compounds (2)		ng/l	11030	10601	-4%	11030	13199	16%	312	417	25%
Percent Removal Total PFAS											

(1) - PFAS State of Maine MCLs for drinking water for six PFAS analytes established June 21, 2021 at 20 ng/l

(2) - Values less than analytical detection limit assumed as zero in calculating average concentration

(3) - Analytical method used by Alpha Analytical is based on USEPA Method 537 Version 1.1 with solid phase extraction and liquid GC/MS methods that use isotope dilution to compensate for matrix interferences.

(4) - Analytical method used by ECT2 based on Isotope Dilution(non-potable water matrix) EU-047 (variation of draft EPA 1633)

(5) - Analytical method used by Sanexen based on LC-MS using a modified USEPA Method 533 and modified USEPA Method 8327

NT - Not Tested

NA - Not Applicable

APPENDIX D-2

BENCH SCALE FF RESULTS FOR DOLBY LEACHATE BY SANEXEN

SME
SEVEE & MAHER
ENGINEERS

ALTRA

PFAS TREATMENT SOLUTIONS

DRAFT

Results of Laboratory-Scale Tests on a Landfill Leachate (cf., Dolby, ME Landfill): PFAS removal using SANEXEN's ALTRA PFAS Treatment Technologies

Property Located at Dolby Landfill Rd, East Millinocket, ME, USA

Matthew W. Muzzy, P.E.
Sevee & Maher Engineers
4 Blanchard Road, P.O. Box 85A
Cumberland Center, ME 04021 United States

July 20, 2022

SANEXEN

O/Ref. : DA22

Results of Laboratory-Scale Tests on a Landfill Leachate (cf., Dolby Landfill, ME): PFAS removal using SANEXEN's ALTRA PFAS Treatment Technologies

Property Located at Dolby Landfill Rd,
East Millinocket, ME, USA

SEVEE & MAHER ENGINEERS

Prepared and verified by:

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Project Manager
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(OCQ: 2012-220)

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Etienne Belisle-Roy
Director
Research and Development, Engineering

Draft report

July 20, 2022

O/Ref. : DA22

SANEXEN

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1. SUMMARY OF LABORATORY TESTS

The State of Maine Environmental and Natural Resources committee passed LD 1875 in April 2022 to address PFAS Pollution at State-owned Solid Waste Landfills. LD 1875 includes language requiring that the Bureau of General Services (BGS) completes a study of methods, other than dilution, for treating leachate collected at State-owned landfills. Sevee & Maher Engineers have been contracted by BGS to conduct a study to identify and assess treatment alternatives for reducing the concentration of PFAS in leachates that discharge from State-owned solid waste landfills, Dolby landfill and Juniper Ridge landfill. The treated leachate standard is to meet the Maine Interim Drinking Water Standards. Sevee & Maher Engineers are interested in evaluating whether SANEXEN's ALTRA PFAS Treatment Solutions can be utilized for on-site treatment of the leachate to remove/reduce PFAS to the desired treated leachate standard.

SANEXEN's ALTRA PFAS Treatment Solutions offers several treatment technologies to address PFAS contamination in landfill leachate. To determine which of SANEXEN's treatment technologies are best suited to efficiently treat the landfill leachate at the Dolby Landfill site, SANEXEN has conducted preliminary treatment tests at the laboratory scale. As a starting point, SANEXEN performed the extraction of PFAS from liquid waste streams using the ALTRA Proprietary Process (based on Foam Fractionation). The generated stream was then filtered through a specialized ion exchange resin (IER) in a separate step.

The guidance values for this project are Maine's maximum contaminants limits (MCLs) which are currently established as a composite concentration, given by the sum of six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA). The composite concentration must be lower than 20 ng/L. However, the state does offer some flexibility if the current technologies cannot bring the contamination levels down to these criteria. Those cases must be reviewed in collaboration with the Maine Department of Environmental Protection (MEDEP).

The objective of the laboratory scale tests is to evaluate the performance of SANEXEN's ALTRA PFAS Treatment Solutions to determine what PFAS levels could be achieved in the treated leachate and whether the concentrations of those six PFAS compounds in the treated leachate would be low enough to meet Maine's proposed MCLs for Interim drinking water standards.

SANEXEN has completed the bench testing of the Dolby Landfill raw leachate using the ALTRA Proprietary Process (Foam Fractionation), as presented in Figure 1, followed by filtration of the Foam Fractionation treated leachate using Ion Exchange Resin (IER), as well as the analysis of the treated leachates.

FIGURE 1– Laboratory scale setup of SANEXEN's ALTRA Proprietary Process

Experiments were performed with the as-received leachate samples. All tests were completed at SANEXEN's laboratory at the National Research Council Canada facility in Boucherville, QC. PFAS analyses were performed on SANEXEN's LC-MS/MS system, using a modified USEPA method 533 and a modified USEPA method 8327. A total of 25 PFAS[1] were monitored throughout the experiments. Only the PFAS that were detected in the raw leachate are reported in the test results.

For Quality control purposes, an isotopic internal standard is added to each sample. The results are corrected according to the recovery percentages of that standard to ensure that any matrix effect or any loss of analytes through the whole process are accounted for. Each sample batch includes a blank and a standard to confirm that the instrument is operating properly at the time of the analysis. A blank run is also added to the end of the batch to ensure that no analyte or contaminant was carried over from analysis to analysis. The acceptable ranges for those controls are the same as those listed in the EPA methods. For this project, dilutions were done on the final SPE extract and the results are compared to ensure that they fall within an acceptable statistical range from one another. Results for PFAS compounds that have an undefined, branched, and linear form that can clearly be identified are reported as the sum of those isomers. This type of mixture can sometimes be known as a technical mixture in some reports.

---

[1] PFBA, PFMPA, PFPeA, PFBS, PPFMBA, PFEESA, NFDHA, 4:2FTS, PFHxA, PFPeS, HFPO-DA, PFHpA, PFHxS, DONA, 6:2FTS, PFOA, PFHpS, PFNA, PFOS, 9Cl-PF3ONS, 8:2 FTS, PFDA, PFUnDA, 11Cl-FP3OUdS, PFDoDA

2. RESULTS

2.1 PFAS Removal

A 12-L batch of raw leachate (at 21 oC, 70 oF) was treated in a miniaturized SANEXEN ALTRA Proprietary Process column that closely replicates SANEXEN's commercial scale foam fractionation (FF) process. Initial testing indicated that the foam generated by the raw leachate was insufficient to contribute to the treatment process. A surfactant (Sodium dodecyl sulfate) was added to the raw leachate (final concentration 5 mg/L) to generate an adequate volume of foam. This mixture was treated in batch mode over a period of 30 minutes. The resulting FF-treated leachate was then filtered on a specialized Ion Exchange Resin (IER) as a polishing step.

TABLE 1
Dolby Landfill Leachate Properties

Color	Pale transparent Yellow
pH	7-8 (indicator paper)
Comment(s)	• Low foaming • Almost free of suspended particulates matter

Of the 25 PFAS analyzed, 10 were detected in the raw leachate: PFBA, PFPeA, PFBS, PFHxA, PFHpA, PFHxS, 6:2 FTS, PFOA, PFNA, PFOS.

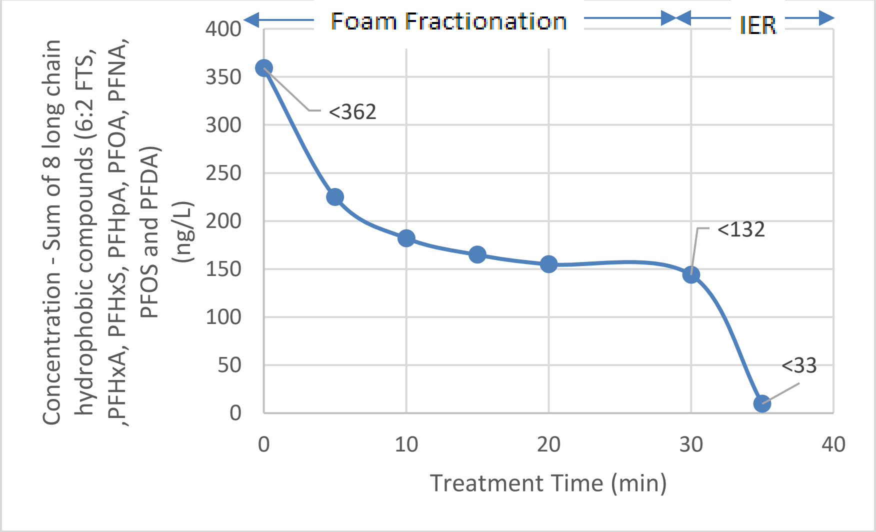

FIGURE 2– Removal of PFAS (Sum of 8, long-chain, hydrophobic PFAS: 6:2 FTS, PFHxA, PFHxS, PFHpA, PFOA, PFNA, PFOS and PFDA) by SANEXEN's ALTRA Proprietary Process

As illustrated in Figure 2, the ALTRA Proprietary Process (Foam Fractionation) efficiently removes the long-chain, hydrophobic PFAS: 6:2 FTS, PFHxA, PFHxS, PFHpA, PFOA, PFNA, PFOS and PFDA. The sum of these eight long-chain, hydrophobic PFAS was decreased from less than 362 ng/L to less than 132 ng/L, representing an **overall removal of 59% by weight after 30 minutes of treatment**, using only Foam Fractionation. Adding the polish step lowered the concentration of these eight long-chain, hydrophobic PFAS to less than 33 ng/L, representing an **overall removal of more than 91% by weight.**

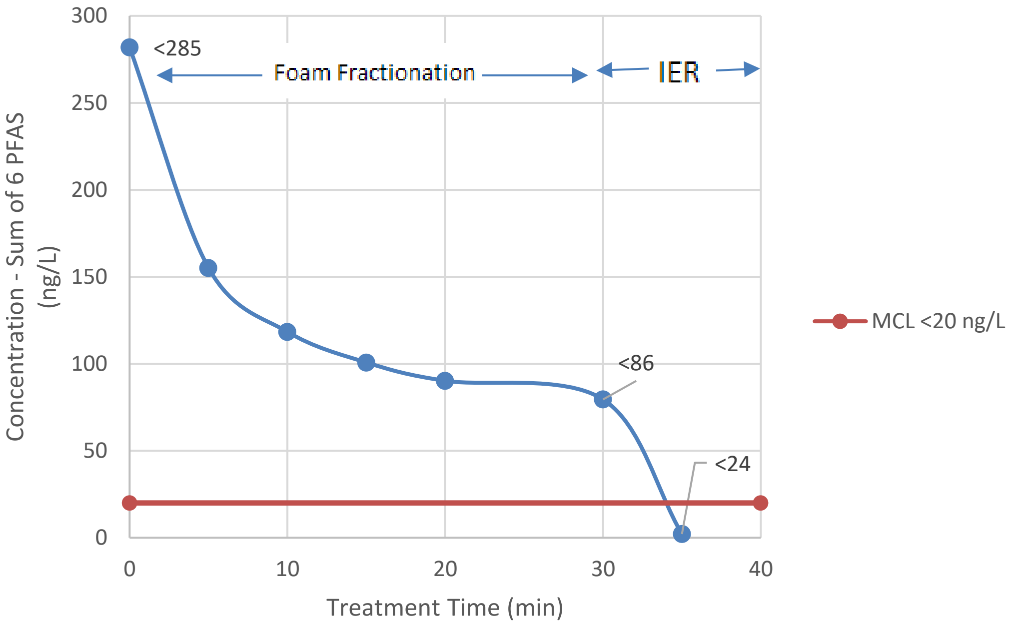

FIGURE 3– Removal of the six PFAS listed in Maine's MCLs (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA)

As illustrated in Figure 3, the ALTRA Proprietary Process (Foam Fractionation) efficiently removed the six PFAS compounds listed in Maine's MCLs. The sum of these six PFAS compounds was decreased from less than 285 ng/L to less than 86 ng/L, representing an overall removal of more than 70% by weight after 30 minutes of treatment, using only the ALTRA Proprietary Process (Foam Fractionation). Adding filtration by IER lowered the concentration of these six PFAS compounds to less than 24 ng/L, essentially meeting Maine's MCLs.

TABLE 2

PFAS concentrations in raw leachate, leachate treated (30 min) by the ALTRA Proprietary Process (FF), and filtered on Ion Exchange Resin

	PFAS	Raw Leachate ng/L (ppt)	ALTRA FF treated Leachate ng/L (ppt)	ALTRA treated leachate (FF and IER) ng/L (ppt)	PFAS removal FF only	PFAS removal FF and IER combined
Shorter chains PFAS	PFBA	40	36	29	10%	28%
	PFPeA	48	48	<2	N/A	>95%
	PFBS	15	15	<3	N/A	>80%
Longer chains PFAS	6:2FTS	17	<5	<5	>71%	>71%
	PFHxA	60	59	<4	2%	>93%
	PFHxS	8	5	<5	38%	38%
	PFHpA	48	46	<3	4%	>94%
	PFOA	123	22	<4	82%	>97%
	PFNA	21	<3	<3	>86%	>86%
	PFOS	81	<6	<5	>94%	>94%
	PFDA	<4	<4	<4	N/A	N/A
	Sum of all PFAS	<460	<249	<67	>46%	>86%
	Maine's MCLs	<285	<86	<24	>70%	>92%
	Sum of long-chain hydrophobic PFAS	<362	<132	<33	59%	>91%

Results in Table 2 report individual PFAS concentrations in the raw leachate, in the FF-treated leachate (30°min) by the ALTRA Proprietary Process (Foam Fractionation), and in the IER filtered leachate. Those PFAS compounds that are listed in Maine's proposed Drinking Water MCL are listed in red text.

Based on the bench test results, the ALTRA PFAS Treatment Solution (FF process followed by filtration with IER) will produce treated leachate that shows a significant reduction of the PFAS listed in Maine's MCLs for six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA), from a sum of <285 ng/L in the raw leachate down to a sum of <86 ng/L in the FF-treated leachate and down to a sum of <24ng/L in the IER filtered leachate.

This Table, as well as Figure 3, indicates clearly that the ALTRA PFAS Treatment Solution (FF process followed by filtration using IER) will produce treated leachate that comes very close to meeting Maine's proposed Drinking Water MCL, sum of six PFAS < 20 ng/L.

Although the MCLs are not met, Maine's Department of Environmental Protection (ME DEP) offers the possibility to consider a different standard should available technologies not fully meet <20 ng/L. SANEXEN is confident that through the use of a more specific IER, or an alternate filtration media, we will meet or exceed the MCL target of <20 ng/L.

3. CONCLUSIONS AND NEXT STEPS

The laboratory scale tests conducted by SANEXEN on the Dolby Landfill leachate demonstrated that SANEXEN's ALTRA PFAS Treatment Solution (FF process followed by filtration with IER) will produce treated leachate that shows a significant reduction of the PFAS compounds listed in Maine's proposed Drinking Water MCLs for six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA), from a sum of <285 ng/L in the raw leachate, down to a sum of <86 ng/L in the FF-treated leachate, and down to a sum of <24 ng/L in the IER filtered leachate.

The results clearly indicate that the ALTRA PFAS Treatment Solution (FF process followed by filtration using IER) will produce treated leachate that comes very close to meeting Maine's proposed Drinking Water MCL, sum of six PFAS < 20 ng/L.

Although the MCLs are not met, Maine's Department of Environmental Protection (ME DEP) offers the possibility to consider a different standard should available technologies not fully meet <20 ng/L.

SANEXEN is very confident that we will be able to treat the Dolby Landfill raw leachate with our full-scale, commercial, ALTRA PFAS Treatment Solution (FF followed by filtration using a more specific IER, or an alternate filtration media), to meet or exceed Maine's proposed Drinking Water MCL target of <20 ng/L for the sum of six PFAS compounds.

As a next step, SANEXEN proposes to conduct a paid Demo Field Pilot Test (duration to be discussed, possibly 2 to 4 weeks) to validate the laboratory results on-site, to identify opportunities for improvement, to optimize process parameters, and to estimate capital and operational costs of full-scale treatment.

We will be happy to discuss these results with you in greater detail, and we hope to have the opportunity to conduct a Demo Field Pilot test at the Dolby Landfill in conjunction with Sevee & Maher Engineers in the near future.

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APPENDIX D-3

BENCH SCALE FF RESULTS FOR JRL LEACHATE BY ECT2

SME
SEVEE & MAHER
ENGINEERS

Juniper Ridge Landfill Foam Fractionation Bench Testing Report - Amended

Submission Date: 9/29/2022

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1.0 Introduction

The R&D laboratory facility owned by ECT2 conducted a bench study on the landfill leachate provided in late July of 2022. ECT's FOAM-X foam fractionation technology was utilized in conjunction with the addition of different concentrations of boosting agents to better understand the technology's potential for PFAS reduction.

The implementation of this specific Bench Study had the following objectives:

- Evaluate the effects of foam fractionation conditions on foam fractionation efficacy in conjunction with the addition of boosting agents as well as the technology without chemical addition
- Treat PFAS species; specifically the 6 compounds currently regulated by the state of Maine: PFOS, PFOA, PFHpA, PFNA, PFHxS, PFDA
- Understand total PFAS reduction potential

2.0 FOAM-X Foam Fractionation

Foam fractionation is a separation process capable of concentrating amphiphilic species from aqueous solution. Foam fractionation has long been employed for separation of proteins (such as fish waste in aquariums) and is gaining interest as a PFAS separation technology applied to contaminated waters. Foam fractionation involves the introduction of high volumes of small gas bubbles through a liquid volume, this creats a high surface area of contact between the gas bubbles and the liquid phase. Amphiphilic molecules (molecules with a non-polar tail and polar head) preferentially adsorb to the gas and concentrate on the gas bubble surface, creating high quantities of foam that is highly concentrated in these amphiphilic species. The concentrated foam is collected and condensed (called foamate) for further treatment. Treated water exits the fractionator (referred to as raffinate) and may be released or subject to additional polishing steps. A simple diagram of a typical foam fractionation is shown in Figure 1.

PFAS species are a candidate for foam fractionation treatment due to their amphiphilic nature. The basic PFAS structure consists of a polar head (typically carboxylic or sulfonic acids) bonded to a non-polar perfluorinated tail. Generally, long-chain PFAS species such as PFOA and PFOS are more susceptible to foam fractionation separation due to the highly non-polar nature of the long perfluorinated tails, while species with shorter perfluorinated tails display less amphiphilicity and are thus less readily separated by foam fractionation. ECT2 has employed a strategy to enhance the viability of foam fractionation by incorporating an additional surfactant, known as a boosting agent. Addition of this surfactant increases the foaming potential of the influent water, creates additional interfacial surface area for PFAS adsorption, and may contribute to PFAS separation through fluorine-hydrogen interactions.

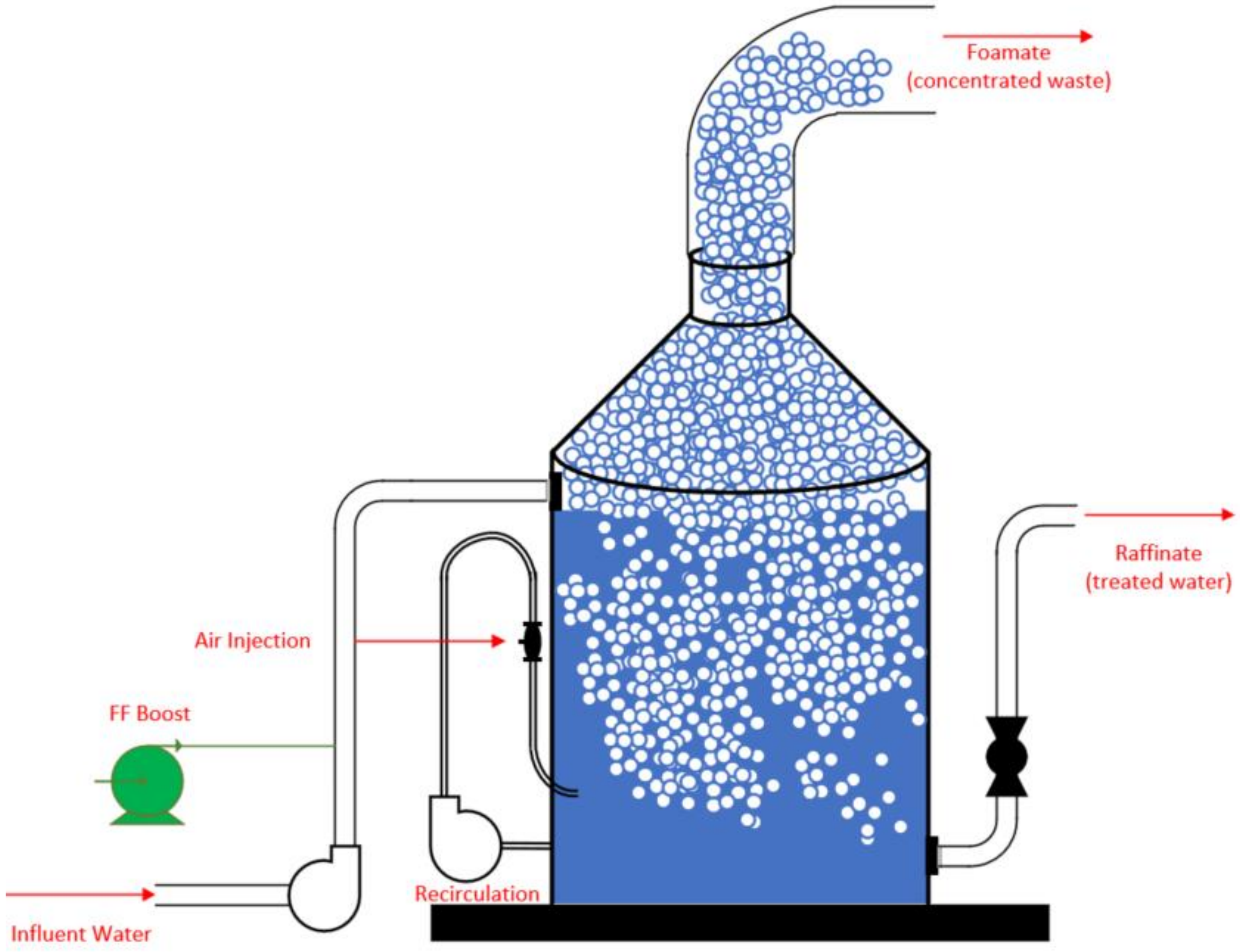

Figure 1. Diagram of a typical foam fractionator used for PFAS removal

The viability of foam fractionation as a treatment technology for a specific water is highly dependent on various factors, including PFAS concentrations and background chemistry. Foam fractionation is highly attractive as a treatment method for waters that contain high levels of co-occurring species such as sulfate and chloride that interfere with media-based treatments, however, effective treatment is highly dependent on reliable and consistent foam formation within the reactor. Shifts in influent chemistry may change the foam forming potential of the water and limit efficacy of foam fractionation. Effluent goals and permit requirements must also be considered when evaluating fractionation as a treatment technology considering the challenges associated with short chain PFAS species.

3.0 Background Water Chemistry

Provided by Sevee & Maher Engineers and Crawford Engineers prepared for BSG that was collected and testing in June 2022.

Table 1. JRL Provided Data – Background Water Chemistry

Parameter		Value (mg/L)
Conventional/Nutrients	Biochemical Oxygen Demand	140
	Total Organic Carbon	443
	Total Suspended Solids	53
	Ammonia as Nitrogen	685
	pH	7.4
Toxic Metals	Zinc	<0.1
Toxic Organics	Alpha Terpineol	49.2
	Benzoic Acid	234
	p-Cresol	108
	Phenol	53.5
	Total Volatile Organic Compounds	Not Sampled (NS)
Anions/Cations	Barium	0.853
	Calcium	239
	Magnesium	160
	Potassium	894
	Sodium	2130
	Strontium	2.37
	Bicarbonate	2810
	Chloride	5100
	Nitrate	<0.1
	Sulfate	150
Other Parameters	Alkalinity as $CaCO_3$	2810
	Hardness as $CaCO_3$	1260
	Iron	9.24
	Manganese	2.51
	Total Dissolved Solids	9900
	Conductivity	19000

Table 2. JRL Provided Data – PFAS May-22

Parameter		Value (ppt)
PFAS **Six ME Regulated**	PFOS	148
	PFOA	1410
	PFHpA	652
	PFNA	68.7
	PFHxS	316
	PFDA	32.1
	Sum of Six Regulated Compounds	**2627**
PFAS **Other Unregulated**	PFBS	1770
	PFBA	1340
	PFDS	<20
	PFDoA	<20
	PFHpS	<20
	PFHxDA	<40
	PFHxA	2050
	PFNS	<20
	PFODA	<40
	PFOSA	<20
	PFPES	35
	PFPeA	1150
	PFTA	<20
	PFTrDA	<20
	PFUnA	<20
	8:2FTS	<20
	4:2FTS	<20
	6:2FTS	345
	HFPO-DA	<500
	ADONA	<20
	NMEFOSAA	83.2
	NEtFOSSA	<20
Sum of All PFAS Compounds		**9400**

3.1 Test Setup

Table 3. Test Setup Overview

Test	Description
Control	No treatment
1	FF treatment w/no chemical addition
2	FF treatment w/10 mg/L Boosting Agent C
3	FF treatment w/20 mg/L Boosting Agent C
4	FF treatment w/40 mg/L Boosting Agent C
5	FF treatment w/20 mg/L Boosting Agent B
6	FF treatment w/40 mg/L Boosting Agent B
7	FF treatment w/80 mg/L Boosting Agent B
8	FF treatment w/20 mg/L Boosting Agent E
9	FF treatment w/40 mg/L Boosting Agent E
10	FF treatment w/80 mg/L Boosting Agent E
11	FF treatment w/700 mg/L Boosting Agent E

Figure 2. Bench foam fractionation unit used for testing

The testing was preformed on the unit pictured above as a batch process run approximately 30 minutes to an hour as increasing amounts of boosting agents were added. ECT2 feels this is the most feasible method with the volume of leachate provided and recommends continuous flow piloting to move beyond feasibility testing and better understand operational parameters.

4.0 Results

4.1 Maine 6 Regulated

Foam Fractionation alone was able to achieve very high, +99% removal of the 6 PFAS compounds currently regulated by the state of Maine as illustrated in the table below:

Table. 4 Maine 6 Compounds – No Chemical Addition

		JRL Influent (ppt)	JRL Raffinate 1 (ppt)	% Removal
			No Chemical Addition	
6 Regulated Compounds	PFHpA	723	0.762 U	100%
	PFOA	1166	8.13	99%
	PFNA	58.5	0.293 J	99%
	PFDA	19.7	0.321 J	98%
	PFHxS	337	1.19 U	100%
	PFOS	115	1.59 J	99%
	Total	2419.2	**12.29**	99.49%

Table. 5 Overview – Maine 6 Compounds Only

Test	**Description**	**Effluent (Raffinate) Concentration (ppt)**	**% Removal**
1	FF treatment w/no chemical addition	12.29	99.49%
2	FF treatment w/10 mg/L Boosting Agent C	5.71	99.76%
3	FF treatment w/20 mg/L Boosting Agent C	18.97	99.22%
4	FF treatment w/40 mg/L Boosting Agent C	22.10	99.09%
5	FF treatment w/20 mg/L Boosting Agent B	34.98	98.55%
6	FF treatment w/40 mg/L Boosting Agent B	35.45	98.53%
7	FF treatment w/80 mg/L Boosting Agent B	46.58	98.07%
8	FF treatment w/20 mg/L Boosting Agent E	12.35	99.49%
9	FF treatment w/40 mg/L Boosting Agent E	16.38	99.32%
10	FF treatment w/80 mg/L Boosting Agent E	7.41	99.69%
11	FF treatment w/700 mg/L Boosting Agent E	13.26	99.45%

Table. 6 Overview – Maine 6 Concentration Ranges

	Min	Max
PFHpA	0.762 U	1.020 U
PFOA	1.83 U	16
PFNA	0.293 J	1.63 J
PFDA	0.44 J	1.55 J
PFHxS	1.19 U	11.3
PFOS	1.59 J	12.1

Table 6 above illustrates ranges of concentrations for all 11 tests, J and U indicating estimates that are below detection. All PFAS analyses were conducted in a separate laboratory going through standard QA/QC, the method used for this study was isotope dilution (non-potable water) EU-047 which is a variation the draft EPA 1633 method.

4.2 Total PFAS Removal

Total PFAS removal was significant with and without boosting agent. Figure 3 below illustrated the boosting agent affect, which had a larger impact on the non-regulated PFAS compounds especially.

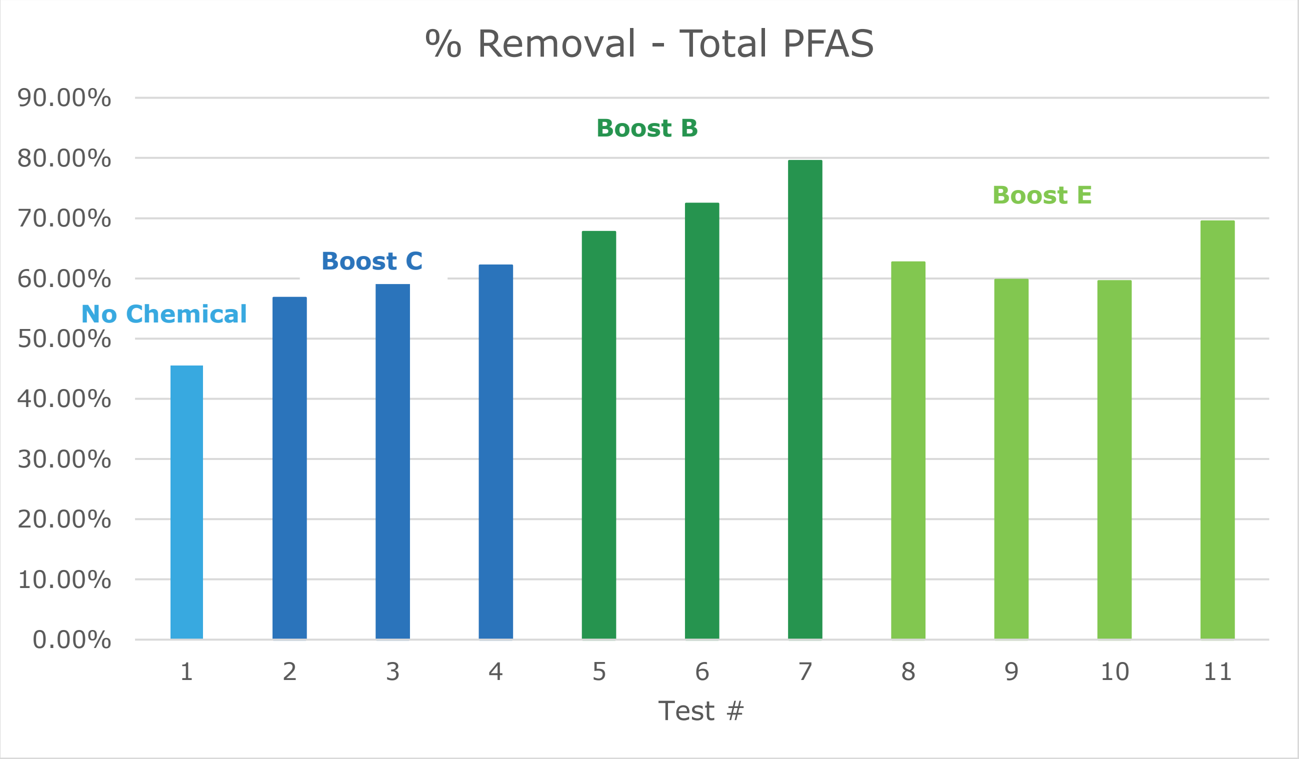

Figure 3. Total PFAS Removal – All Analyzed Compounds

5.0 Conclusions and Recommendations

In conclusion, Foam Fractionation has the potential to effectively remove PFAS from leachate that can also be cost effective for the Juniper Ridge Landfill. Of note all of the boosting agents assisted in total PFAS reduction, especially on non-regulated analytes, agents B and C being conventional boosters used previously. Boosting Agent E is an unconventional, non-toxic option that shows promising results based upon the bench study. The bench study shows success meeting the 6 analytes of concern for the state of Maine, ECT2 recommends piloting as the next step. There are multiple avenues to help optimize by leverage ECT2's experience and augmenting air flow rate, multiple units in series, chemical dosing and location during a continuous flow pilot. ECT2 has invested in multiple piloting systems that have the ability to optimize the process to better design full scale systems. Piloting JRL's leachate will help evaluate treatment as influent conditions change and help facilitate better understanding of potential operational conditions and costs.

6.0 Closing

We appreciate the opportunity to submit this report and look forward to our continued association with you on this project. Please do not hesitate to contact Nicole Bolea (952.270.8923, nmbolea@ect2.com), or myself (585.770.4361, mnickelsen@ect2.com), if you have any questions.

Sincerely yours,

MGNickelsen

Michael G. Nickelsen, Ms. Sci.
Vice President of Research & Development

Cc: Steve Woodard, PhD, PE, Chief Innovation Officer
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APPENDIX D-4

BENCH SCALE FF RESULTS FOR JRL LEACHATE BY SANEXEN

SME
SEVEE & MAHER
ENGINEERS

ALTRA
PFAS TREATMENT SOLUTIONS

DRAFT

Results of Laboratory-Scale Tests on a Landfill Leachate (cf., Juniper Ridge, ME Landfill): PFAS removal using SANEXEN's ALTRA PFAS Treatment Technologies

Property Located at 2828 Bennoch Rd, Alton, ME, USA

Matthew W. Muzzy, P.E.
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July 20, 2022

SANEXEN

O/Ref. : DA22

Results of Laboratory-Scale Tests on a Landfill Leachate (cf., Dolby Landfill, ME): PFAS removal using SANEXEN's ALTRA PFAS Treatment Technologies

Property Located at 2828 Bennoch Rd,
Alton, ME, USA

SEVEE & MAHER ENGINEERS

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Draft report

July 20, 2022

O/Ref. : DA22

SANEXEN

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TABLE 2 PFAS concentrations in raw leachate, leachate treated (30 min) by Foam Fractionation (FF) and filtered on Ion Exchange Resin.....7

1. SUMMARY OF LABORATORY TESTS

The State of Maine Environmental and Natural Resources committee passed LD 1875 in April 2022 to address PFAS Pollution at State-owned Solid Waste Landfills. LD 1875 includes language requiring that the Bureau of General Services (BGS) completes a study of methods, other than dilution, for treating leachate collected at State-owned landfills. Sevee & Maher Engineers have been contracted by BGS to conduct a study to identify and assess treatment alternatives for reducing the concentration of PFAS in leachates that discharge from State-owned solid waste landfills, Dolby landfill and Juniper Ridge landfill. The treated leachate standard is to meet the Maine Interim Drinking Water Standards. Sevee & Maher Engineers are interested in evaluating whether SANEXEN's ALTRA PFAS Treatment Solutions can be utilized for on-site treatment of the leachate to remove/reduce PFAS to the desired treated leachate standard.

SANEXEN's ALTRA PFAS Treatment Solutions offers several treatment technologies to address PFAS contamination in landfill leachate. To determine which of SANEXEN's treatment technologies are best suited to efficiently treat the landfill leachate at the Juniper Ridge Landfill site, SANEXEN has conducted preliminary treatment tests at the laboratory scale. As a starting point, SANEXEN performed the extraction of PFAS from liquid waste streams using the ALTRA Proprietary Process (based on Foam Fractionation). The generated stream was then filtered through a specialized ion exchange resin (IER) in a separate step.

The guidance values for this project are Maine's maximum contaminants limits (MCLs) which are currently established as a composite concentration, given by the sum of six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA). The composite concentration must be lower than 20 ng/L. However, the state does offer some flexibility if current technologies cannot bring the contamination levels down to these criteria. Those cases must be reviewed in collaboration with the Maine Department of Environmental Protection (MEDEP).

The objective of the laboratory scale tests is to evaluate the performance of SANEXEN's ALTRA PFAS Treatment Solutions to determine what PFAS levels could be achieved in the treated leachate, and whether the concentrations of those six PFAS compounds in the treated leachate would be low enough to meet Maine's proposed MCLs for Interim drinking water standards.

SANEXEN has completed the bench testing of the Juniper Ridge Landfill raw leachate using the ALTRA Proprietary Process (Foam Fractionation), as presented in Figure 1, followed by filtration of the Foam Fractionation treated leachate using Ion Exchange Resin (IER), as well as the analysis of the treated leachates.

FIGURE 1 – Laboratory scale setup of SANEXEN's ALTRA Proprietary Process

Experiments were performed with the as-received leachate samples. All tests were completed at SANEXEN's laboratory at the National Research Council Canada facility in Boucherville, QC. PFAS analyses were performed on SANEXEN's LC-MS/MS system, using a modified USEPA method 533 and a modified USEPA method 8327. A total of 25 PFAS[1] were monitored throughout the experiments. Only the PFAS that were detected in the raw leachate are reported in the test results.

For Quality control purposes, an isotopic internal standard is added to each sample. The results are corrected according to the recovery percentages of that standard to ensure that any matrix effect or any loss of analytes through the whole process are accounted for. Each sample batch includes a blank and a standard to confirm that the instrument is operating properly at the time of the analysis. A blank run is also added to the end of the batch to ensure that no analyte or contaminant was carried over from analysis

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[1] PFBA, PFMPA, PFPeA, PFBS, PPFMBA, PFEESA, NFDHA, 4:2FTS, PFHxA, PFPeS, HFPO-DA, PFHpA, PFHxS, DONA, 6:2FTS, PFOA, PFHpS, PFNA, PFOS, 9Cl-PF3ONS, 8:2 FTS, PFDA, PFUnDA, 11Cl-FP3OUdS, PFDoDA

to analysis. The acceptable ranges for those controls are the same as those listed in the EPA methods. For this project, dilutions were done on the final SPE extract and the results are compared to ensure that they fall within an acceptable statistical range from one another. Results for PFAS compounds that have an undefined, branched, and linear form that can clearly be identified are reported as the sum of those isomers. This type of mixture can sometimes be known as a technical mixture in some reports.

2. RESULTS

2.1 PFAS Removal

A 12-L batch of raw leachate (at 21 °C, 70 °F) was treated in a miniaturized SANEXEN ALTRA Proprietary Process column that closely replicates SANEXEN's commercial scale foam fractionation (FF) process. Initial testing indicated that foam was easily generated with the raw leachate, and so, the addition of a surfactant was not required to make the raw leachate foam. The raw leachate was treated in batch mode over a period of 30 minutes. The resulting FF-treated leachate was then filtered on IER in a separate step.

TABLE 1
Juniper Ridge Landfill Leachate Properties

Color	Dark brown
pH	7-8 (indicator paper)
Comment(s)	• Foams easily • High buffering capacity • Foams intensely when mixed with acids

Of the 25 PFAS analyzed, 13 were detected in the raw leachate: PFBA, PFBS, PFPeA, PFPeS, PFHxA, PFHxS, PFHpA, 6:2 FTS, PFOA, PFNA, PFOS, 8:2 FTS, PFDA.

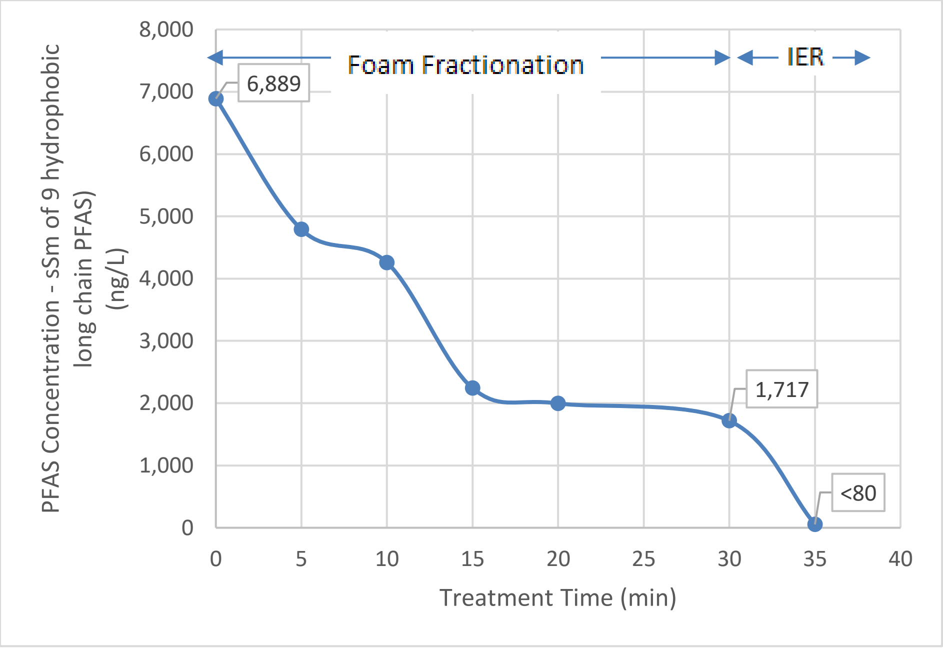

FIGURE 2– Removal of PFAS (sum of nine long-chain, hydrophobic PFAS) by SANEXEN's Foam Fractionation Process and IER

As illustrated in Figure 2, the ALTRA Proprietary Process (Foam Fractionation) efficiently removed the long-chain, hydrophobic PFAS: PFHxA, PFHpA, PFHxS, 6:2 FTS, PFOA, PFNA, PFOS, 8:2 FTS, PFDA. The sum of these nine long-chain, hydrophobic PFAS was decreased from 6,889 ng/L to 1,717 ng/L, representing an overall removal of 80% by weight after 30 minutes of treatment, using only the ALTRA Proprietary Process (Foam Fractionation). Adding the IER lowered the concentration of these eight long-chain, hydrophobic PFAS to less than <80 ng/L representing an overall removal of >99%.

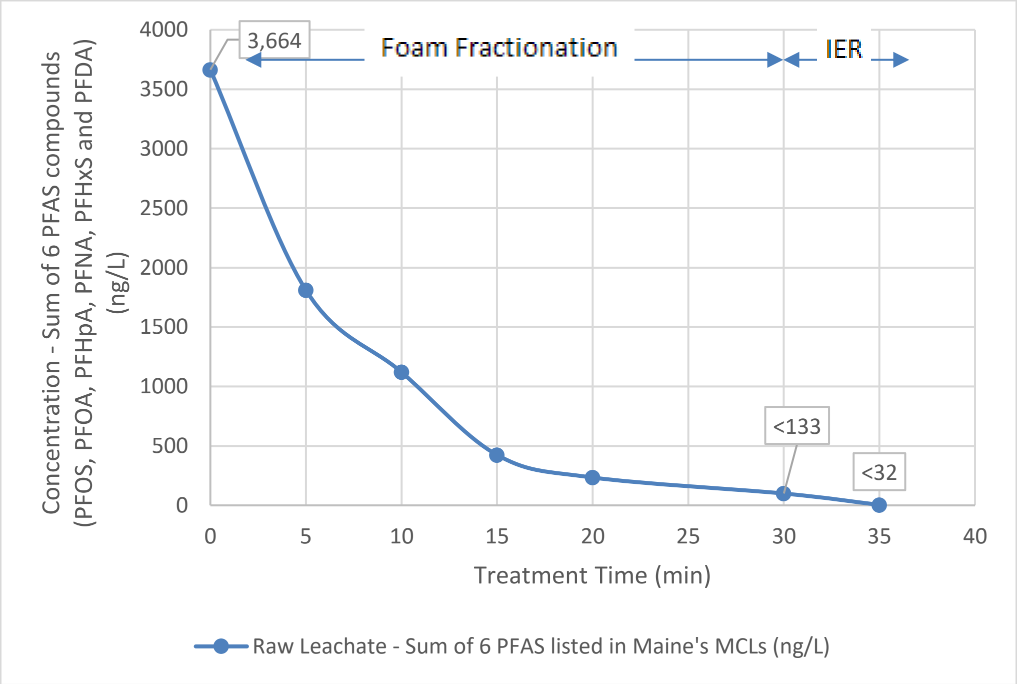

FIGURE 3– Removal of PFAS (sum of compounds listed in Maine's MCLs: PFHpA, PFHxS, PFOA, PFNA, PFOS, PFDA) by SANEXEN's Foam Fractionation Process and IER.

As illustrated in Figure 3, the ALTRA Proprietary Process (Foam Fractionation) efficiently removed the six PFAS compounds listed in Maine's MCLs. The sum of these six PFAS compounds was decreased from 3,664 ng/L to less than 133 ng/L, representing an overall removal of 96% by weight after 30 minutes of treatment, using only the ALTRA Proprietary Process (Foam Fractionation). Adding filtration by IER lowered the concentration of these six PFAS compounds to less than 32 ng/L representing an overall removal of >99%.

TABLE 2

PFAS concentrations in raw leachate, leachate treated (30 min) by Foam Fractionation (FF) and filtered on Ion Exchange Resin

	PFAS	Raw Leachate ng/L (ppt)	ALTRA FF treated Leachate ng/L (ppt)	IER treated leachate ng/L (ppt)	PFAS removal (ALTRA FF only)	PFAS removal (ALTRA FF combined with IER filtration)
Shorter chain PFAS	PFBA	1,800	1,380	550	23%	69%
	PFPeA	1,430	1,100	180	23%	87%
	PFBS	3,000	2,500	11	17%	99.6%
	PFPeS	80	37	<2	53%	>97.5%
Longer chain PFAS	PFHxA	2,800	1,590	24	43%	99.1%
	PFHpA	1,200	80	<10	93%	>99.1%
	PFHxS	500	<5	<5	>99.3%	>99.7%
	6:2FTS	400	<5	<5	>98.7%	>98.7%
	PFOA	1,630	<4	<4	>99.7%	>99.8
	PFNA	95	<3	<3	>97%	>97%
	PFOS	200	<18	<6	>91%	>97%
	8:2FTS	25	<8	<8	>68%	>68%
	PFDA	39	<4	<4	>90%	>90%
	Sum of all measured PFAS	13,200	6,734	812	49%	>93.8%
	Maine's MCL	3,664	<133	<32	>96%	>99.1%
	Sum of long-chain hydrophobic PFAS	6,889	1,717	<80	75%	>99%

Results in Table 2 report individual PFAS concentrations in the raw leachate, in the FF-treated leachate (30 min) by the ALTRA Proprietary Process (Foam Fractionation), and in the IER filtered leachate. Those PFAS compounds that are listed in Maine's proposed Drinking Water MCL are listed in red text.

Based on the bench test results, the ALTRA PFAS Treatment Solution (FF process followed by filtration with IER) will produce treated leachate that shows a significant reduction of the PFAS listed in Maine's MCLs for six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA), from a sum of 3,664 ng/L in the raw leachate down to a sum of less than 133 ng/L in the FF-treated leachate and down to a sum of <32 ng/L in the IER filtered leachate.

This table, as well as Figure 3, indicates clearly that the ALTRA PFAS Treatment Solution (FF process followed by filtration using IER) will produce treated leachate that comes very close to meeting Maine's proposed Drinking Water MCL, sum of 6 PFAS < 20 ng/L.

Although the MCLs are not met, Maine's Department of Environmental Protection (ME DEP) offers the possibility to consider a different standard should available technologies not fully meet <20 ng/L. SANEXEN is confident that through the use of a more specific IER, or an alternate filtration media, we will meet or exceed the MCL target of <20 ng/L.

3. CONCLUSIONS AND NEXT STEPS

The laboratory scale tests conducted by SANEXEN on the Juniper Ridge Landfill leachate demonstrated that SANEXEN's ALTRA PFAS Treatment Solution (FF process followed by filtration with IER) will produce treated leachate that shows a significant reduction of the PFAS compounds listed in Maine's proposed Drinking Water MCLs for six PFAS compounds (PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA), from a sum of 3,664 ng/L in the raw leachate, down to a sum of less than 133 ng/L in the FF-treated leachate, and down to a sum of <32 ng/L in the IER filtered leachate.

The results clearly indicate that the ALTRA PFAS Treatment Solution (FF process followed by filtration using IER) will produce treated leachate that comes very close to meeting Maine's proposed Drinking Water MCL, sum of six PFAS < 20 ng/L.

Although the MCLs are not met, Maine's Department of Environmental Protection (ME DEP) offers the possibility to consider a different standard should available technologies not fully meet <20 ng/L.

SANEXEN is very confident that we will be able to treat the Juniper Ridge Landfill raw leachate with our full-scale, commercial, ALTRA PFAS Treatment Solution (FF followed by filtration using a more specific IER, or an alternate filtration media), to meet or exceed Maine's proposed Drinking Water MCL target of <20 ng/L for the sum of six PFAS compounds.

As a next step, SANEXEN proposes to conduct a paid Demo Field Pilot Test (duration to be discussed, possibly 2 to 4 weeks) to validate the laboratory results on-site, to identify opportunities for improvement, to optimize process parameters, and to estimate capital and operational costs of full-scale treatment.

We will be happy to discuss these results with you in greater detail, and we hope to have the opportunity to conduct a Demo Field Pilot test at the Juniper Ridge Landfill in conjunction with Sevee & Maher Engineers in the near future.

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APPENDIX E

OPINION OF PROBABLE CONSTRUCTION AND OPERATION & MAINTENANCE COSTS – DOLBY LEACHATE

SME
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TABLE E-1. COST ESTIMATE FOR DOLBY BULK PFAS REDUCTION VIA FF AND INDIRECT DISCHARGE TO EMWWTP

CONSTRUCTION ELEMENT	DESCRIPTION	COST
A. SITE WORK/PROJECT DEVELOPMENT CAPEX		
1. Modify Existing PS and Install New Inf Pipeline	Modify Wet Well and Construct Pipeline from PS to FF Trailer	$ 180,000.00
2. TE Pipeline from FF to New Pump Station	Gravity line and new pump station from Dolby to EMWWTP	$ 219,500.00
3. Site Work/Foundation Slab & Containment	Site work/foundation slab & containment for FF trailers	$ 82,000.00
4. Install New Electrical Service for FF Trailer	Run electrical service to FF trailer pad location	$ 20,000.00
5. Construct Additional Leachate Holding EQ Capacity	Holding Pond(s) for Raw Leachate Storage During Spring	$ 3,462,000.00
6. Construct New Inf/Eff Lines and PS for EQ Storage	Extend Lines to Supplemental EQ Storage and PS	$ 390,000.00
7. Install line for process water	Extend potable water to trailer locations	$ 10,000.00
8. Cost for Mobilization/Demobilization	Mob/Demob Costs are Upfront Capital Cost	$ 240,000.00
9. Provide Standby Generators	Two Units: one at leachate storage pond & one at FF unit	$ 70,000.00
SUBTOTAL SITE WORK CAPEX		$ 4,673,500.00
Engineering	Based on 12 percent of construction cost	$ 560,820.00
Construction Management	Based on 12 percent of construction cost	$ 560,820.00
Contingency	Based on 40 percent of consturction cost	$ 1,869,400.00
TOTAL SITE WORK CAPEX		$ 7,664,540.00
B. ANNUAL LEASE/OTHER O&M COSTS (5)		
1. FF Process Equipment Lease (1)	Integrated FF trailer(s) with reactors, booster chemicals, etc.	$ 412,800.00
2. Foamate Storage/Concentrator Lease (2)	Foamate volume estimated at 5,500 gpd (5%)	$ 186,000.00
3. IEX Polishing of Raffinate (if necessary) (3)	Estimate Based on 110,000 gpd (include only if necessary)	$ 93,600.00
4. Super IEX Loading Process Lease (4)	Estimate based on volume of super foamate of 550 gpd (0.5%)	$ 36,000.00
5. Foamate Stabilization Process Lease	Estimate based on volume of super foamate of 550 gpd (0.5%)	-
6. Service Contract Cost	Cost per gallon of leachate treated - FF only	$ 846,216.00
	Cost per gallon of leachate treated - FF and IEX polishing	$ 2,135,688.00
7. Electricity - FF Process/Concentrator/IER Polishing	See projected electrical consumption spreadsheet	$ 85,920.00
8. Replacement of Spent Foamate Media	Media based on foamate volume of 550 gpd; 550 ft3 media	$ 165,000.00
9. Disposal of Spent Foamate Media in Landfill	Disposal of Saturated Super-Loaded Media (30 cy/yr)	$ 30,000.00
10. Disposal of IEX Resin for PFAS Polishing of Raffinate (if necessary) (3)	Disposal of Media (53 cy/yr) in LF; Replacement media incld in Service $	$ 53,000.00
11. Electricity - Other than FF Process	Pumps, heaters, etc not related to FF	$ 12,000.00
12. Analytical Testing	See quote from Alpha Analytical for details	$ 62,400.00
13. Program Management and Reporting	Monthly Reporting Reports/General PM Oversight	$ 24,000.00
14. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer and $200/mo for support	$ 14,400.00
SUBTOTAL ANNUAL UPFRONT FF PFAS REMOVAL	Assumes FF Only; no IEX polishing	$ 1,874,736.00
SUBTOTAL ANNUAL UPFRONT FF PFAS REMOVAL	Assumes FF and IEX polishing	$ 3,310,808.00
ESTIMATED COST TO TREAT PER GALLON LEACHATE	Assumes FF Only; no IEX polishing (based on volume for 2024)	$ 0.047
ESTIMATED COST TO TREAT PER GALLON LEACHATE	Assumes FF and IEX polishing (based on volume for 2024)	$ 0.082
C. COST SUMMARY		
Capital Cost Present Worth		
PW Site Work/Project Development	Capital Cost	$ 7,664,540
PW Annual Lease/Other O&M - FF Only	PW Cost based on 5-year period and interest of 5 percent	$ 8,116,670
PW Annual Lease/Other O&M Cost - FF/IEX Polishing	PW Cost based on 5-year period and interest of 5 percent	$ 14,334,143
TOTAL LIFE CYCLE PW COSTS - FF ONLY		$ 15,781,210
TOTAL LIFE CYCLE PW COSTS - FF PLUS IEX POLISHING		$ 21,998,683
PW COST PER MG OF LEACHATE TREATED - FF ONLY	Cost per MG Treated - FF only	$ 89,055
PW COST PER MG OF LEACHATE TREATED - FF PLUS IEX	Cost per MG Treated - FF plus IEX Polishing	$ 124,141

(1) - FF process trailers includes an integrated process with pre-filters, FF Reactors, air injectors, recirculation pumps, surfactant dosing system, break tank and I&C;
FF is capable of processing maximum day leachate volume of 150,000 gpd during high flow spring conditions; annual average flow in 2024 is 110,400 gpd.

(2) - Foamate storage and concentrator trailer includes foamate storage tanks and concentrator to reduce roughly 5,500 gpd of foamate to 550 gpd of super-foamate.

(3) - IEX Polishing of raffinate if necessary to reach PFAS(6) of 20 ng/l.

(4) - Super IEX Loading trailer includes IEX adsorbers and feed equipment necessary to sorb concentrated PFAS onto IEX resin and then dispose of spent media in landfill.

(5) - All labor cost, consumables (surfactants, resins), etc. are included in the Annual Lease/Operations contract with the exception of electricity, analytical testing and program management.

TABLE E-2. COST ESTIMATE FOR DOLBY BULK PFAS REDUCTION VIA EAOP AND INDIRECT DISCHARGE TO EMWWTP

CONSTRUCTION ELEMENT	DESCRIPTION	COST
A. SITE WORK/PROJECT DEVELOPMENT		
1.Modify Existing PS and Install New Inf Pipeline	Modify Wet Well and Construct Pipeline from Wet Well to EAOP Trailer	$ 180,000.00
2. TE Pipeline from EAOP to New Pump Station	Gravity line and new pump station from Dolby to EMWWTP	$ 219,500.00
3. Site Work/Foundation Slab & Containment	Site work/foundation slab & containment for 16 EAOP trailers	$ 178,500.00
4. Install New Electrical Service for EAOP Trailer	Run electrical service to EAOP trailer pad location	$ 100,000.00
5. Construct Additional Leachate Holding EQ Capacity	Holding Pond(s) for Raw Leachate Storage During Spring	$ 3,462,000.00
6. Construct New Inf/Eff Lines and PS for EQ Storage	Extend Lines to Supplemental EQ Storage and PS	$ 390,000.00
7. Install line for process water	Extend potable water to trailer locations	$ 10,000.00
8. Cost for Mobilization/Demobilization	Mob/Demob Costs are Upfront Capital Cost	-
9. Provide Standby Generators	Two Units: one at leachate storage pond & one at EAOP unit	$ 105,000.00
SUBTOTAL SITE WORK CAPEX		$ 4,645,000.00
Engineering	Based on 12 percent of construction cost	$ 557,400.00
Construction Management	Based on 12 percent of construction cost	$ 557,400.00
Contingency	Based on 40 percent of consturction cost	$ 1,858,000.00
TOTAL SITE WORK CAPEX		$ 7,617,800.00
B. ANNUAL LEASE/OTHER O&M COSTS (2)		
1. Service Cost to Operate EAOP Trailers (1)	Integrated EAOP trailers with reactors	$ 4,835,520.00
2. Electricity - EAOP Process	See Vendor Estimate	$ 362,880.00
3. Electricity - Other than EAOP	See projected electrical consumption spreadsheet	$ 12,000.00
4. Analytical Testing	See quote from Alpha Analytical for details	$ 62,400.00
5. Program Management and Reporting	Monthly Reporting/General PM Oversight	$ 24,000.00
6. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer and $200/mo for support	$ 14,400.00
SUBTOTAL ANNUAL EAOP PFAS REMOVAL		$ 5,311,200.00
ESTIMATED COST TO TREAT PER GALLON	EAOP Treatment based on volume for 2024	$ 0.132
C. COST SUMMARY		
Capital Cost Present Worth		
PW Site Work/Project Development	Capital Cost	$ 7,617,800.00
PW Annual Lease/Other O&M Costs	PW Cost based on 5-year period and interest of 5 percent	$ 22,994,840.40
TOTAL LIFE CYCLE PW COSTS - EAOP		$ 30,612,640.40
PW COST/MG OF LEACHATE TREATED - EAOP ONLY	Cost per MG Treated - 2 yrs @ 110,000 gpd; 3 yrs @ 88,500 gpd	$ 172,750

(1) - EAOP trailers include integrated process with 128 reactors contained within 16 skid units

(2) - All labor cost, consumables, etc. are included in the Annual Lease/Operations contract with the exception of electricity, analytical testing, office trailer and program management.

TABLE E-3. COST ESTIMATE FOR DOLBY PFAS REDUCTION VIA RO/CONCENTRATE TREATED BY EAOP/INDIRECT DISCHARGE TO EMWWTP

CONSTRUCTION ELEMENT	DESCRIPTION	COST
A. SITE WORK/PROJECT DEVELOPMENT CAPEX		
1. Modify Existing PS and Install New Inf Pipeline	Modify Wet Well and Construct Pipeline from PS to FF Trailer	$ 180,000.00
2. TE Pipeline from RO to New Pump Station	Gravity line and new pump station from Dolby to EMWWTP	$ 219,500.00
3. Site Work/Foundation Slab & Containment	Site work/foundation slab & containment for RO/EAOP	$ 69,300.00
4. Install New Electrical Service for RO and EAOP Processes	Run electrical service to RO/EAOP trailer pad location	$ 100,000.00
5. Construct Supplemental Off-Line Leachate Storage	Holding Pond(s) for Raw Leachate Storage During Spring	$ 3,462,000.00
6. Construct New Inf/Eff Lines and PS for EQ Storage	Extend Lines to Supplemental EQ Storage and PS	$ 390,000.00
7. Install line for process water	Extend potable water to trailer locations	$ 10,000.00
8. Cost for Mobilization/Demobilization	Mob/Demob Costs are Upfront Capital Cost	-
9. CAPEX to Locate EAOP Units	Not Applicable	-
10. Provide Standby Generators	Two Units: one at leachate storage pond & one at RO unit	$ 150,000.00
SUBTOTAL SITE WORK/PROJECT DEVELOPMENT CAPEX		$ 4,580,800.00
RO and EAOP CAPEX Development		
1. Integrated RO System	2 - 75,000 gpd skid units with HPRO, ancillary tankage, pumps, degassifier	$ 3,660,000.00
2. CAPEX to Locate RO/Building, etc.	Construct Building for RO Treatment Process (60' x 70')	$ 630,000.00
SUBTOTAL RO/EAOP CAPEX DEVELOPMENT		$ 4,290,000.00
SUBTOTAL SITE DEVELOPMENT AND RO/EAOP CAPEX DEVELOPMENT		$ 8,870,800.00
Engineering	Based on 12 percent of construction cost	$ 1,064,496.00
Construction Management	Based on 12 percent of construction cost	$ 1,064,496.00
Contingency	Based on 40 percent of consturction cost	$ 3,548,320.00
TOTAL SITE WORK CAPEX		$ 14,548,112.00
B. ANNUAL LEASE/OTHER O&M COSTS (3)		
1. Service Contract for RO Process Equipment Lease (1)	Not Applicable, CAPEX is provided above; No RO Service Contract	-
2. Electricity - RO Process	Projected 275 kw of power; estimated at 2,310,000 kw-hr/yr	$ 277,200.00
3. Service Contract for EAOP Concentrate Lease (2)	EAOP trailers with reactors, avg annual Q = 5.9 MG/yr @ 16,200 gpd	$ 1,593,000.00
4. Electricity - EAOP Process for Concentrate Treatment	Projected 450 Amps, 240 V, 3 ph; 907,200 kw-hr/yr	$ 108,864.00
5. Electricity - Other than RO and EAOP Processes	Pumps, heaters, etc not related to RO/EAOP	$ 12,000.00
6. Labor	Assume 1 FT with 10% OT and On-Call	$ 150,000.00
7. Chemicals (H2SO4, Caustic Cleaners, Anti-scalant)	Based on 80 clean cycles/yr, H2SO4 continuous (7.35k gal/yr), plus anti-scale	$ 142,155.00
8. Membrane Replacement	Assume 3-yr membrane life and $105/m^2 ($83,600/yr)	$ 112,140.00
9. Equipment Repair/Replacement (R/R)	Based on 3.5 % of RO CAPEX	$ 128,167.00
10. Analytical Testing	See quote from Alpha Analytical for details	$ 62,400.00
11. Program Management and Reporting	Monthly Reporting Reports/General PM Oversight	$ 24,000.00
12. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer and $200/mo support	$ 14,400.00
13. Concentrate Hauling Between Dolby/JRL	Not Applicable - EAOP Dedicated to Dolby Site Only	-
SUBTOTAL ANNUAL PFAS REMOVAL USING RO AND EAOP	RO and EAOP for Concentrate	$ 2,624,326.00
ESTIMATED COST TO TREAT PER GALLON LEACHATE	RO and EAOP for Concentrate (based on volume for 2024)	$ 0.065
C. COST SUMMARY		
Capital Cost Present Worth		
PW Site Work/Project Development	Capital Cost	$ 14,548,112
PW Annual Lease/Operations Contract - RO and EAOP	PW Cost based on 5-year period and interest of 5 percent	$ 11,362,019
TOTAL LIFE CYCLE PW COSTS - RO and EAOP		$ 25,910,131
PW COST PER MG OF LEACHATE TREATED - RO and EAOP	Cost per MG Treated - RO and EAOP	$ 146,214

(1) - RO process includes an integrated process with pre-filters, two-pass RO process and ultra high pressure (UHP) RO, CIP backwashing, I&C, etc.
RO is capable of processing maximum day leachate volume of 150,000 gpd during high flow spring conditions; annual average flow in 2024 is 110,400 gpd.

(2) - EAOP trailer includes one unit with 8 reactors

(3) - All labor cost, consumables, etc. are included in the Annual Lease/Operations contract with the exception of electricity, analytical testing and program management.

TABLE E-4. COST ESTIMATE FOR DOLBY BIOLOGICAL PRETREATMENT, TERTIARY FILTRATION AND GAC FOR PFAS REMOVAL

CONSTRUCTION ELEMENT	DESCRIPTION	COST Q max = 0.877 mgd (2)	COST Q max = 1.3 mgd (2)
A. SITE WORK/PROJECT DEVELOPMENT			
General Site Development			
1. Site Work/Foundation Slab	General Site Work at EMWWTP	$ 40,000.00	$ 40,000.00
2. Install New Electrical Service forTertiary Processes	Run electrical service to biological WWTP/GAC Reactors location	$ 20,000.00	$ 20,000.00
3. Construct Additional Leachate Holding Ponds	Construct Additional Off-Line Storage for Raw Leachate EQ	$ 2,216,000.00	$ 2,216,000.00
SUBTOTAL GENERAL SITE DEVELOPMENT		$ 2,276,000.00	$ 2,276,000.00
Pretreatment and Sorption PFAS Development			
1. Iron and Manganese Pre-engineered System	Pre-packaged Fe/Mn System with Oxidation	$ 750,000.00	$ 1,312,500.00
2. Pre-filtration Prior to GAC	Pre-engineered Cermic Membrane Filter Operation	$ 2,000,000.00	$ 3,500,000.00
3. Pre-engineered GAC System	Pre-Engineered Systems/GAC Only; Two Trains with Lead/Lag Layout	$ 1,950,000.00	$ 3,412,500.00
4. WWTP Building forTertiary Treatment Operation	Building for Fe/Mn Removal, Tertiary Membrane Filters, GAC, etc (50x100)	$ 750,000.00	$ 937,500.00
5. Construct Diversion from DeCl2 to New Wet Well	Pipeline to and from tertiary operations	$ 90,000.00	$ 90,000.00
6. Install New Tertiary Influent Pump Station	Install new tertiary influent feed pumps and wet well	$ 125,000.00	$ 125,000.00
7. Install filtrate recycle and PS from tertiary building to influent	Prefilter recycle FM and PS from tertiary bldg to WWTP influent location	$ 150,000.00	$ 150,000.00
8. Integrate IEX PLC to EMWWTP SCADA	Integrate I&C from IEX into EMWWTP SCADA system	$ 50,000.00	$ 50,000.00
9. Extend process water and electrical to New Tertiary Treatment	Run either potable water or plant water to treatment process	$ 10,000.00	$ 10,000.00
10. Provide Office Trailer with Bathroom	Not Necessary at EMWWTP Location	-	-
11. Annual Repairs/Equipment R/R	Annual Equipment Repair/Replacement	$ 5,000.00	$ 5,000.00
12. Building/Laboratory Supplies	Annual Misc Supplies	$ 2,000.00	$ 2,000.00
SUBTOTAL PRETREATMENT AND SORPTION DEVELOPMENT		$ 5,882,000.00	$ 9,594,500.00
SUBTOTAL SITE WORK/PROJECT DEVELOPMENT		$ 8,158,000.00	$ 11,870,500.00
Engineering	Based on 12 percent of construction cost	$ 978,960.00	$ 1,424,460.00
Construction Management	Based on 12 percent of construction cost	$ 978,960.00	$ 1,424,460.00
Contingency	Based on 40 percent of consturction cost	$ 3,263,200.00	$ 4,748,200.00
TOTAL SITE WORK/PROJECT DEVELOPMENT		$ 13,379,120.00	$ 19,467,620.00
B. ANNUAL LEASE/OTHER O&M COSTS			
1. Mobilize and Operate Prefilter, GAC and IEX Process (1)	Process includes purchased equipment and no service or annual leases	No Cost	No Cost
2. Electricity - Pretreatment, Tertiary Filtration, PFAS Sorption	See projected electrical consumption spreadsheet	$ 48,000.00	$ 48,000.00
3. Electricity - Other Processes Outside Tertiary/GAC Operation	Pumps, heaters, mixers not related to GAC/IEX Process	$ 6,000.00	$ 6,000.00
4. Analytical Testing	See quote from Alpha Analytical for details	$ 72,800.00	$ 72,800.00
5. GAC Media Change-Out and Disposal	Volume of media based on annual EMWWTP flow of 470,000 gpd	$ 468,600.00	$ 468,600.00
6. IEX Resin Change-out and Disposal	Volume of media based on annual EMWWTP flow of 470,000 gpd	-	-
7. Chemicals for Tertiary Processes	Oxidant for Fe/Mn; Ox. Alum, Caustic, Acid for Tertiary Membranes	$ 84,000.00	$ 84,000.00
8. Dredging, Dewatereing and Disposal of WAS	Dredged WAS likely tainted with PFAS and will require disposal	-	-
9. Labor Cost for O&M Tertiary and GAC Operations	Labor Cost Assumed to be EMWWTP Support Staff (includes OT & On-Call)	$ 129,386.40	$ 129,386.40
10. Annual Repair and Replacement for Equipment	Nominal Equipment Replacement	$ 5,000.00	$ 5,000.00
11. Supplies for Buildings/Grounds	Nominal Supplies for Buildings and Laboratory	$ 2,000.00	$ 2,000.00
12. Program Management and Reporting	Monthly Reporting/General PM Oversight	$ 24,000.00	$ 24,000.00
SUBTOTAL OTHER O&M COST		$ 839,786.40	$ 839,786.40
C. COST SUMMARY			
Capital Cost and Present Worth of Annual O&M			
PW Site Work/Project Development		$ 13,379,120	$ 19,467,620
PW Annual Lease/Other O&M Costs	PW Cost based on 5-year period and interest of 5 percent	$ 3,635,855	$ 3,635,855
TOTAL LIFE CYCLE PW COSTS		$ 17,014,975	$ 23,103,475
PW COST/MG OF LEACHATE TREATED -	Cost per MG Treated - 2 yrs @ 110,000 gpd; 3 yrs @ 88,500 gpd	$ 96,017	$ 130,375

(1) - Integrated tertiary pretreatment and PFAS adsorption process includes prefilters, Fe/Mn Removal, membrane filters, GAC Reactors, I&C, and heaters in new building.
GAC process is capable of processing maximum day EMWWTP effluent of 877,000 gpd and an annual average flow of 470,000 gpd.

(2) - Projected maximum flows estimated at between 0.877 mgd and 1.3 mgd assuming off-line storage at Dolby and former GNP emergency wastewater pond

APPENDIX F

OPINION OF PROBABLE CONSTRUCTION AND OPERATION & MAINTENANCE COSTS – JRL LEACHATE

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TABLE F-1. COST ESTIMATE FOR JRL BULK PFAS REDUCTION VIA FF AND INDIRECT DISCHARGE TO NINE DRAGONS

CONSTRUCTION ELEMENT	DESCRIPTION	COST
A. SITE WORK/PROJECT DEVELOPMENT		
1. Install Mixer in Leachate Storage Tank	Install PAX mixer or equivalent for uniform mixing	$ 36,000.00
2. Install New PS and Modify Inf Pipeline	Construct pipeline and PS from AST to FF Trailer	$ 100,000.00
3. Site Work/Foundation & Containment Slab	Site work/foundation slab/containment for FF trailers	$ 72,000.00
4. Install New Electrical Service for FF Trailer	Run electrical service to FF trailer pad location	$ 24,000.00
5. Install New 0.5 MG Treated Eff Holding Tank	Holding Tank for FF Raffinate/Secondary Containment	$ 1,054,000.00
6. Treated Effluent/PS from Treatment to New EQ Tank	TE pump station and force main to new EQ tank	$ 155,000.00
7. Extend process water to Treatment Area	Run either potable water or plant water to treatment process	$ 10,000.00
8. Cost for Mobilization/Demobilization	Mob/Demob Cost are Upfront Capital Cost	$ 130,000.00
9. Coordinate Standby Power	Integrate standby power to include pumps and treatment units	$ 20,000.00
SUBTOTAL SITE WORK/PROJECT DEVELOPMENT		$ 1,601,000.00
Engineering	Based on 12 percent of construction cost	$ 192,120.00
Construction Management	Based on 12 percent of construction cost	$ 192,120.00
Contingency	Based on 40 percent of consturction cost	$ 640,400.00
TOTAL SITE WORK/PROJECT DEVELOPMENT		$ 2,625,640.00
B. ANNUAL LEASE/OPERATIONS CONTRACT (5)		
1. Mobilize/Operate FF Process (1)	Monthly Lease Cost for Equipment - FF	$ 208,800.00
2. Mobilize/Operate IEX Polishing Raffinate (if necessary) (2)	Monthly Lease Cost for IEX Resin Process for Raffinate	$ 46,800.00
3. Mobilize/Operate Foamate Storage/Concentrator (3)	Monthly Lease Cost for Concentrator at 350 gpd (0.5%)	$ 92,400.00
4. Super IEX Loading Process Lease (4)	Estimate based on volume of super foamate of 350 gpd (0.5%)	$ 24,000.00
5. Foamate Stabilization Process Lease	Estimate based on volume of super foamate of 350 gpd (0.5%)	-
6. Service Contract Cost	Cost per gallon of leachate treated - FF only	$ 418,509.00
	Cost per gallon of leachate treated - FF and IEX polishing	$ 1,056,237.00
7. Electricity - FF Process/Concentrator/IER Polishing	See Vendor projections	$ 85,920.00
8. Replacement of Spent Foamate Media	Media based on foamate volume of 350 gpd; 350 ft3 media	$ 105,000.00
9. Disposal of Spent Foamate Media in Landfill	Disposal of Media Saturated (20cy/yr)	$ 20,000.00
10. Disposal of IEX Resin for PFAS Polishing of Raffinate (if necessary) (3)	Disposal of Media (53 cy/yr) in LF; Replacement media incld in Service $	$ 53,000.00
11. Electricity - Other than FF Process	Pumps, heaters, mixers, etc. not related to FF Process	$ 12,000.00
12. Analytical Testing	See quote from Alpha Analytical for details	$ 62,400.00
13. Program Management and Reporting	Monthly Reporting Reports/General PM Oversight	$ 24,000.00
14. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer and $200/mo for support	$ 14,400.00
SUBTOTAL ANNUAL UPFRONT FF PFAS REMOVAL	Assumes FF Only; no IEX polishing	$ 1,053,029.00
SUBTOTAL ANNUAL UPFRONT FF PFAS REMOVAL	Assumes FF and IEX polishing	$ 1,804,957.00
ESTIMATED COST TO TREAT PER GALLON LEACHATE	Assumes FF Only; no IEX (based on 5-yr average Q = 54,500 gpd)	$ 0.053
ESTIMATED COST TO TREAT PER GALLON LEACHATE	Assumes FF and IEX (based on 5-yr average Q = 54,600 gpd)	$ 0.091
C. COST SUMMARY		
Capital Cost Present Worth		
PW Site Work/Project Development		$ 2,625,640
PW Annual Lease/Operations Contract - FF Only	PW Cost based on (P/A, 5%, 5 yr); PW factor = 0.43295	$ 4,559,089
PW Annual Lease/Operations Contract - FF/IEX Polishing	PW Cost based on (P/A, 5%, 5 yr); PW factor = 0.43295	$ 7,814,561
TOTAL LIFE CYCLE PW COSTS - FF ONLY		$ 7,184,729
TOTAL LIFE CYCLE PW COSTS - FF PLUS IEX POLISHING		$ 10,440,201
PW COST PER MG OF LEACHATE TREATED - FF ONLY	Cost per MG Treated - FF only	$ 72,236
PW COST PER MG OF LEACHATE TREATED - FF PLUS IEX	Cost per MG Treated - FF plus IEX Polishing	$ 104,774

(1) - FF process trailers includes an integrated process with pre-filters, FF Reactors, air injectors, recirculation pumps, surfactant dosing system, break tank and I&C; FF is capable of processing maximum day leachate volume of 114,400 gpd during high flow spring conditions; annual average flow in 2024 is 69,300 gpd; avg flow over 5 yrs is 54,600 gpd.

(2) - IEX Polishing of raffinate if necessary to reach PFAS(6) of 20 ng/l.

(3) - Foamate storage and concentrator trailer includes foamate storage tanks and concentrator to reduce roughly 3,500 gpd of foamate to 350 gpd of super-foamate.

(4) - Super IEX Loading trailer includes IEX adsorbers and feed equipment necessary to sorb concentrated PFAS onto IEX resin and then dispose of spent media in landfill.

(5) - All labor cost, consumables (surfactants, resins), etc. are included in the Annual Lease/Operations contract with the exception of electricity, analytical testing and program management.

TABLE F-2. COST ESTIMATE FOR JRL BULK PFAS REDUCTION VIA EAOP AND INDIRECT DISCHARGE TO NINE DRAGONS

A. SITE WORK/PROJECT DEVELOPMENT

CONSTRUCTION ELEMENT	DESCRIPTION	COST
1. Install Mixer in Leachate Storage Tank	Install PAX mixer or equivalent for uniform mixing	$ 36,000.00
2. Install New PS and Modify Inf Pipeline	Construct pipeline and PS from AST to EAOP Trailer	$ 100,000.00
3. Site Work/Foundation Slab & Containment	Site work/foundation slab/containment for 9 EAOP trailers	$ 106,000.00
4. Install New Electrical Service for EAOP Trailer	Run electrical servicedrops to EAOP trailer pad location	$ 100,000.00
5. Install New 0.5 MG Treated Eff Holding Tank	Holding Tank for EAOP Treated Effluent	$ 1,054,000.00
6. Treated Effluent/PS from Treatment to New EQ Tank	TE pump station and force main to new EQ tank	$ 155,000.00
7. Extend process water to Treatment Area	Run either potable water or plant water to treatment process	$ 10,000.00
8. Cost for Mobilization/Demobilization	Mob/Demob Cost are Upfront Capital Cost	-
9. Coordinate Standby Power	Integrate standby power at JRL including pumps & treatment	$ 20,000.00
SUBTOTAL SITE WORK/PROJECT DEVELOPMENT		$ 1,581,000.00
Engineering	Based on 12 percent of construction cost	$ 189,720.00
Construction Management	Based on 12 percent of construction cost	$ 189,720.00
Contingency	Based on 40 percent of consturction cost	$ 632,400.00
TOTAL SITE WORK/PROJECT DEVELOPMENT		$ 2,592,840.00

B. ANNUAL LEASE/OTHER O&M COSTS (2)

CONSTRUCTION ELEMENT	DESCRIPTION	COST
1. Service Cost to Operate EAOP Trailers (1)	EAOP trailers with reactors, avg annual Q = 54,500 gpd @ 5 yrs	$ 2,188,175.00
2. Electricity - EAOP Process	See Vendor Estimate	$ 215,308.80
3. Electricity - Other than EAOP Process	Pumps, heaters, etc not related to EAOP	$ 12,000.00
4. Analytical Testing	See quote from Laboratory for details	$ 62,400.00
5. Program Management and Reporting	Monthly Reporting Reports/General PM Oversight	$ 24,000.00
6. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer & $200/mo support	$ 14,400.00
SUBTOTAL LEASES/OTHER O&M COST		$ 2,516,283.80
ESTIMATED COST TO TREAT PER GALLON	EAOP Treatment based on 54,500 gpd average volume for 5 yrs	$ 0.126

C. COST SUMMARY

CONSTRUCTION ELEMENT	DESCRIPTION	COST
Capital Cost Present Worth		
PW Site Work/Project Development		$ 2,592,840
PW Annual Lease/Other O&M	PW Cost based on (P/A, 5%, 5 yr); PW factor = 0.43295	$ 10,894,251
TOTAL LIFE CYCLE PW COSTS		$ 13,487,091
PW COST/MG OF LEACHATE TREATED - EAOP ONLY	Cost per MG Treated - EAOP @ 54,600 gpd average over 5 years	$ 135,351

(1) - EAOP trailers include integrated process with 72 reactors within 9 skid units

(2) - All labor cost, consumables (polymers, salt, etc.) are included in the Annual Lease/Operations contract with the exception of electricity, analytical testing and program management.

TABLE F-3. COST ESTIMATE FOR JRL BULK PFAS REDUCTION VIA RO AND INDIRECT DISCHARGE TO NINE DRAGONS

CONSTRUCTION ELEMENT	DESCRIPTION	COST
A. SITE WORK/PROJECT DEVELOPMENT CAPEX		
1. Install Mixer in Leachate Storage Tank	Install PAX mixer or equivalent for uniform mixing	$ 36,000.00
2. Install New PS and Modify Inf Pipeline	Construct pipeline and PS from AST to EAOP Trailer	$ 100,000.00
3. Site Work/Foundation Slab & Containment	Site work for RO building/EAOP Pad	$ 30,000.00
4. Install New Electrical Service for EAOP Trailer	Run electrical service drops to RO/EAOP pad location	$ 100,000.00
5. Install New 0.5 MG Treated Eff Holding Tank	Holding Tank for EAOP Treated Effluent	$ 1,054,000.00
6. Treated Effluent/PS from Treatment to New EQ Tank	TE pump station and force main to new EQ tank	$ 155,000.00
7. Extend process water to Treatment Area	Run either potable water or plant water to treatment process	$ 10,000.00
8. Cost for Mobilization/Demobilization	Mob/Demob Cost are Upfront Capital Cost	-
9. CAPEX to Locate EAOP Unit(s)	Not Applicable	-
10. Coordinate Standby Power	Integrate standby power at JRL including pumps & treatment	$ 20,000.00
SUBTOTAL SITE WORK/PROJECT DEVELOPMENT		$ 1,505,000.00
RO and EAOP CAPEX Development		
1. Integrated RO System	2 - 60,000 gpd skid units with HPRO, ancillary tankage, pumps, degassifier	$ 2,772,400.00
2. CAPEX to Locate RO/Building, etc.	Construct Building for RO Treatment Process (60' x 70')	$ 630,000.00
SUBTOTAL RO/EAOP CAPEX DEVELOPMENT		$ 3,402,400.00
SUBTOTAL SITE DEVELOPMENT AND RO/EAOP CAPEX DEVELOPMENT		$ 4,907,400.00
Engineering	Based on 12 percent of construction cost	$ 588,888.00
Construction Management	Based on 12 percent of construction cost	$ 588,888.00
Contingency	Based on 40 percent of consturction cost	$ 1,962,960.00
TOTAL SITE WORK/PROJECT DEVELOPMENT		$ 8,048,136.00
B. ANNUAL LEASE/OTHER O&M COSTS (2)		
1. Service Contract for RO Process Equipment Lease	Not Applicable, CAPEX is provided above; No RO Service Contract	-
2. Electricity - RO Process	Projected 150 kw of power; estimated at 1,260,000 kw-hr/yr	$ 151,200.00
3. Service Contract for EAOP Concentrate Lease (1)	EAOP trailers with reactors, avg annual Q = 4.52 MG/yr @ 12,400 gpd	$ 1,084,800.00
4. Electricity - EAOP Process for Concentrate Treatment	Projected 300 Amps, 240 V, 3 ph; 604,800 kw=hr/yr	$ 72,576.00
5. Electricity - Other than EAOP Process	Pumps, heaters, etc not related to RO/EAOP	$ 12,000.00
6. Labor	Assume 1 FT with 10% OT and On-Call	$ 150,000.00
7. Chemicals (H2SO4, Caustic Cleaners, Anti-scalant)	Based on 80 clean cycles/yr, H2SO4 continuous (33k gal/yr), plus anti-scale	$ 220,320.00
8. Membrane Replacement	Assume 3-yr membrane life and $105/m^2 ($83,600/yr)	$ 83,600.00
9. Equipment Repair/Replacement (R/R)	Based on 3.5 % of RO CAPEX	$ 97,000.00
10. Analytical Testing	Weekly Testing for both RO and EAOP processes	$ 124,800.00
11. Program Management and Reporting	Monthly Reporting Reports/General PM Oversight	$ 24,000.00
12. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer& $200/mo support facilities	$ 14,400.00
13. Concentrate Hauling Between Dolby/JRL	Not Applicable - EAOP Dedicated to JRL Site Only	-
SUBTOTAL ANNUAL PFAS REMOVAL USING RO AND EAOP	RO and EAOP for Concentrate	$ 2,034,696.00
ESTIMATED COST TO TREAT PER GALLON LEACHATE	RO and EAOP for Concentrate (based on 5-yr avg 54,600 gpd)	$ 0.102
C. COST SUMMARY		
Capital Cost Present Worth		
PW Site Work/Project Development		$ 8,048,136
PW Annual Lease/Other O&M Costs	PW Cost based on (P/A, 5%, 5 yr); PW factor = 0.43295	$ 8,809,216
TOTAL LIFE CYCLE PW COSTS		$ 16,857,352
PW COST/MG OF LEACHATE TREATED - RO and EAOP	Cost per MG Treated - EAOP @ 54,600 gpd average over 5 years	$ 169,174

(1) - EAOP trailers include integrated process with 8 reactors within one skid unit

(2) - All labor cost, consumables (polymers, salt, etc.) are included in the Annual Lease/Operations contract with the exception of items listed below

TABLE F-4. COST ESTIMATE FOR JRL PC & BIOLOGICAL (MBR) PRETREATMENT, GAC FOR PFAS AND DISCHARGE TO NDWWTP

CONSTRUCTION ELEMENT	DESCRIPTION	COST
A. SITE WORK/PROJECT DEVELOPMENT		
1. Install Mixer in Leachate Storage Tank	Install PAX mixer or equivalent for uniform mixing	$ 36,000.00
2. Install New PS and Modify Inf Pipeline	Construct pipeline and PS from AST to Treatment Location	$ 100,000.00
3. Site Work/Foundation Slab & Containment	Site work for pretreatment and Adsorption operations	$ 25,000.00
4. Install New Electrical Service for PC/ MBR/GAC Processes	Run electrical service to biological WWTP/GAC Reactors location	$ 24,000.00
5. Install New 0.5 MG Treated Eff Holding Tank	Holding Tank for PFAS treated effluent to haul to NDWWTP	$ 1,054,000.00
6. Treated Effluent/PS from Treatment to New EQ Tank	TE pump station and force main to new EQ tank	$ 155,000.00
7. Extend process water to Treatment Area	Run either potable water or plant water to treatment process	$ 10,000.00
8. Coordinate Standby Power	Integrate standby power to include pumps and treatment units	$ 20,000.00
SUBTOTAL GENERAL SITE DEVELOPMENT		$ 1,424,000.00
Pretreatment and Sorption PFAS Development		
1. Iron and Manganese Pre-engineered System	Pre-packaged Fe/Mn System with Oxidation	$ 750,000.00
2. Construct Physical-Chemical Treatment Process	Install Integrated Coagulation/Flocculation/Precipitation Pretreat	$ 1,500,000.00
3. Construct Integrated MBR Process	Integrated process to include RAS, WAS, recycle pumps, MBE, I&C	$ 2,625,000.00
4. Install Supplemental Carbon Dosing System	Separate carbon supplement such as glygerin or Micro C	$ 100,000.00
5. Install Supplemental Phosphorus Dosing System	Separate TP dosing system with storage and pumps	$ 100,000.00
6. Install pH Neutralization System	Separate HCl acid storage and dosing equipment	$ 100,000.00
7. Secondary Effluent Pump Station	MBR effluent pumps to GAC process	$ 90,000.00
8. WWTP Building for Biology/IEX Operation	Building to accommodate MBR and GAC Processes	$ 750,000.00
9. Pre-engineered GAC System	Pre-Engineered Systems/GAC Only; Two Trains with Lead/Lag Layout	$ 1,950,000.00
10. Construct WAS Decanting and Storage Tanks	Conical tanks with Mixers/Pumps for decanting/thickening sludge	$ 300,000.00
11. Install Polymer System for WAS/Truck Loading Sta.	Polymer dosing system for thickening sludge	$ 50,000.00
12. SCADA System for Biology/IEX Operation	Integrated SCADA using Hach Wins or equivalent	$ 125,000.00
13. Mechanical/Electrical	Miscellaneous Installation	$ 250,000.00
14. Instrumentation and Controls	Integrated I&Cs for biological pretreatment and IEX/GAC process	$ 250,000.00
SUBTOTAL PRETREATMENT AND SORPTION DEVELOPMENT		$ 8,940,000.00
SUBTOTAL SITE WORK/PROJECT DEVELOPMENT		$ 10,364,000.00
Engineering	Based on 12 percent of construction cost	$ 1,243,680.00
Construction Management	Based on 12 percent of construction cost	$ 1,243,680.00
Contingency	Based on 40 percent of consturction cost	$ 4,145,600.00
TOTAL SITE WORK/PROJECT DEVELOPMENT		$ 16,996,960.00
B. ANNUAL LEASE/OTHER O&M COSTS		
1. Mobilize and Operate Prefilter, GAC and IEX Process	Integrated pre-engineered prefilters, GAC and IEX system	No Leases
2. Labor	2 FT plus 10% OT plus On-Call	$ 292,552.00
3. Electricity - PFAS Related	Based on New Hartford energy extrapolated	$ 74,196.00
4. Electricity - Non-PFAS Related	Based on 100,000 kw-hr/yr @$0.12/kw-hr per Versant	$ 12,000.00
5. Chemicals	Includes Micro C, Phosphorous, Acid and Polymer extrapolated to New Hartford	$ 97,300.00
6. Sludge Disposal	Assumes 2 trucks/week @ 6500 gal/truck and $750/load	$ 78,000.00
7. GAC Disposal/Replacement	Based on 5,000 BV; 910 lbs/MG @ 25.185 MG/yr = 22,900 lbs/yr @ $3/lb	$ 68,700.00
8. Analytical Testing	See quote from Alpha Analytical for details; $1200/wk PFAS and $200/wk PC	$ 72,800.00
9, R/R of Equipment	Upgrades for repair/replacement per year	$ 5,000.00
10. Supplies for Buildings/Laboratory	Assume $100/wk for laboratory equipment	$ 5,200.00
11. Program Management and Reporting	Monthly Reporting/General PM Oversight: $6,000/qtr	$ 24,000.00
12. Office Trailer and Support Facilities	Monthly Rental/Lease @ $1000/mo for trailer and $200/mo support facilities	$ 14,400.00
SUBTOTAL OTHER O&M COST		$ 744,148.00
C. COST SUMMARY		
Capital Cost and Present Worth of Annual O&M		
PW Site Work/Project Development		$ 16,996,960.00
PW Annual Lease/Other O&M Cost	PW Cost based on (P/A, 5%, 5 yr); PW factor = 0.43295	$ 3,221,788.77
TOTAL LIFE CYCLE PW COSTS		$ 20,218,748.77
PW COST/MG OF LEACHATE TREATED - PC/MBR Pretreat & GAC	Cost per MG Treated - Pretreat PC/MBR & GAC @ average flow of 54,600 gpd	$ 202,908