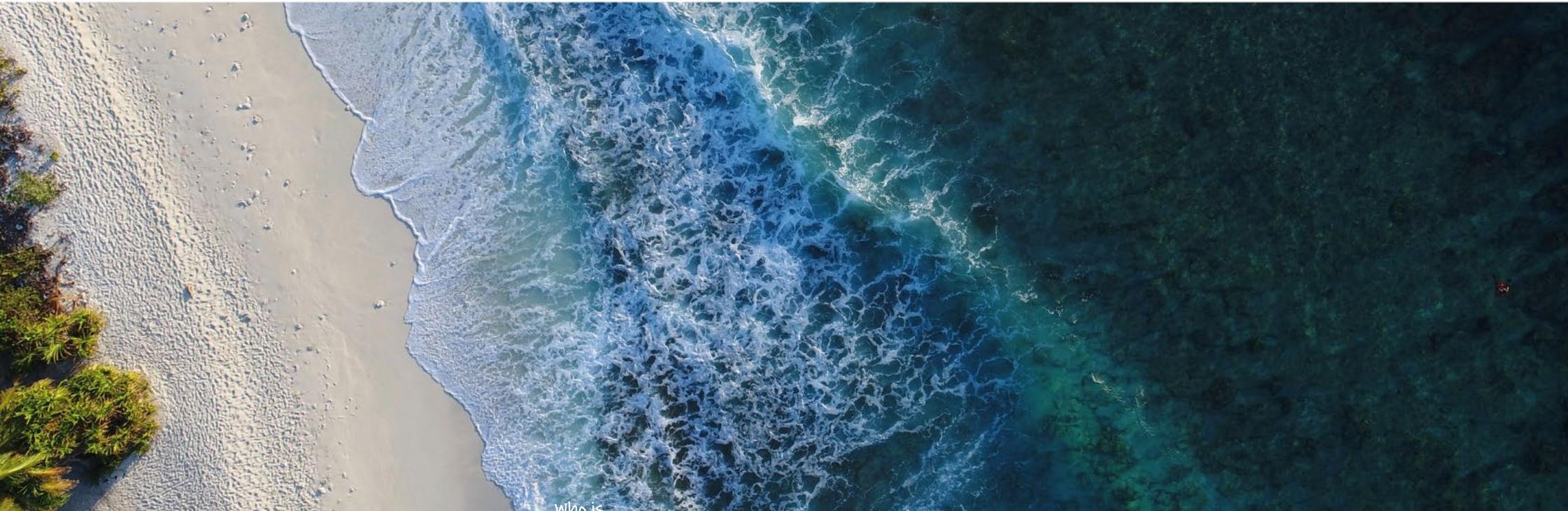
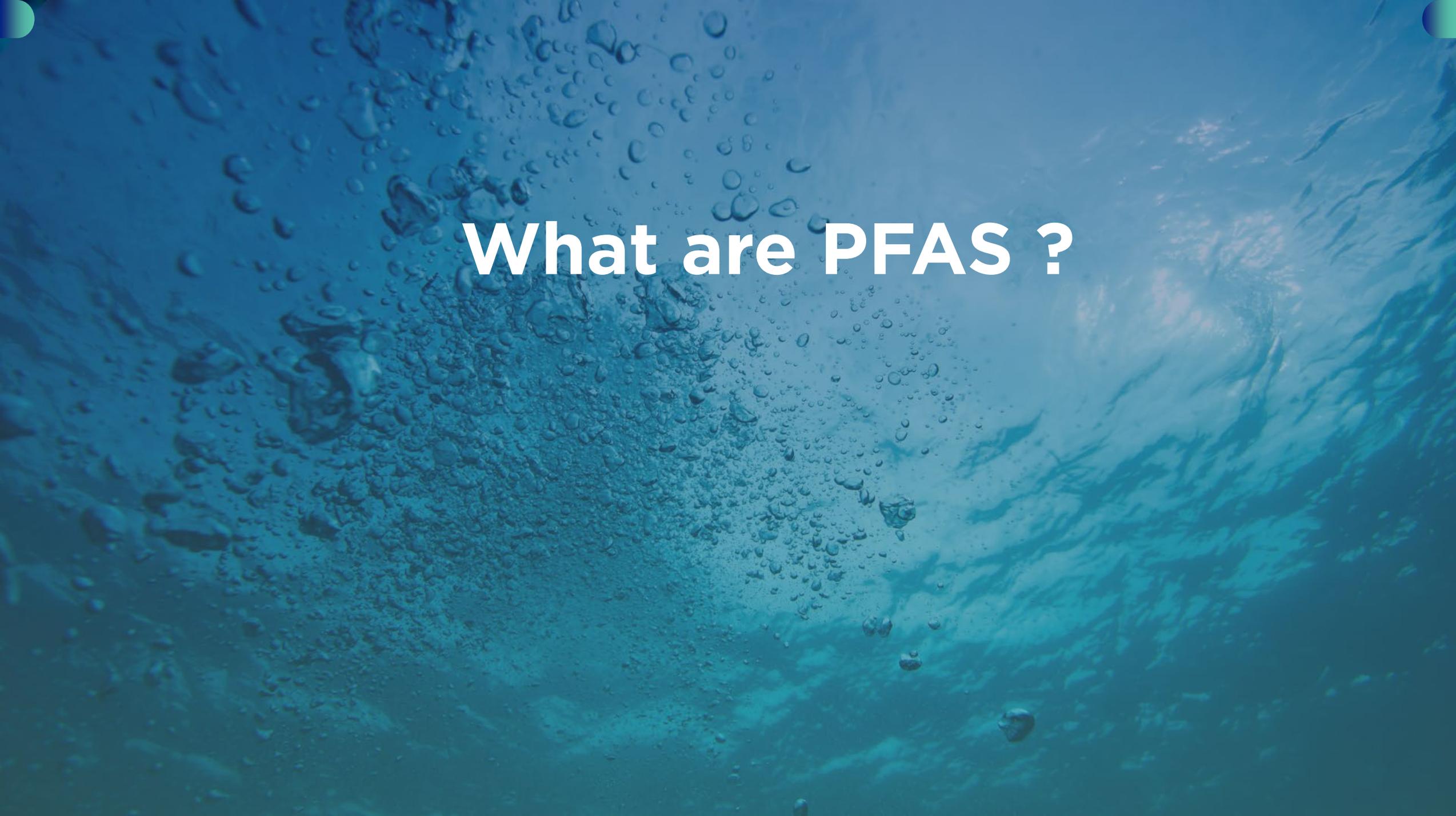




Advanced PFAS Treatment Technologies in Practice

Brad Dalrymple & Blake Allingham

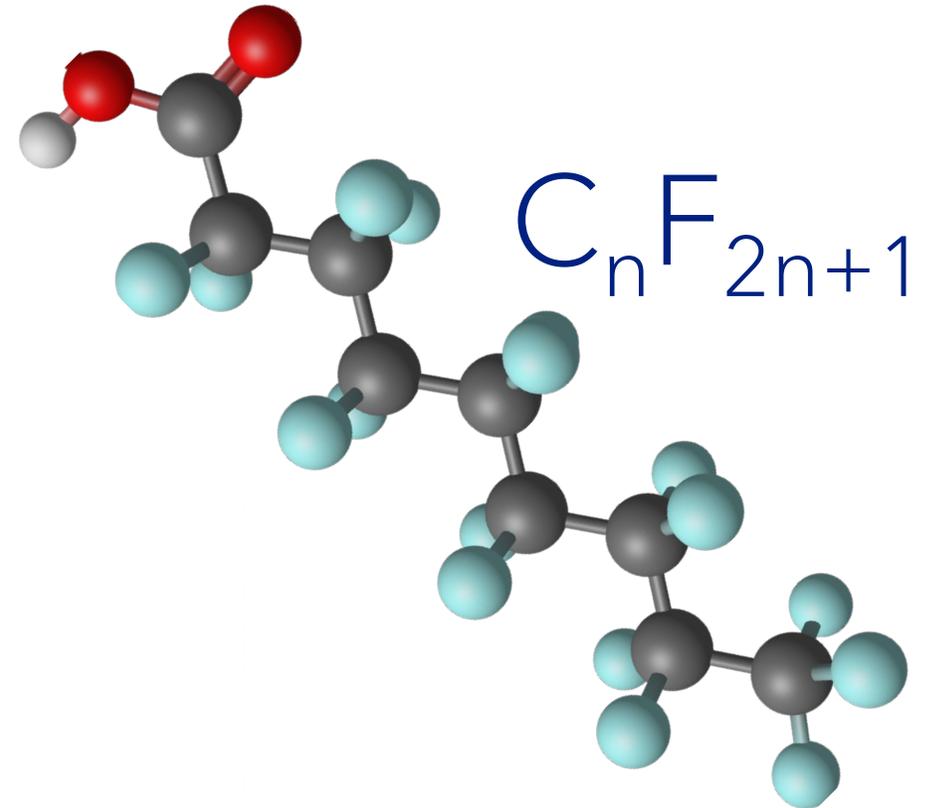


An underwater scene with numerous bubbles rising from the bottom towards the surface. The water is a deep blue color, and the light from the surface creates a shimmering effect on the bubbles and the water's surface.

What are PFAS ?

Per & poly-fluoroalkyl substances (PFAS)

- ⌚ Manufactured 'forever chemicals'
- ⌚ Produced since ~1930's
- ⌚ Used in various products
 - carpets, clothes, food packaging & paper, firefighting foams, pesticides & stain repellents
 - make products non-stick, oil- & water-repellent, and fire, weather- and stain-resistant

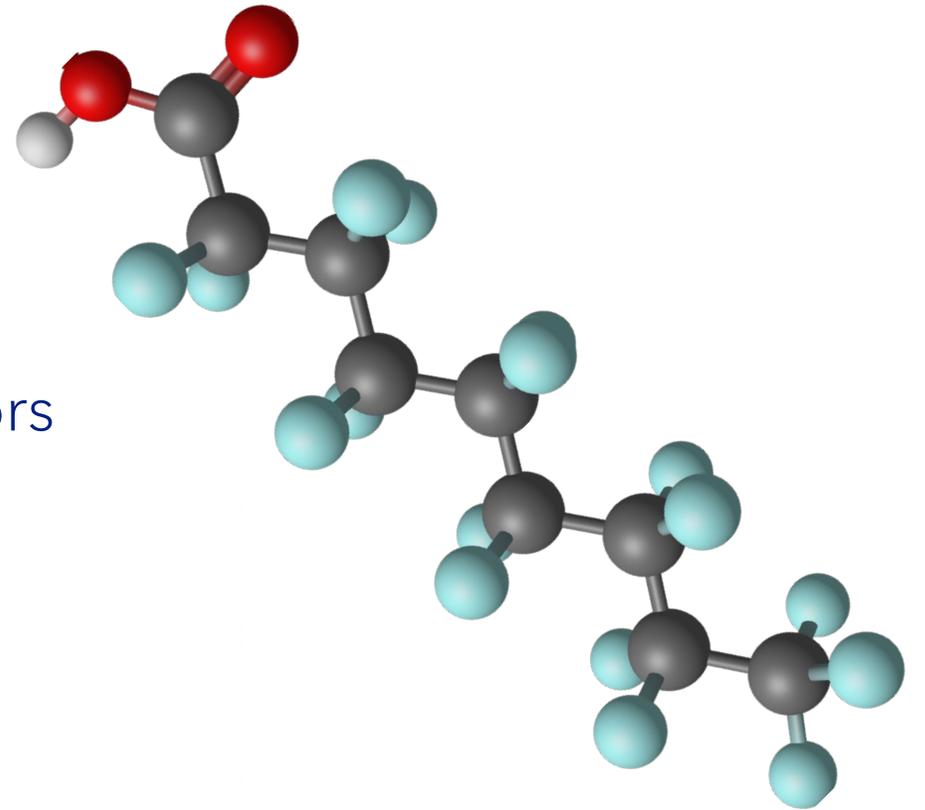


An underwater scene with a blue color palette. The background shows light rays filtering through the water, creating a shimmering effect. Numerous bubbles of various sizes are scattered throughout the frame, particularly concentrated in the center and lower right. The overall atmosphere is serene and aquatic.

**What's all the
fuss about ?**

What's all the fuss about ?

- ④ Toxic
- ④ Bio-accumulative
- ④ Everywhere
- ④ Links to negative health impacts
- ④ High priority for environmental regulators



In the media (& courts)

WaterNSW disconnects Medlow Dam in the Blue Mountains as investigations continue into presence of 'forever chemicals' in water

By Alan Tennant, Water Pollution

Wed 29 Aug



PFAS 'forever chemicals' found in water filtration plants and platypus livers in NSW

By Xanthe Gregory, Water Pollution

Tue 20 Aug



Scientists from Western Sydney University found perfluorooctane sulfonate (PFOS) in the livers of eight deceased platypuses.

\$212m PFAS payout for property value loss and distress, but residents' contamination fears linger

By Xanthe Gregory

Posted Wed 16 Nov 2022 at 7:31am, updated Wed 10 Mar 2023 at 8:17am



Leaseholders impacted by toxic PFAS foam n out in \$132.7 million compensation payout

By Xanthe Gregory

Posted Tue 16 May 2023 at 8:17am, updated Tue 16 May 2023 at 8:01am



Top US chemical firms to pay \$1.2bn to settle water contamination lawsuits

Dupont, Chemours and Corteva agree deal and 3M also reportedly considering \$10bn settlement to avoid trial due to start on Monday



3M pays \$10.3bn to settle water pollution suit over 'forever chemicals'

Settlement will provide funds to US municipalities over 13 years to test for and treat PFAS contamination in public water systems



3M did not admit liability when reaching the settlement. Photograph: Nicholas Pfoos/Reuters

The Guardian
News Opinion Sport Culture Lifestyle



PFAS
Alarming levels of PFAS in Norwegian Arctic ice pose new risk to wildlife

Oxford University-led study detects 26 types of PFAS compounds in ice around Svalbard, threatening downstream ecosystems



the japan times

NATIONAL
Japan slowly wakes up to health risks of PFAS 'forever chemicals'



nature
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NEWS | 17 March 2023

How the US will remove 'forever chemicals' from its drinking water

The EPA has proposed a strict PFAS limit, but it will take money and innovative technologies to implement the plan.

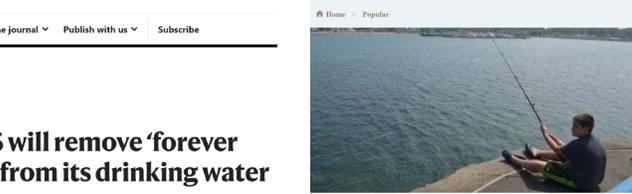
PHYS.ORG
October 26, 2022
Earth | Environment

'Forever chemicals' persist through wastewater treatment, may enter crops

by Pennsylvania State University



Environmental Health News



Jan 13, 2023
Just one meal of caught fish per year is a significant dose of PFAS
"These fish are incredibly contaminated."

DEFENCE
Defence says 30 kilograms of toxic PFAS is still flowing into creeks in Darwin each year

By Jane Gibson
Posted Sun 28 Aug 2022 at 7:05am, updated Sun 29 Aug 2022 at 7:17am



100NEWS
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Launceston Airport sues Airservices Australia over PFAS chemical clean-up

By Ellen Coulter
Posted Thu 16 Dec 2021 at 4:38am, updated Thu 16 Dec 2021 at 7:38am

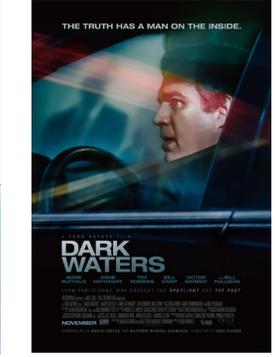
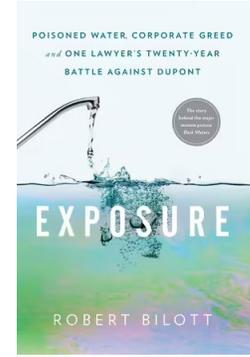


The use of PFAS chemicals in firefighting has been commonplace around Australia. (Supplied: CRC CARE)

CBS NEWS
HEALTHWATCH

Raincoats, undies, school uniforms: Are your clothes dripping in "forever chemicals"?

BY HANNAH NORMAN
MARCH 30, 2023 / 5:00 AM / KAISER HEALTH NEWS



100NEWS

Highest reported PFAS levels in world found in rare Burruran dolphins off Victorian coast

By Natasha Chapova, William Howard, ABC Gippsland, Nature

Tue 21 Nov 2023



PFAS in our rain

BBC

Pollution: 'Forever chemicals' in rainwater exceed safe levels

2 August 2022

Share Save

Matt McGrath
Environment correspondent



PFAS have been found in rain in Tibet

New research shows that rainwater in most locations on Earth contains levels of chemicals that "greatly exceed" safety levels.

ENVIRONMENTAL
Science & Technology

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AC CC

Perspective

Outside the Safe Operating Space of a New Planetary Boundary for Per- and Polyfluoroalkyl Substances (PFAS)

Ian T. Cousins,* Jana H. Johansson, Matthew E. Salter, Bo Sha, and Martin Scheringer

Cite This: *Environ. Sci. Technol.* 2022, 56, 11172–11179

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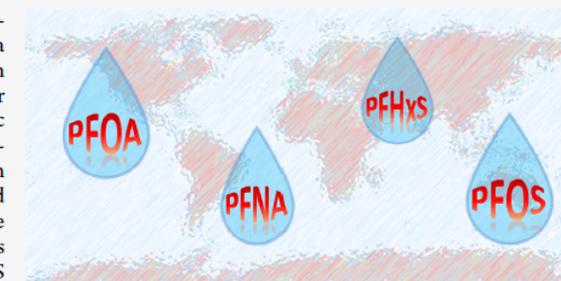
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Supporting Information

ABSTRACT: It is hypothesized that environmental contamination by per- and polyfluoroalkyl substances (PFAS) defines a separate planetary boundary and that this boundary has been exceeded. This hypothesis is tested by comparing the levels of four selected perfluoroalkyl acids (PFAAs) (i.e., perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorohexanesulfonic acid (PFHxS), and perfluorononanoic acid (PFNA)) in various global environmental media (i.e., rainwater, soils, and surface waters) with recently proposed guideline levels. On the basis of the four PFAAs considered, it is concluded that (1) levels of PFOA and PFOS in rainwater often greatly exceed US Environmental Protection Agency (EPA) Lifetime Drinking



PFAS in surface & groundwaters



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9 April 2024

**PFAS 'forever chemicals' above
drinking water guidelines in
global source water**

nature geoscience



Article

<https://doi.org/10.1038/s41561-024-01402-8>

Underestimated burden of per- and polyfluoroalkyl substances in global surface waters and groundwaters

Received: 27 September 2023

Accepted: 15 February 2024

Diana Ackerman Grunfeld¹, Daniel Gilbert¹, Jennifer Hou¹, Adele M. Jones¹,
Matthew J. Lee¹, Tohren C. G. Kibbey² & Denis M. O'Carroll¹✉

PFAS in beer



Pfas detected in US beers in new study, raising safety concerns

Researchers point to contaminated water after 'forever chemicals' found in all but one of 23 sampled beers

● [What are Pfas? Everything you need to know](#)



📷 In wine, there is truth. In beer, there is freedom and also apparently forever chemicals, according to new research. Photograph: Paul Ellis/AFP/Getty Images

> [Environ Sci Technol](#). 2025 May 6;59(17):8368-8379. doi: 10.1021/acs.est.4c11265. Epub 2025 Apr 24.

Hold My Beer: The Linkage between Municipal Water and Brewing Location on PFAS in Popular Beverages

Jennifer Hoponick Redmon ¹, Nicole M DeLuca ¹, Evan Thorp ¹, Chamindu Liyanapatirana ¹, Laura Allen ¹, Andrew J Kondash ¹

PFAS in our dolphins

THE CONVERSATION



Australian dolphins have the world's highest concentrations of 'forever chemicals'

Published: November 24, 2023 1.53pm AEDT

Science of the Total Environment 908 (2024) 168438



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Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv



Hepatic concentrations of *per*- and polyfluoroalkyl substances (PFAS) in dolphins from south-east Australia: Highest reported globally

Chantel S. Foord^{a,b,*}, Drew Szabo^{c,d}, Kate Robb^b, Bradley O. Clarke^c, Dayanthi Nugegoda^a

^a Royal Melbourne Institute of Technology, Bundoora, Australia

^b Marine Mammal Foundation, Mentone, VIC

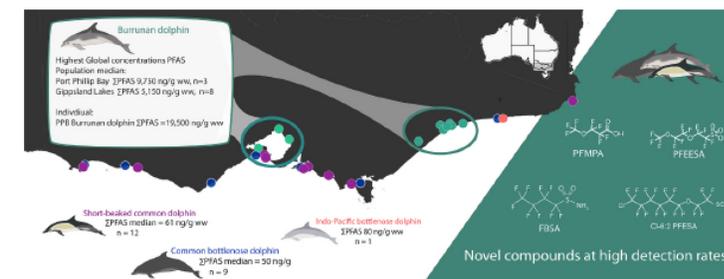
^c Australian Laboratory for Emerging Contaminants, School of Chemistry, University of Melbourne, Victoria 3010, Australia

^d Department of Materials and Environmental Chemistry, Stockholm University, Svante Arrhenius Väg 16C, SE-106 91 Stockholm, Sweden

HIGHLIGHTS

- 25 PFASs quantifiable in stranded dolphin hepatic tissue across Victoria, Australia
- Highest reported dolphin hepatic Σ PFOS (maximum; 18,700 ng/g ww)
- Inshore dolphins have higher PFAS concentrations than offshore dolphins.
- PFOS values exceed thresholds for health impacts by >10 \times .
- Novel compounds PFMPA, PFECBS and 6:2 Cl-PFESA found at high detection rates.

GRAPHICAL ABSTRACT



PFAS in our platypus

ABC NEWS

PFAS 'forever chemicals' found in water filtration plants and platypus livers in NSW

By Xanthe Gregory

Water Pollution

Tue 20 Aug



Scientists from Western Sydney University found perfluorooctane sulfonate (PFOS) in the livers of eight deceased platypuses. (Supplied: Western Sydney University)

Environmental Science and Pollution Research (2024) 31:51037–51042
<https://doi.org/10.1007/s11356-024-34704-w>

SHORT RESEARCH AND DISCUSSION ARTICLE



First report of accumulation of perfluorooctane sulfonate (PFOS) in platypuses (*Ornithorhynchus anatinus*) in New South Wales, Australia

Katherine G. Warwick¹ · Ian A. Wright¹ · Jessica Whinfield^{2,3} · Jason K. Reynolds¹ · Michelle M. Ryan¹

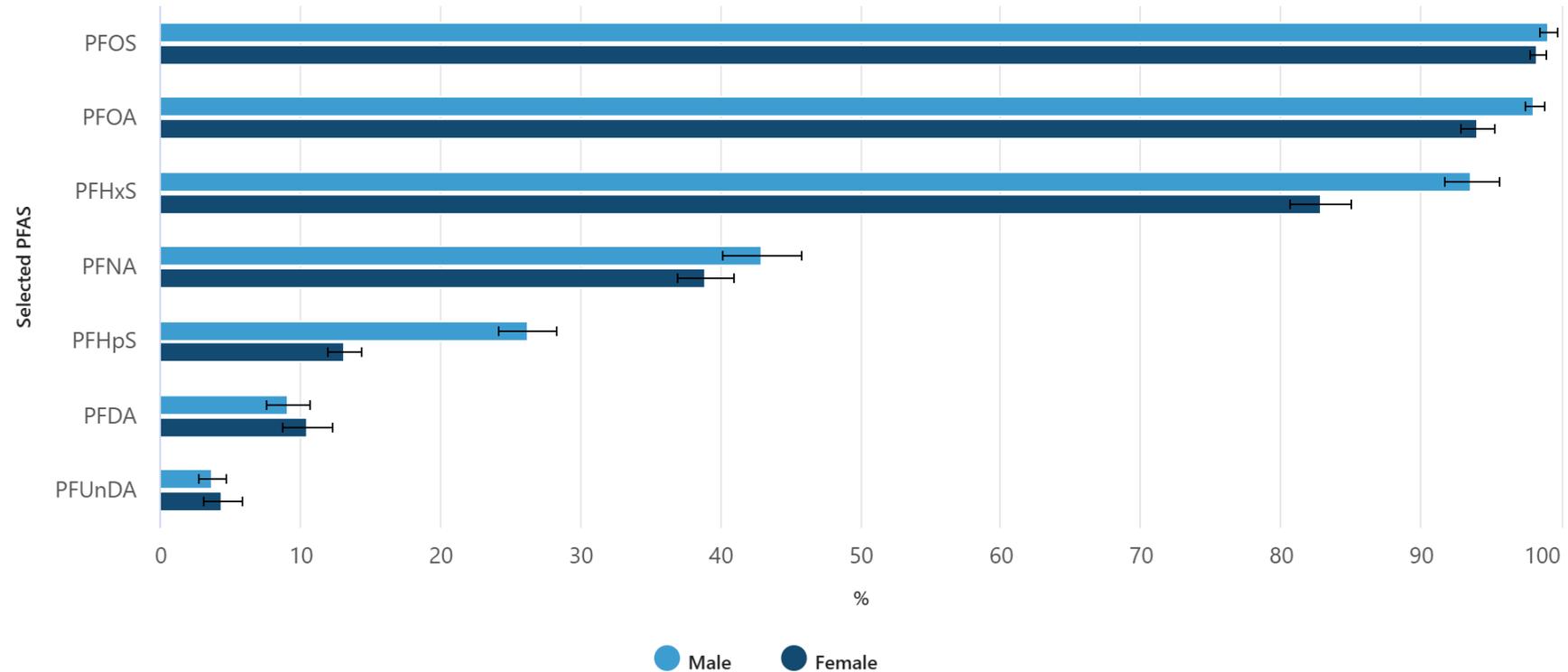
Received: 15 April 2024 / Accepted: 9 August 2024 / Published online: 16 August 2024
© The Author(s) 2024

Abstract

The platypus (*Ornithorhynchus anatinus*) is a semi-aquatic monotreme that occupies a high trophic position in the freshwater ecosystems of eastern mainland Australia and Tasmania. Platypuses are continuously exposed to anthropogenic contaminants including perfluorooctane sulfonate (PFOS). This study examined PFOS concentrations in the livers of deceased platypuses (eight wild; one captive) that were opportunistically collected across NSW over a two- and a half-year period. There was a large variation in PFOS concentrations, ranging from $< 1 \mu\text{g}/\text{kg}$ to $1200 \mu\text{g}/\text{kg}$. This study presents the first report of PFOS contamination in platypuses, revealing their PFOS levels are broadly similar to those found in river otters (*Lutra canadensis*) and lower than those in American mink (*Mustela vison*), both which occupy similar ecological niches in freshwater systems. This study raises concerns about the impact of PFOS on platypus health.

PFAS is in our blood

Proportion of people aged 12 years and over(a) with a detectable level of selected PFAS by sex, 2022–24



a. Weighted results for persons where a blood sample was collected.

Source: Australian Bureau of Statistics, Per- and polyfluoroalkyl substances 27/05/2025

PFAS & human health

Environmental Toxicology and Chemistry—Volume 40, Number 3—pp. 606–630, 2021

Received: 20 July 2020 | Revised: 29 August 2020 | Accepted: 20 September 2020

Critical Review

Per- and Polyfluoroalkyl Substance Toxicity and Human Health Review: Current State of Knowledge and Strategies for Informing Future Research

Suzanne E. Fenton,^a Alan Ducatman,^b Alan Boobis,^c Jamie C. DeWitt,^d Christopher Lau,^e Carla Ng,^f James S. Smith,^g and Stephen M. Roberts^{h,*}

^aNational Toxicology Program Laboratory, National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina, USA

^bWest Virginia University School of Public Health, Morgantown, West Virginia, USA

^cImperial College London, London, United Kingdom

^dDepartment of Pharmacology and Toxicology, Brody School of Medicine, East Carolina University, Greenville, North Carolina, USA

^ePublic Health and Integrated Toxicology Division, Center for Public Health and Environmental Assessment, Office of Research and Development,

US Environmental Protection Agency, Research Triangle Park, North Carolina, USA

^fDepartments of Civil and Environmental Engineering and Environmental and Occupational Health, University of Pittsburgh, Pittsburgh, Pennsylvania, USA

^gNavy and Marine Corps Public Health Center, Portsmouth, Virginia, USA

^hCenter for Environmental & Human Toxicology, University of Florida, Gainesville, Florida, USA

— High certainty

---- Lower certainty

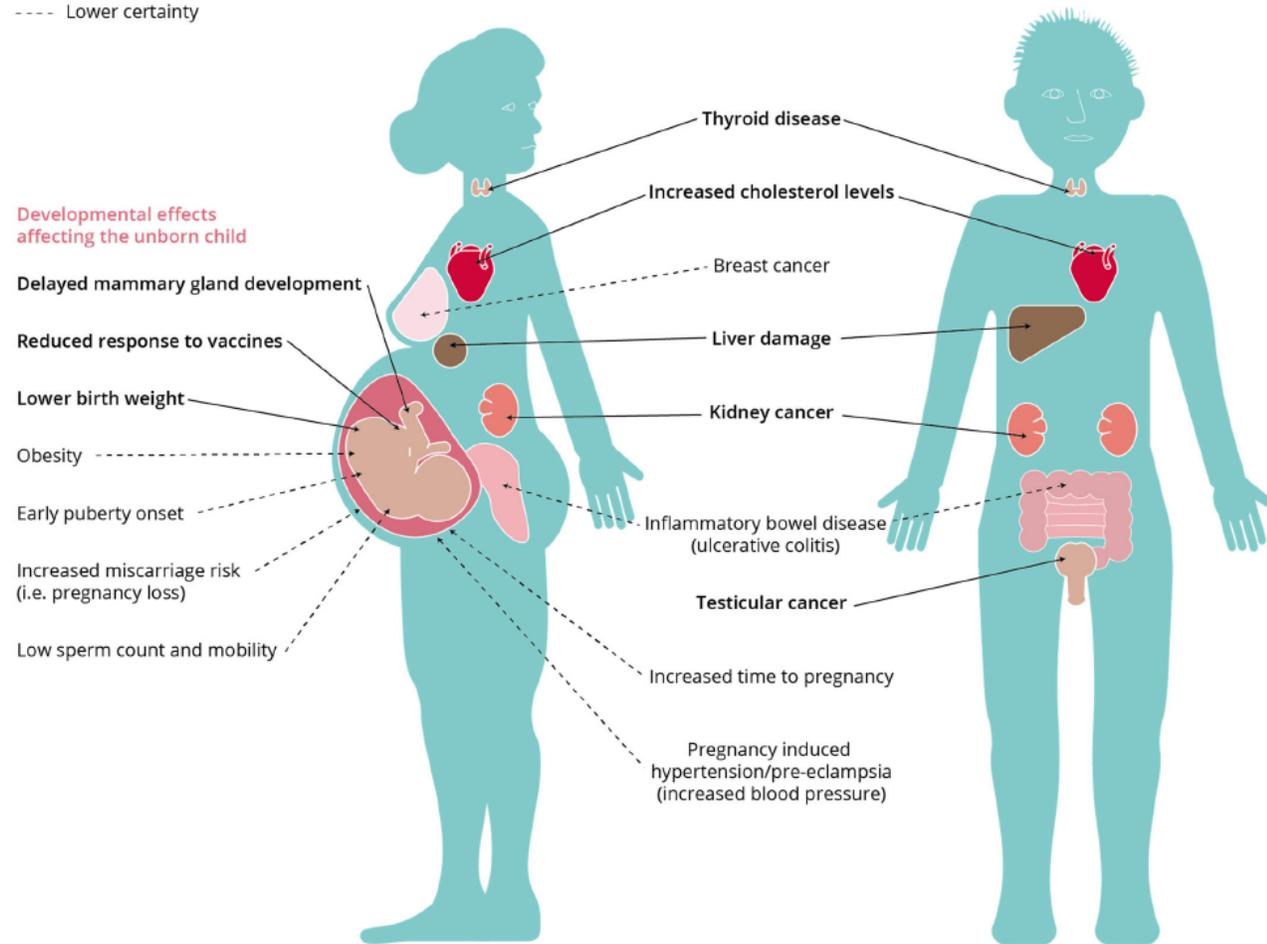


FIGURE 1: Effects of per- and polyfluoroalkyl substances on human health. Used with permission from European Environment Agency (2019). Original sources for this figure: National Toxicology Program (2016), C8 Science Panel (2012), IARC Working Group on the Evaluation of Carcinogenic Risks to Humans (2017), Barry et al. (2013), Fenton et al. (2009), and White et al. (2011b).

Is my water safe to drink ?



© *“PFAS levels measured in Australia by water utilities have been generally below (or well below) the current Australian Drinking Water Guidelines”.*

<https://www.nhmrc.gov.au/health-advice/environmental-health/water/PFAS-review/questions-and-answers>

WaterNSW disconnects Medlow Dam in the Blue Mountains as investigations continue into presence of 'forever chemicals' in water

By Jean Kennedy

Water Pollution

Wed 28 Aug



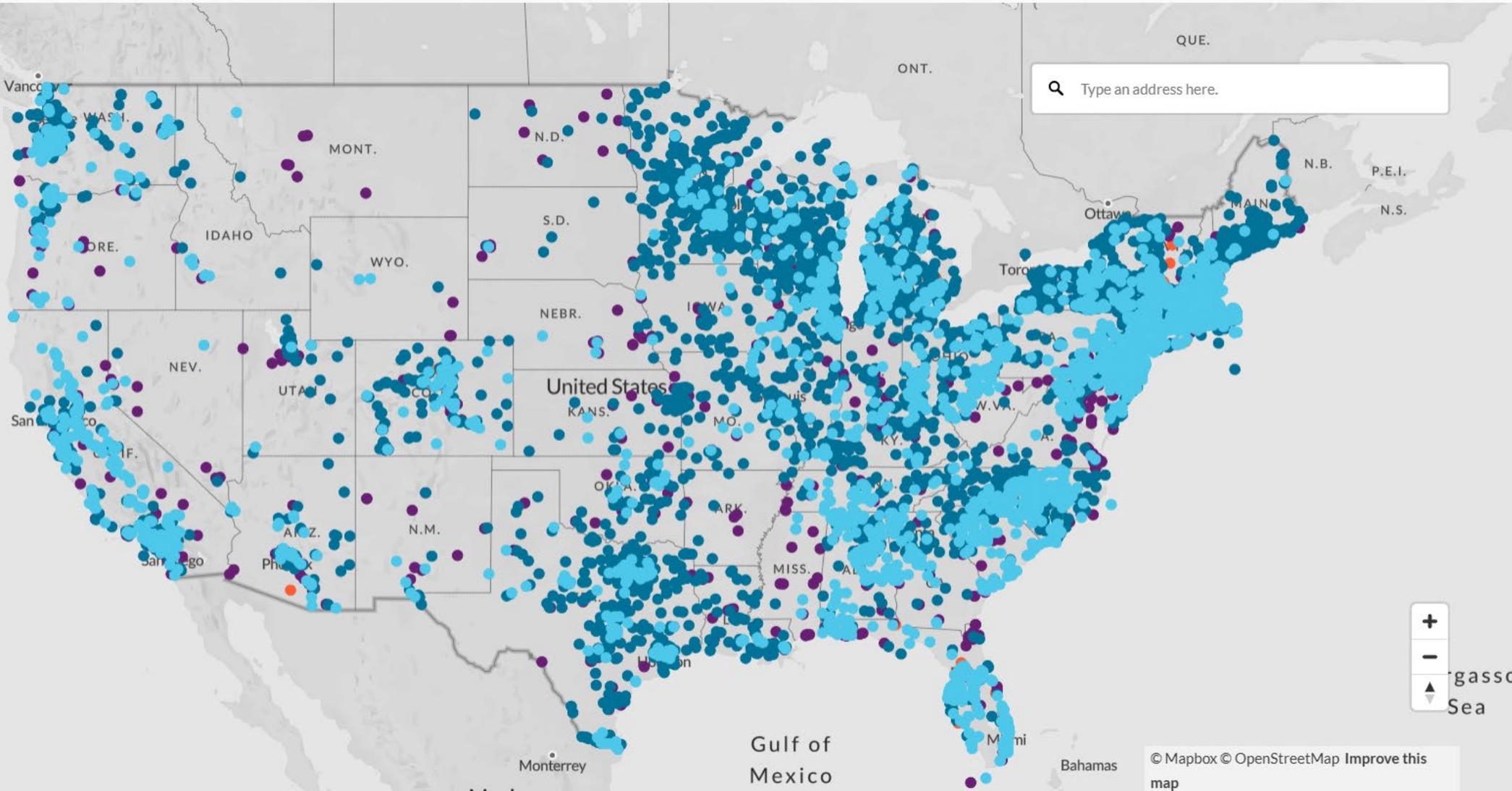
Medlow Dam has been shut off. (Supplied: WaterNSW)



PFAS contamination in the U.S. (August 14, 2025)



-  Drinking Water ABOVE PROPOSED LIMIT
-  Drinking Water BELOW PROPOSED LIMIT
-  Military Sites
-  Other Known Sites



gasso
Sea



PFAS INVESTIGATION AND MANAGEMENT PROGRAM SNAPSHOT – May 2025

REMEDIATION ACTIVITIES

Remediation works targeting contaminated water, soil and other materials are underway or completed at Swartz Barracks, HMAS *Cerberus*, Jervis Bay Range Facility and RAAF Bases Pearce, Edinburgh, Williamtown, East Sale, Tindal, Richmond, Wagga, Darwin and Townsville.

Remediation works are scheduled to commence in the coming months at HMAS *Albatross*, Blamey Barracks, Lavarack Barracks, Bandiana Military Area and RAAF Base Amberley.

KEY STATISTICS

Properties connected to town water **378**

161 rainwater tanks provided to **118** properties

Community engagement events conducted **185**

869 properties have water assistance extended from 6 to 8 years

REMEDIATION

Treated or removed over **180,000** tonnes of contaminated soil

Operate and maintain **7** water treatment plants

Treated over **12.2** billion litres of water

FINANCIAL FACTS

\$850m invested to manage, remediate and conduct research

\$27m provided to other government agencies for research into health and remediation

\$165.4m allocated in FY 2024-2025 to manage and remediate PFAS

COMMUNITY EVENTS

Defence has held 185 engagement events

Recent events

- 13 February 2025 – Jervis Bay Range Facility and HMAS *Creswell*
- 5 December 2024 – RAAF Base Williamtown
- 27 November 2024 – Swartz Barracks
- 16 October 2024 – RAAF Base Tindal
- 15 October 2024 – RAAF Base Darwin
- 6 August 2024 – RAAF Base Amberley

RESEARCH ACTIVITIES

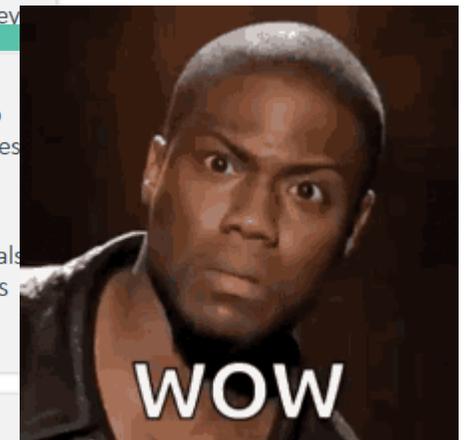
Defence collaborates internationally to share its learnings and to ensure the best remedial actions are implemented on PFAS impacted bases.

Since 2016, Defence has supported trials of new remediation technologies. Trials such as soil stabilisation form part of Defence's remediation approach.

RESEARCH FUNDING

Defence has provided approximately \$26 million in funding for 21 research and technology programs to support PFAS investigation and remediation activities.

Defence provided over \$27 million in additional funding to other government agencies to support PFAS-related health and remediation research.

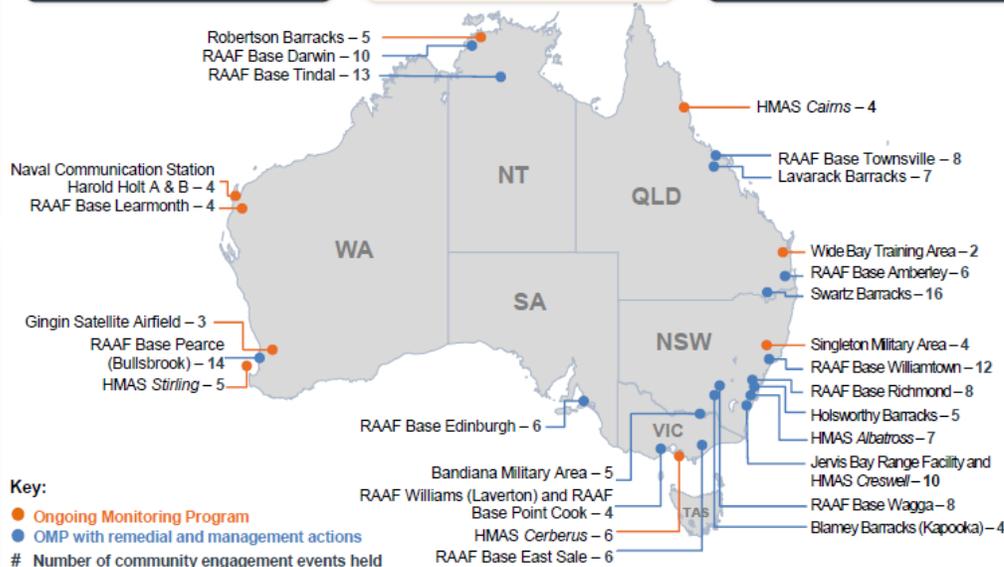


ONGOING MONITORING

Defence regularly monitors for PFAS on and around impacted sites. Monitoring results help Defence understand how PFAS is moving in the environment. This information also guides Defence's remediation and management actions.

DEFENCE ESTATE

Since 2004, Defence has reduced the use of legacy firefighting foams containing PFAS across the Defence Estate. Defence has transitioned its fire vehicles and handheld and portable extinguishers to a PFAS-free foam. To prevent future contamination, Defence is undertaking a program of works to remove foams containing PFAS from the estate.



An underwater scene with a blue-green color palette. The background is filled with numerous bubbles of various sizes, some rising and some falling. Light rays penetrate from the surface, creating a shimmering effect. The overall atmosphere is serene and aquatic.

Sources

Sources

- ② Primary sources – where PFAS has been used
 - Military bases
 - Airports
 - Fire-training facilities
- ② Secondary sources – facilities that receive waste & wastewater containing PFAS
 - landfills
 - wastewater treatment plants



Sources (cont'd)

PFAS National Environmental Management Plan 3.0

National Chemicals Working Group
of the Heads of EPA
Australia and New Zealand

HEPA

Appendix C Activities associated with sources of PFAS contamination

Table C1 and Table C2 identify activities associated with PFAS contamination, focusing on primary and secondary sources.

Table C1 Activities associated with PFAS contamination due to fire risk

Activity	Description
Airports and aviation infrastructure	On-site firefighting – see also further information below
Aluminium production	On-site firefighting
Battery production	On-site firefighting – see also further information below
Bitumen production	Kerosene use and storage
Brewing, distilling and refining	Ethanol production
Coal works	On-site firefighting
Dangerous goods production	On-site firefighting – likely to use specialised firefighting products and systems due to the presence of a range of hydrocarbons, polar solvents etc
Explosives production	On-site firefighting – explosions
Food production	On-site firefighting associated with use of bulk oils and solvents – see also further information below
Fuel exploration, assessment, production, transport and storage including petrochemicals, other fossil fuels and renewable liquid fuels	On-site firefighting, also used as a surfactant for gas well stimulation
General chemical storage	On-site firefighting – likely to use a range of hydrocarbons, polar solvents etc
Generation of electrical power	On-site firefighting – see also further information below
Hardware retailers	Firefighting foam deluge systems – see also further information below on the construction industry

continues

PFAS NEMP 3.0 Appendix C

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Table C1 continued

Activity	Description
Mining	On-site firefighting
Paints, polishes, adhesives production	On-site firefighting – see also further information below
Petroleum products other than fuels	On-site firefighting, potential use in processing
Underground infrastructure including car parks and tunnels	Firefighting foam deluge systems

Table C2 Activities associated with PFAS contamination more broadly

Activity	Description
Agriculture	Potentially used as an adjuvant or active ingredient in fertilisers and pesticides, firefighting foam used in the poultry industry to destroy infected flocks
Automotive industry including retailing, detailing and car wash facilities	Surface treatments including polishing, cleaning, stain and water protection products, lubricants, hydraulic fluids, tubing, oil pan, head gaskets, sealant, wire and cabling, fire retardant and metal plating applications
Aviation, aerospace and defence	As for automotive industry plus aviation-specific products, articles and activities, such as aviation hydraulic fluid
Battery use and disposal	Used in batteries, particularly for high-end use such as lithium-style batteries
Boating and marine supply industry	As for automotive industry plus marine-specific products, articles and activities, such as awnings, painting, waterproofing and sealant applications, and shipboard firefighting
Chrome/metal plating industry	High concentration PFAS mist suppressants used to reduce chromium exposure to workers
Commercial laundries and dry cleaners	Effluent from cleaning of fabrics containing or treated with PFAS
Construction industry	Tile coatings, stone coatings, paints, varnishes, sealants, other architectural coatings for films, facades and infrastructure, rigid foams, silicone rubber, thread sealant tapes and pastes and personal protective equipment (PPE)

continues

PFAS NEMP 3.0 Appendix C

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Table C2 continued

Activity	Description
Electricity, telecommunication and information technologies	Wireless devices, hard drives, fibre optic cables, dirt-repellent coatings on glass surfaces such as smartphone screens, flame-resistant devices, fittings, coatings and wrappings, semiconductor etching, firefighting at electricity generation sites and in electricity distribution networks with oil-containing equipment such as transformers, reactors, large regulators, circuit breakers, pipe-type cable systems and bulk storage tanks, reported to be in high-end lithium batteries
Firefighting and fire protection sales and services	Storage and disposal of large quantities of firefighting foam associated with formulation, transport, sale and servicing of firefighting and fire protection products and services including refurbishment of deluge systems and fire extinguishers at fire protection retailers, rural supply stores, council depots and outstation service centres
Manufacturing of building products	As for construction industry
Manufacturing of chemicals, fertilisers and pesticides	Equipment and fittings including pipes, tanks and valves, use as an intermediate in the production of other substances, potentially used as an adjuvant in fertilisers and pesticides
Manufacturing of food, food packaging and food preparation products	Baking paper, aluminium foil, fast food wrappers, non-stick equipment including food processing facility surfaces, pipes, tanks and valves, and firefighting especially at facilities where bulk oil is used
Manufacturing of healthcare products	Surface protection for medical garments, small quantities in X-ray film, charged-coupled devices (CCDs), artificial blood, flexible tubing, needle coatings, denture cleaners, potentially in contact lenses
Manufacturing of household appliances	Heaters, heat lamps, irons, stoves, refrigerators, other flammable components, and high-end (lithium) batteries
Manufacturing of personal care products	Cosmetics, shampoo, shaving cream, dental floss, sunscreen, nail polish, salt, lotions
Manufacturing of textiles, leather, upholstery, carpets, clothing, shoes, outdoor gear	Widespread use of fluorinated compounds to provide stain, water and fire protection

continues

PFAS NEMP 3.0 Appendix C

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Table C2 continued

Activity	Description
Manufacturing of safety gear	Widespread use of fluorinated compounds to provide stain, water and fire protection for PPE and bulletproof clothing
Manufacturing of paints, polishes, coatings and adhesives	Historically used in sealants, adhesive products, coatings, paint and varnishes
Manufacturing of paper or pulp	Used in internal and surface sizing agents for paper manufacturing
Printing, packaging and merchandising	Used to apply grease, oil and water resistance to packaging product, also used in inks particularly for inkjet and photo printing
Recovery of waste oil	Collection and processing of PFAS-containing waste oil
Soap and detergents production	Household goods such as shampoos and cosmetics, commercial and industrial cleaning products such as floor polishes and vehicle cleaning agents
Solar energy	Used in photovoltaic solar cells to repel dirt and in lithium batteries
Sporting goods manufacturers and suppliers and sports facilities	Ski wax, high performance textiles including outdoor clothing, water-resistant treatments
Waste processing and disposal	PFAS-containing solid and liquid waste and leachate in landfill, high temperature incineration, chemical and other treatment regimes
Waste storage – hazardous, restricted solid, liquid, clinical, asbestos waste	On- and off-site storage and/or collection of waste PFAS-containing products
Wastewater treatment	Inputs from domestic sewage and commercial and industrial wastewater and outputs applied to land or discharged to the environment

PFAS NEMP 3.0 Appendix C

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Issue 12, 2020



From the journal:

Environmental Science: Processes & Impacts

An overview of the uses of per- and polyfluoroalkyl substances (PFAS)†

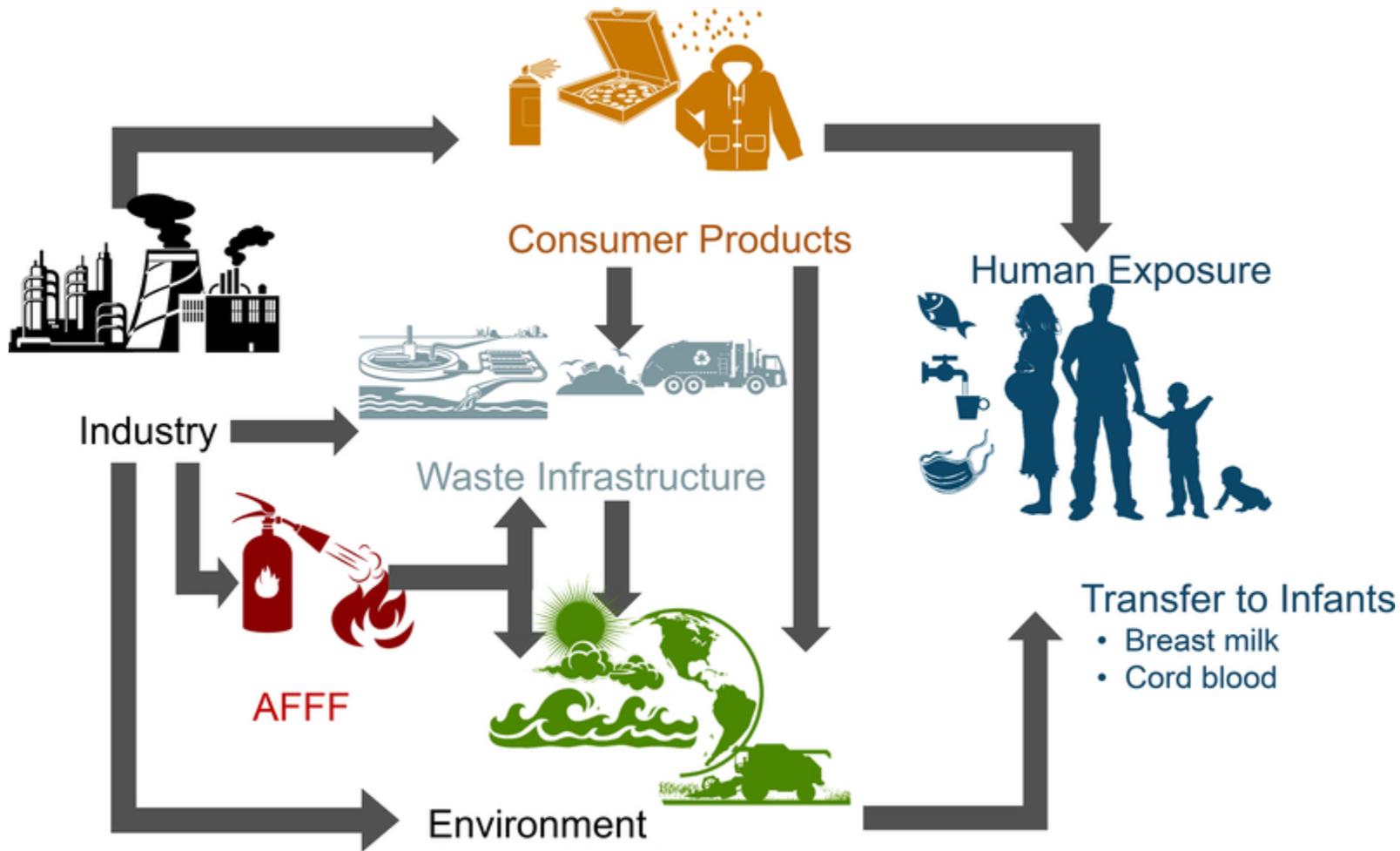
Check for updates

Juliane Glüge, ^{id} ^{*a} Martin Scheringer, ^{id} ^a Ian T. Cousins, ^{id} ^b Jamie C. DeWitt, ^c Gretta Goldenman, ^d Dorte Herzke, ^{id} ^{ef}

Rainer Lohmann, ^{id} ^g Carla A. Ng, ^{id} ^h Xenia Trier ⁱ and Zhanyun Wang ^j

Previous Article

Next Article



The background is an underwater scene with a blue color palette. It features numerous bubbles of various sizes rising from the bottom, and light rays filtering down from the surface, creating a shimmering effect. The overall texture is fluid and dynamic.

Guidance & regulation

PFAS guideline levels (in Australia)

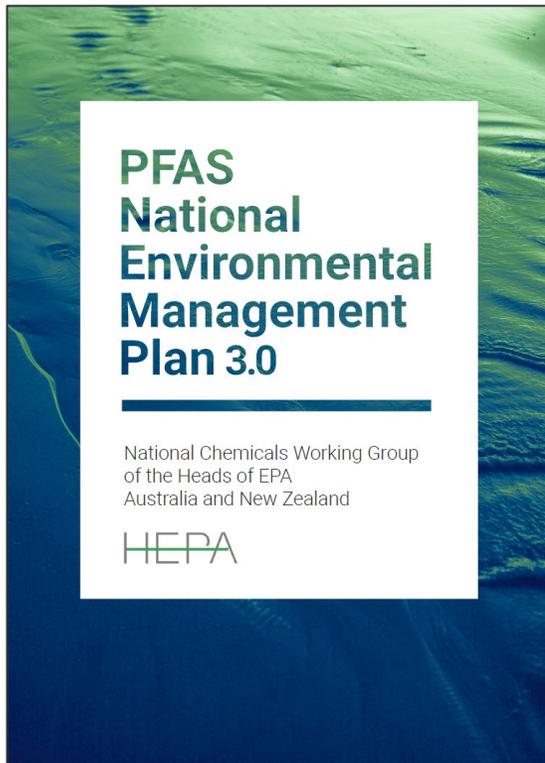


Table 4 Health-based guideline values developed by health authorities

Description	Sum of PFOS and PFHxS ^a	PFOA	Comments and source
Tolerable daily intake (TDI)	0.02µg/kg _{bw} /day	0.16µg/kg _{bw} /day	FSANZ 2017
Drinking water quality guideline	0.07µg/L	0.56µg/L	NHMRC 2011 New Zealand Government Department of Internal Affairs 2022
Recreational water quality guideline ^{b,c}	2µg/L	10µg/L	NHMRC 2019

- a Where the criteria refer to the sum of PFOS and PFHxS, this means concentrations of PFOS only, PFHxS only, and the sum of the two.
- b NHMRC (2019) notes that people's use of recreational water is not the same, given Australia's climate and geography. Some recreational water resources may be used less frequently than the assumed guidelines (150 days/year), and (in rare cases) some may be used more frequently. For example, surfing activities may be longer in duration and higher in ingestion risk, compared to NHMRC assumptions. In such cases more locally appropriate recreational guidance based on actual event frequency can be considered in consultation with the state or territory health regulator.
- c The guidelines address natural fresh, estuarine and marine recreational water bodies but specifically exclude swimming pools, spas and hydrotherapy pools (NHMRC 2008).

Table 8 Ecological water quality guideline values

Exposure scenario	Guideline value	PFOS µg/L	PFOA µg/L
Freshwater ^a	99% species protection – high conservation value systems ^b	0.00023	19
	95% species protection – slightly to moderately disturbed systems ^c	0.13	220
	90% species protection – highly disturbed systems	2	632
	80% species protection – highly disturbed systems	31	1824
Interim marine ^d	99% species protection – high conservation value systems	0.00023	19
	95% species protection – slightly to moderately disturbed systems	0.13	220
	90% species protection – highly disturbed systems	2	632
	80% species protection – highly disturbed systems	31	1824

Data source: Australian and New Zealand Guidelines for Fresh and Marine Water Quality – interim default guideline values for PFOS and PFOA (ANZG 2023).

- a The interim guidelines do not account for effects which result from the bioaccumulation and biomagnification of toxicants in air-breathing animals or in animals which prey on aquatic organisms.
- b The 99% species protection level for PFOS is close to the commercially available ultra-trace level of detection. Agencies may wish to apply an 'ultra-trace detect' threshold in such circumstances rather than a quantified measurement.
- c The WQG advise that the 99% level of protection be used for slightly to moderately disturbed systems. This approach is generally adopted for chemicals that bioaccumulate and biomagnify in wildlife. Environmental regulators may specify, or environmental legislation may prescribe, the level of species protection required, rather than allowing for case-by-case assessments.
- d Freshwater values are to be used on an interim basis until final marine guideline values can be set using the nationally agreed process under the WQG. The WQG advise that in the case of estuaries, the most stringent of freshwater and marine criteria apply, taking account of any available salinity correction. Marine guideline values developed by CRC CARE are under consideration through the nationally agreed water quality guideline development process.

US EPA National Primary Drinking Water Regulation

© www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

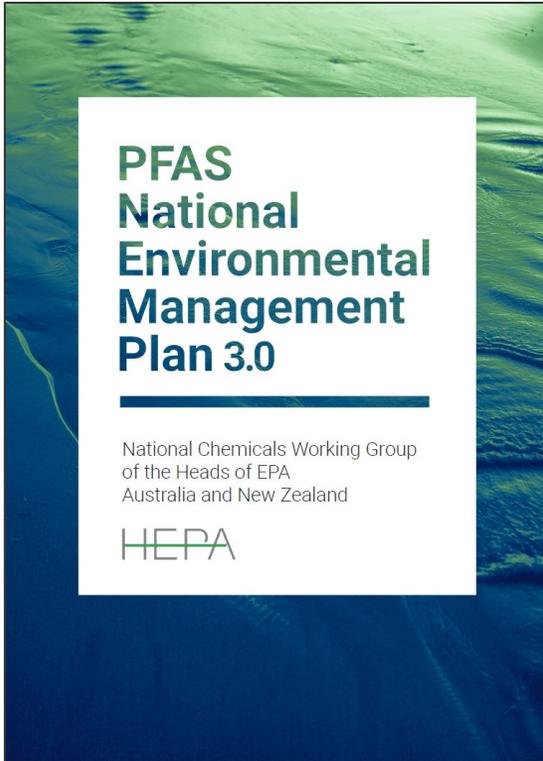
Compound	Final MCLG	Final MCL (enforceable levels) ¹
PFOA	Zero	4.0 parts per trillion (ppt) (also expressed as ng/L)
PFOS	Zero	4.0 ppt
PFHxS	10 ppt	10 ppt
PFNA	10 ppt	10 ppt
HFPO-DA (commonly known as GenX Chemicals)	10 ppt	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS	1 (unitless) Hazard Index	1 (unitless) Hazard Index

¹ Compliance with MCLs is determined by running annual averages at the sampling point.

An underwater scene with a blue color palette. The water is filled with numerous bubbles of various sizes, some rising and some falling. Light rays penetrate from the surface, creating a shimmering effect. The overall atmosphere is serene and dynamic.

“Solutions”

PFAS water treatment technologies available in Australia



② Separation & concentration

- Adsorption
 - Adhesion of PFAS to the surface of an adsorbent
- Reverse osmosis & nanofiltration
 - Removal of PFAS from water using semipermeable membranes
- Foam fractionalisation/ separation
 - Separation of PFAS from water into a foam using air or ozone bubbles

(requires concentrated PFAS to be managed appropriately)

Disposal of solid PFAS-contaminated material to landfill

PFAS National Environmental Management Plan 3.0

National Chemicals Working Group
of the Heads of EPA
Australia and New Zealand

HEPA

Table 11 Landfill acceptance criteria

In New Zealand, provisions in the *Hazardous Substances (Storage and Disposal of Persistent Organic Pollutants) Notice 2024* must be followed.

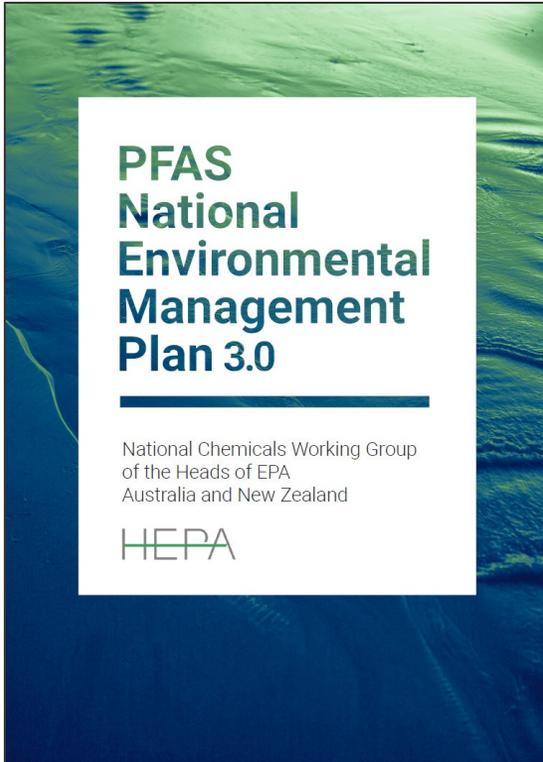
Landfill type	Concentration type	Interim landfill acceptance criteria ^{a,b}		Comments
		Sum of PFOS and PFHxS ^c	PFOA	
Unlined	ASLP leachable concentration (µg/L)	0.07µg/L	0.56µg/L	Drinking water × 1 (Department of Health 2017)
	Total concentration (mg/kg)	20mg/kg	50mg/kg	Soil – Human health industrial/commercial × 1 Total concentration for PFOA (including related substances) of 50mg/kg based on a proposed Basel Convention LPCL
Clay/single composite lined	ASLP leachable concentration (µg/L)	0.7µg/L	5.6µg/L	Drinking water × 10 (Department of Health 2017)
	Total concentration (mg/kg)	50mg/kg	50mg/kg	Soil – Human health industrial/commercial × 10 Total concentration for PFOS + PFHxS and PFOA (including related substances) of 50mg/kg based on the Basel Convention's LPCLs
Double composite lined	ASLP leachable concentration (µg/L)	7µg/L	56µg/L	Drinking water × 100 (Department of Health 2017)
	Total concentration (mg/kg)	50mg/kg	50mg/kg	Soil – Human health industrial/commercial × 100 Total concentration for PFOS + PFHxS and PFOA (including related substances) of 50mg/kg based on the Basel Convention's LPCLs

^a Waste concentrations must be less than both the relevant leachable concentration and the total concentration values for the type of landfill.

^b Where significant PFAS are present beyond PFOS, PFOA, and PFHxS, these solid PFAS-contaminated materials may not be acceptable for landfill disposal. This should be discussed with the environmental regulator.

^c Where the criteria refer to the sum of PFOS and PFHxS, this means concentrations of PFOS only, PFHxS only, and the sum of the two, including their respective related compounds.

Destruction of solid PFAS-contaminated material



Process	Definition	Application	Media	Status	
Destruction or transformation	Pyrolysis and oxidative thermal destruction (Ross et al. 2018)	Alteration of chemical composition to convert to inorganic fluoride using high temperature in the absence or presence of limited oxygen	High temperature plasma arc, cement kilns	Soil, aqueous film-forming foam concentrates, solid concentrates from adsorption, liquid concentrates from reverse osmosis, nanofiltration and ion exchange	Facilities available in Australia and trials to improve this technology, to make it more portable, are underway

An underwater photograph showing a dense field of bubbles rising from the bottom. Sunlight filters through the water from the right, creating a bright, shimmering area. The overall color palette is various shades of blue and teal.

**Nature-based
“treatment” ?**

Nature-based “treatment” - studies

Contents lists available at [ScienceDirect](#)

 **Science of the Total Environment** 

journal homepage: www.elsevier.com/locate/scitotenv

Constructed wetlands as nature-based solutions in managing per- and poly-fluoroalkyl substances (PFAS): Evidence, mechanisms, and modelling

Pinelopi Savvidou, Gabriela Dotro, Pablo Campo, Frederic Coulon, Tao Lyu*

School of Water, Energy and Environment, Cranfield University, College Road, Cranfield, Bedfordshire MK43 0AL, United Kingdom



 **Journal of Hazardous Materials** 

Volume 429, 5 May 2022, 128326

Research Paper

Application of native plants in constructed floating wetlands as a passive remediation approach for PFAS-impacted surface water

John Awad^{a, b}, Gianluca Brunetti^a, Albert Juhasz^c  , Mike Williams^b, Divina Navarro^b, Barbara Drigo^c, Jeremy Bougoure^d, Joanne Vanderzalm^b, Simon Beecham^a

OCCURRENCE, FATE, AND TRANSPORT OF AQUATIC AND TERRESTRIAL CONTAMINANTS | September 17, 2025

Mitigating Ecological Risks: Role of Arbuscular Mycorrhizal Symbiosis in Translocation and Transformation of Per- and Polyfluoroalkyl Substances in Constructed Wetlands

Yuchen Wang, Shanshan Hu, Fengxiang Zhu, Xue Li, Lexing You, Zhongbing Chen, Bo Hu*, and Feng Zhao*

Nature-based “treatment”

- ② Further research needed, e.g.
 - Effectiveness
 - Long-term performance
- ② How to:
 - Manage (e.g. remove, immobilize, destroy) ‘spent’ filter media, plants etc ?
 - Prevent being an ‘ecological trap’ ?



Photo Source: Paul Dubowski (2014: Pers.Comm.)

An underwater scene with numerous bubbles rising from the bottom and light rays filtering down from the surface. The water is a deep blue color.

**Quick break for
questions ?**

An underwater scene with numerous bubbles rising from the bottom and light rays filtering down from the surface. The water is a deep blue color. The text is centered in the middle of the frame.

Solution development & testing

An underwater scene with numerous bubbles rising from the bottom and light rays filtering down from the surface. The water is a deep blue color. The text "The StormFilter®" is centered in the middle of the image.

The StormFilter®

What is StormFilter ?

- ⌚ Radial treatment technology
- ⌚ Flexible configurations
- ⌚ Multiple media options
- ⌚ Self-cleaning functionality
- ⌚ Accessible & rechargeable cartridges



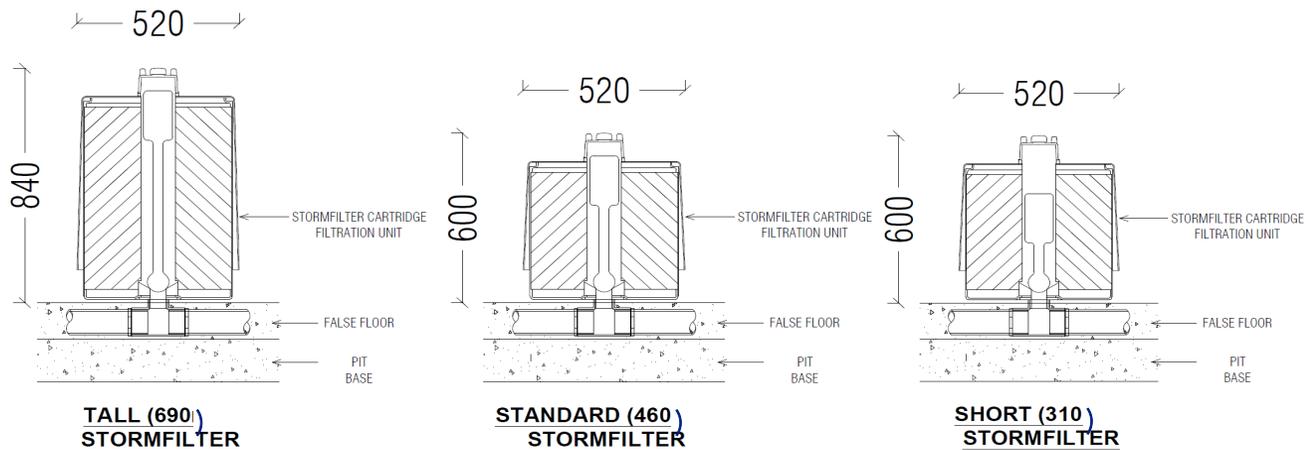
Application

- ⦿ Commercial, industrial & residential areas
- ⦿ Other projects (e.g. roads, airports)



Configuration

- ⦿ Precast concrete pits & tanks
- ⦿ Custom above ground HDPE/aluminium tanks
- ⦿ Integrated within on-site detention structures
- ⦿ On-line or off-line
- ⦿ 3 x cartridge heights



Performance

- ④ 4 x 'real world', published studies
- ④ 4 x peer review reports
- ④ 2 x SQIDEP certificates
- ④ 1 x longevity study
- ④ Council approved performance values



Case studies

- ⌚ Over 40,000 installed in Australia
- ⌚ Over 300,000 installed overseas



Case Study - LAX Crossfield Taxiway

- © Installed 2010
- © (2) CON/SPAN® Filtration System
- © 1,647 x StormFilter®

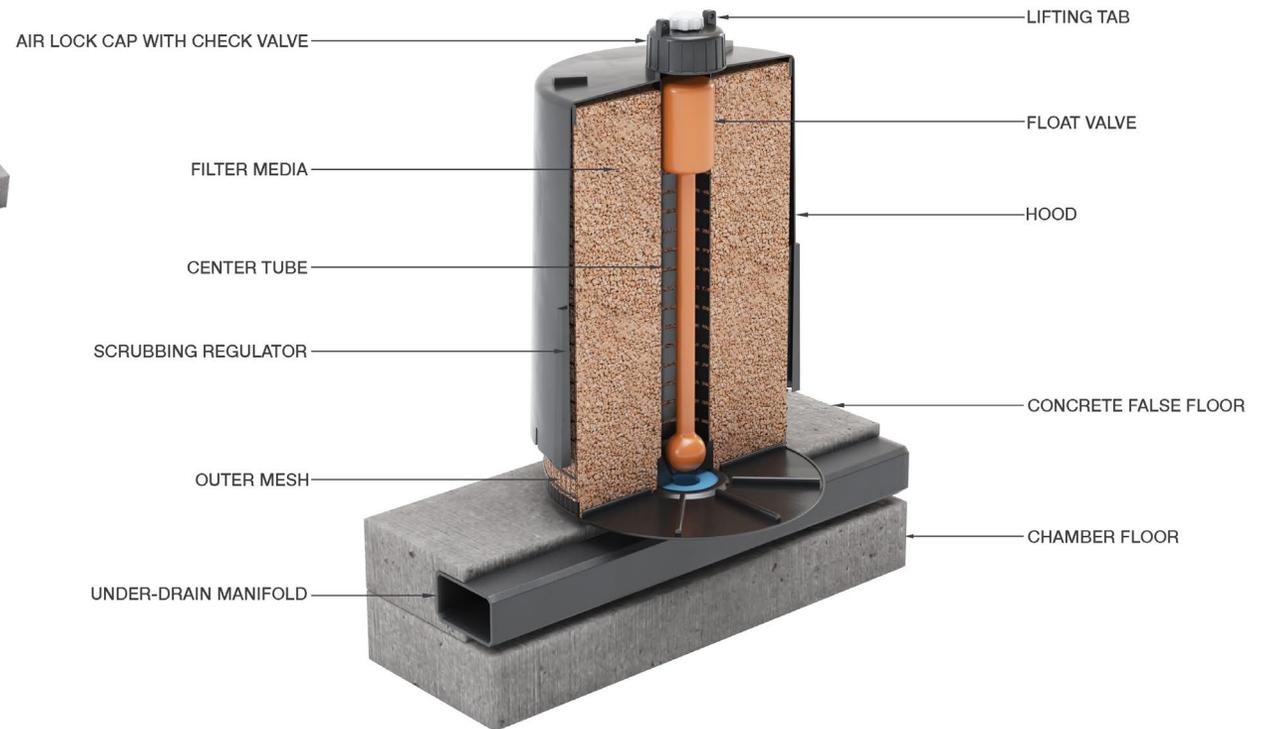


Case Study - Sacramento International Airport Terminal B

- ⦿ Installed 2009-12
- ⦿ 4 x StormFilter® Vaults
- ⦿ 229 x StormFilter® cartridges



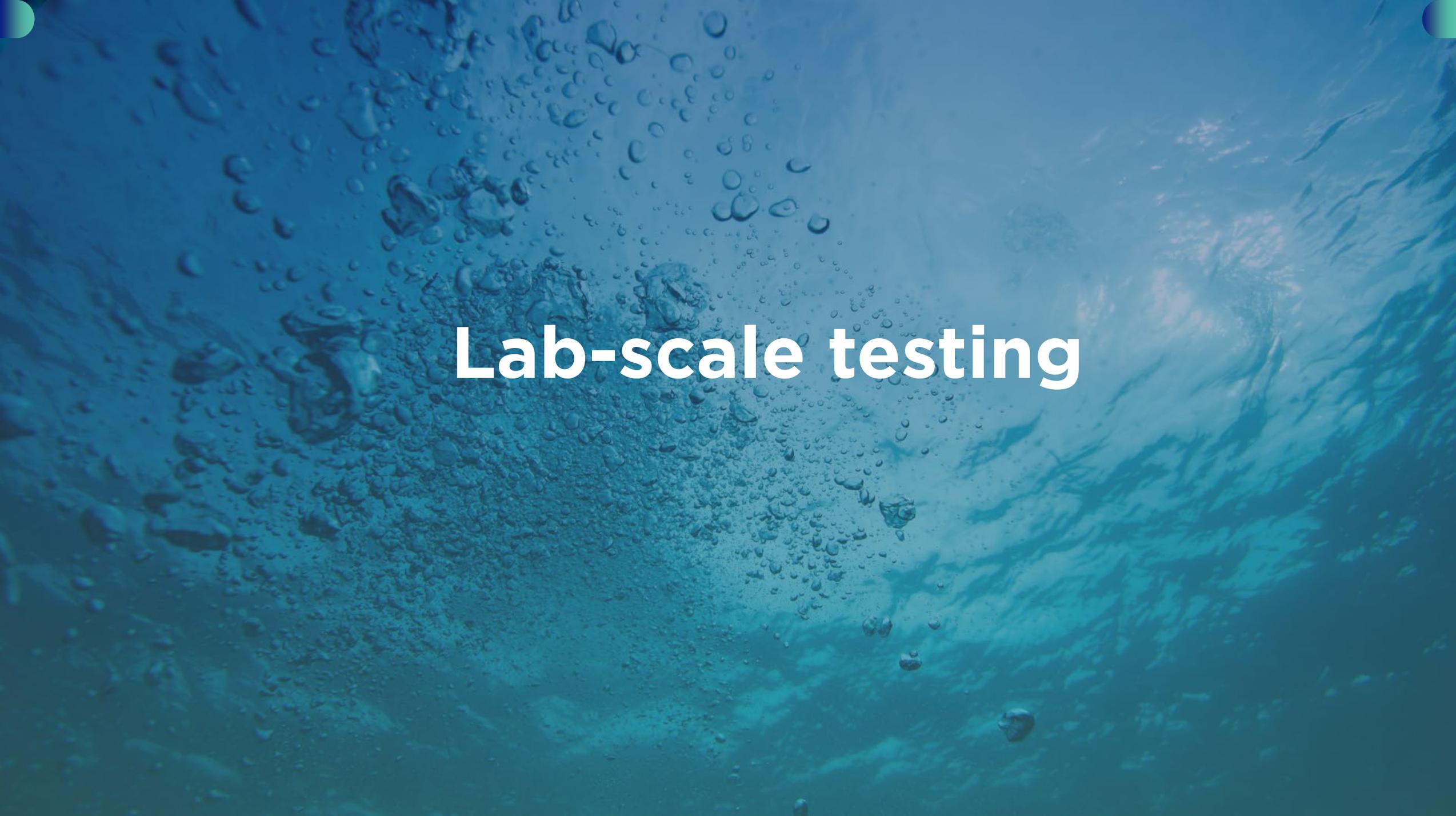
StormFilter



Solution development & testing

- ④ Lab-scale testing of potential media options
- ④ Field-scale testing



The background is a deep blue underwater scene. Numerous bubbles of various sizes are visible, rising from the bottom towards the surface. Light rays penetrate from the top, creating a shimmering effect on the water's surface. The overall atmosphere is serene and scientific.

Lab-scale testing

Lab-sale testing



Per and Polyfluoroalkyl Substance Removal in Stormwater by Radial Flow Treatment Technology

Honours Research Thesis submitted as a requirement of Bachelor Degree in Civil Engineering

The School of Civil and Environmental Engineering
University of New South Wales

By
Blake Allingham

August 2021

15th International Conference on Urban Drainage, Melbourne, October, 2021

Per and Polyfluoroalkyl Substance Removal in Stormwater by Radial Flow Treatment Technology

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²Department of Civil and Environmental Engineering, University of New South Wales, Sydney, New South Wales, 2052, Australia
*Corresponding author email: Blake@oceanprotect.com.au

Abstract

The use of per and polyfluoroalkyl substances (PFAS) has been common in aqueous film forming foams for use in fire-fighting and associated training. The Australian government has had a ban on these substances since April 2021. However, due to their strong Carbon-Fluorine bond they are still found in high concentrations where historic use has occurred and low concentrations in surrounding areas (NSW Environment Protection Authority 2021a).

The suspension and transportation of PFAS occurs in stormwater runoff originating from contaminated areas. The focus of this study is the treatment of this runoff using existing radial flow treatment technology with selected granular activated carbons and an ion-exchange resin.

The first stage was to identify appropriate media that is capable of treating PFAS to meet the *Australian Drinking Water Guidelines* (Sum of PFOS and PFHxS to 0.07µg/litre and PFOA to 0.56µg/litre). (Australian Government 2011). This was completed using a bench scale radial flow horizontal column representing a 1/24th scale of the radial treatment technology. Two media identified as 'ACS' and 'IX1' were capable of reducing the sum of concentrations of perfluorohexanesulfonic acid and perfluorooctanesulfonate ranging from 0.717 µg/litre - 0.830 µg/litre down to 0.001 µg/litre - 0.004 µg/litre.

The reduction in perfluorooctanoic acid in 'ACS' and 'IX1' ranged from 0.018 µg/litre - 0.020 µg/litre down to below the limit of reporting (LOR) of the ultra-high-performance liquid chromatography combined with mass spectrometry method (0.002 µg/litre). During this initial testing, three flow rates were trialled at 11.43 litres/minute/m², 26.79 litres/minute/m² and 44.64 litres/minute/m² with no significant difference in performance.

A controlled field study of radial treatment technology using ACS was commenced to determine the amount of volume of contaminated water that can be treated before the media needs to be replaced, which is defined as the 'breakthrough volume'. The controlled field study was conducted at a flow rate of 44.64 litres/minute/m². Results to date are up to 3600 bed volumes of treated water and show no signs of breakthrough volume being reached. Over the 3600 bed volumes of water treated, the total PFAS, sum of PFHxS and PFOS and PFOA influent concentrations ranged from 0.789 - 2.684 µg/litre, 0.396 - 2.065 µg/litre and 0.008 - 0.054 µg/litre respectively. The removal efficiency of total PFAS, sum of PFHxS and PFOS and PFOA ranged from 75.2% - 88.8%, 74.8% - 92.1% and 31.5% - 87.5% respectively. At this stage no definite breakthrough can be determined and continued bed volumes will be treated to provide an appropriate analysis on the longevity of the ACS media.

Keywords

Per and Polyfluoroalkyl Substances (PFAS); Stormwater; Treatment.

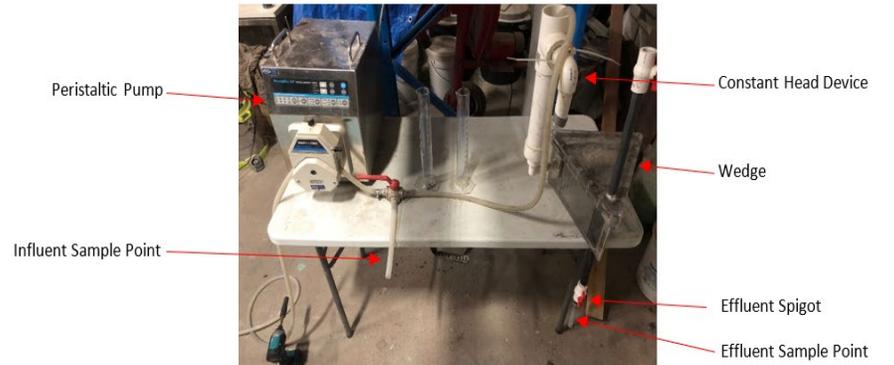
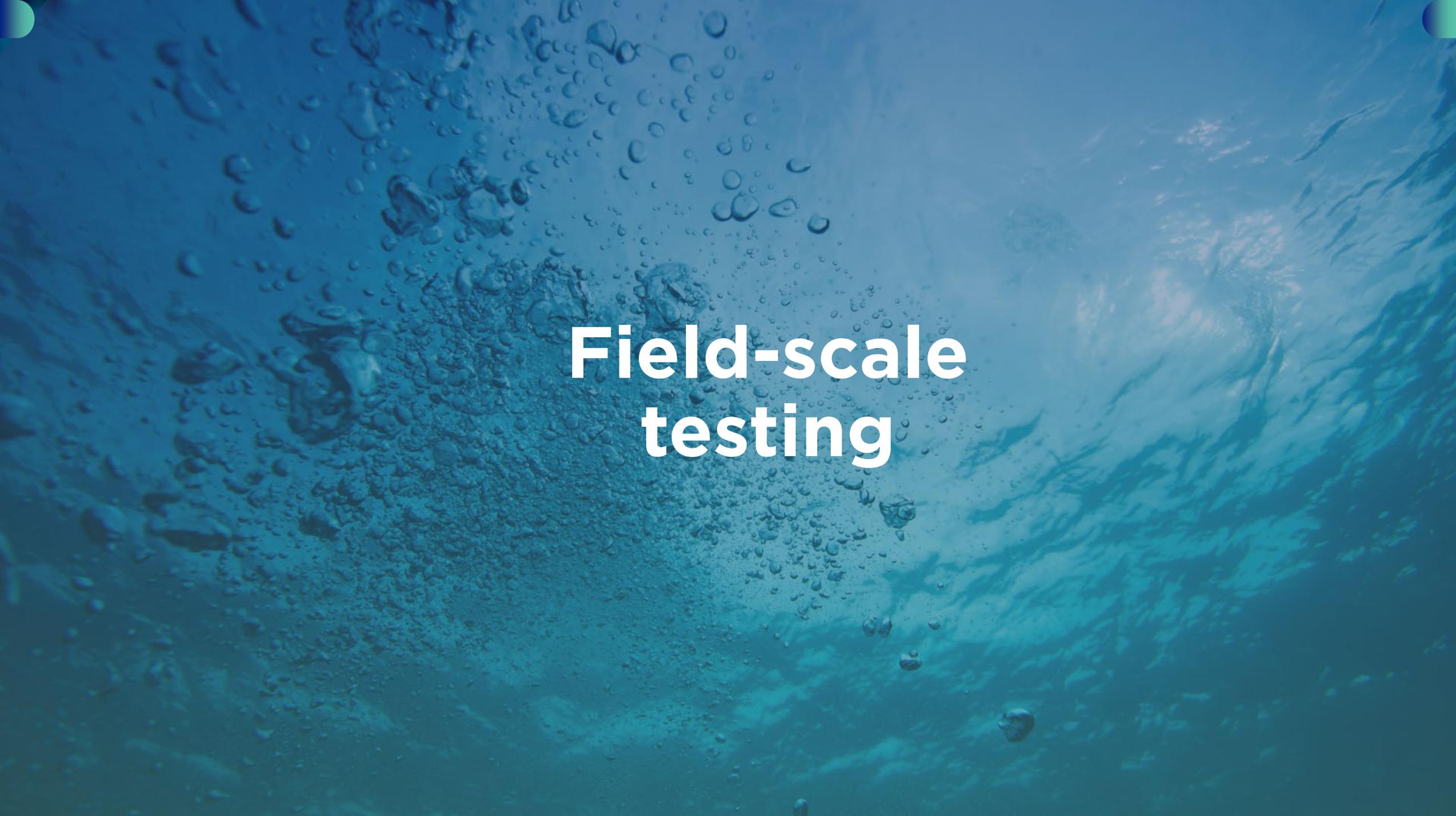


Table 1. Summary of removal efficiency for selected media and flow rate.

Media	Contaminant	Flow Rate (Litres/minute/m ²)	Average Influent Conc. (µg/litre)	Average Effluent Conc. (µg/litre)	Removal Efficiency	Australian Drinking Water Guidelines (c/nc)*
ACS	Sum of PFHxS and PFOS	11.43	0.717	<i>0.001</i>	99.86%	c
	PFOA		0.019	<i>0.001</i>	94.64%	c
	Sum of PFHxS and PFOS	26.79	0.718	0.002	99.72%	c
IX1	PFOA		0.019	<i>0.001</i>	94.83%	c
	Sum of PFHxS and PFOS	44.64	0.719	0.004	99.44%	c
	PFOA		0.019	<i>0.001</i>	94.74%	c
IX1	Sum of PFHxS and PFOS	11.43	0.810	<i>0.001</i>	99.88%	c
	PFOA		0.019	<i>0.001</i>	94.59%	c
	Sum of PFHxS and PFOS	26.79	0.769	<i>0.001</i>	99.87%	c
IX1	PFOA		0.019	<i>0.001</i>	94.64%	c
	Sum of PFHxS and PFOS	44.64	0.830	<i>0.001</i>	99.88%	c
	PFOA		0.020	<i>0.001</i>	95.08%	c

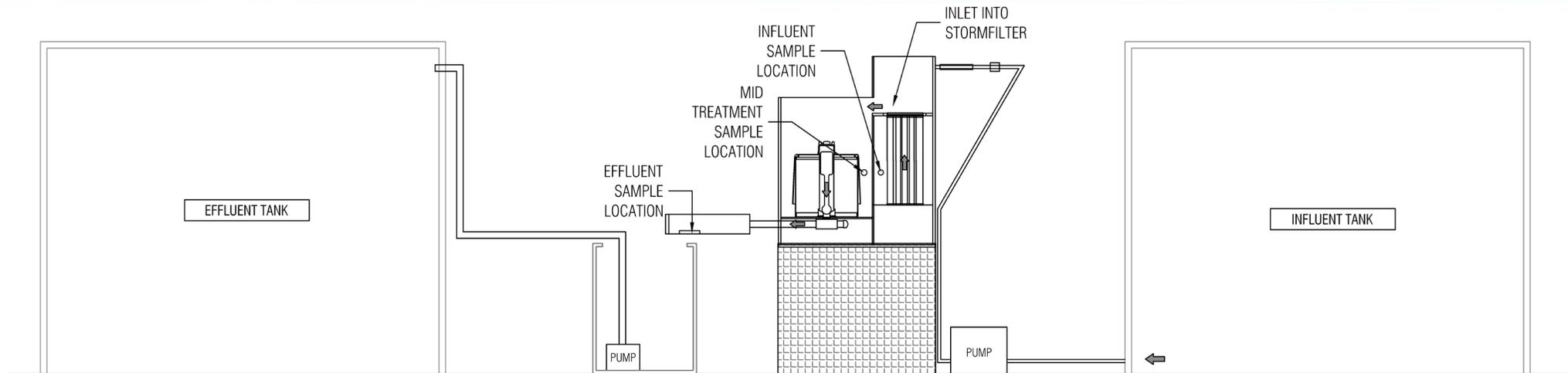
*: c = Compliant;
nc = non-Compliant

Italicised values are values recorded as below the laboratory level of reporting (LOR) and are presented as being equal to half of the Limit of Reporting.

An underwater scene with numerous bubbles rising from the bottom and light rays filtering down from the surface. The water is a deep blue color. The text "Field-scale testing" is centered in the middle of the image.

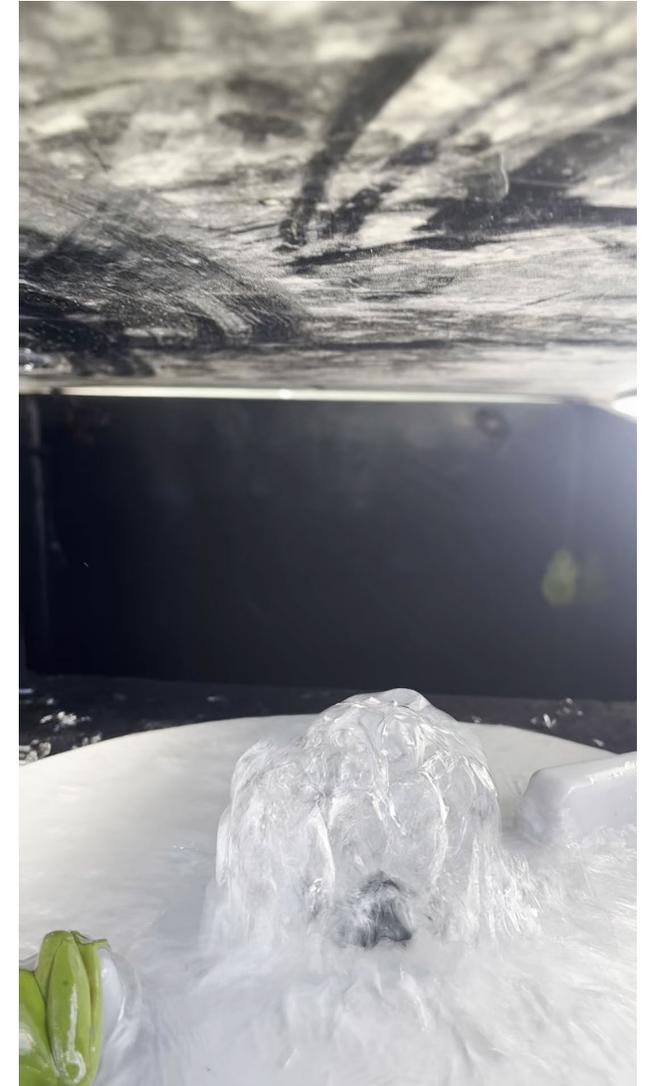
Field-scale testing

Overview of Field Scale Study

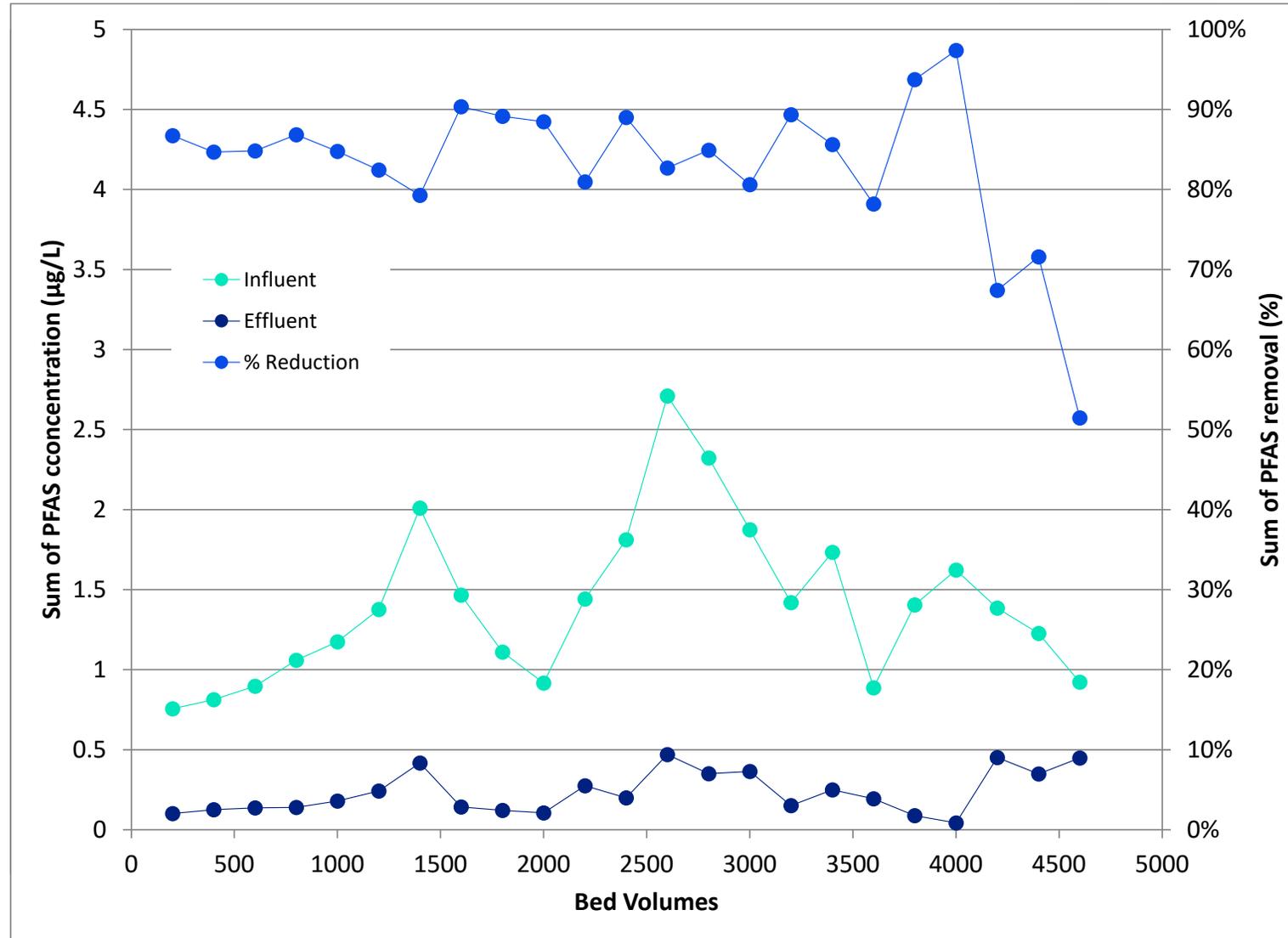


Field-scale testing – study 1 (2021)

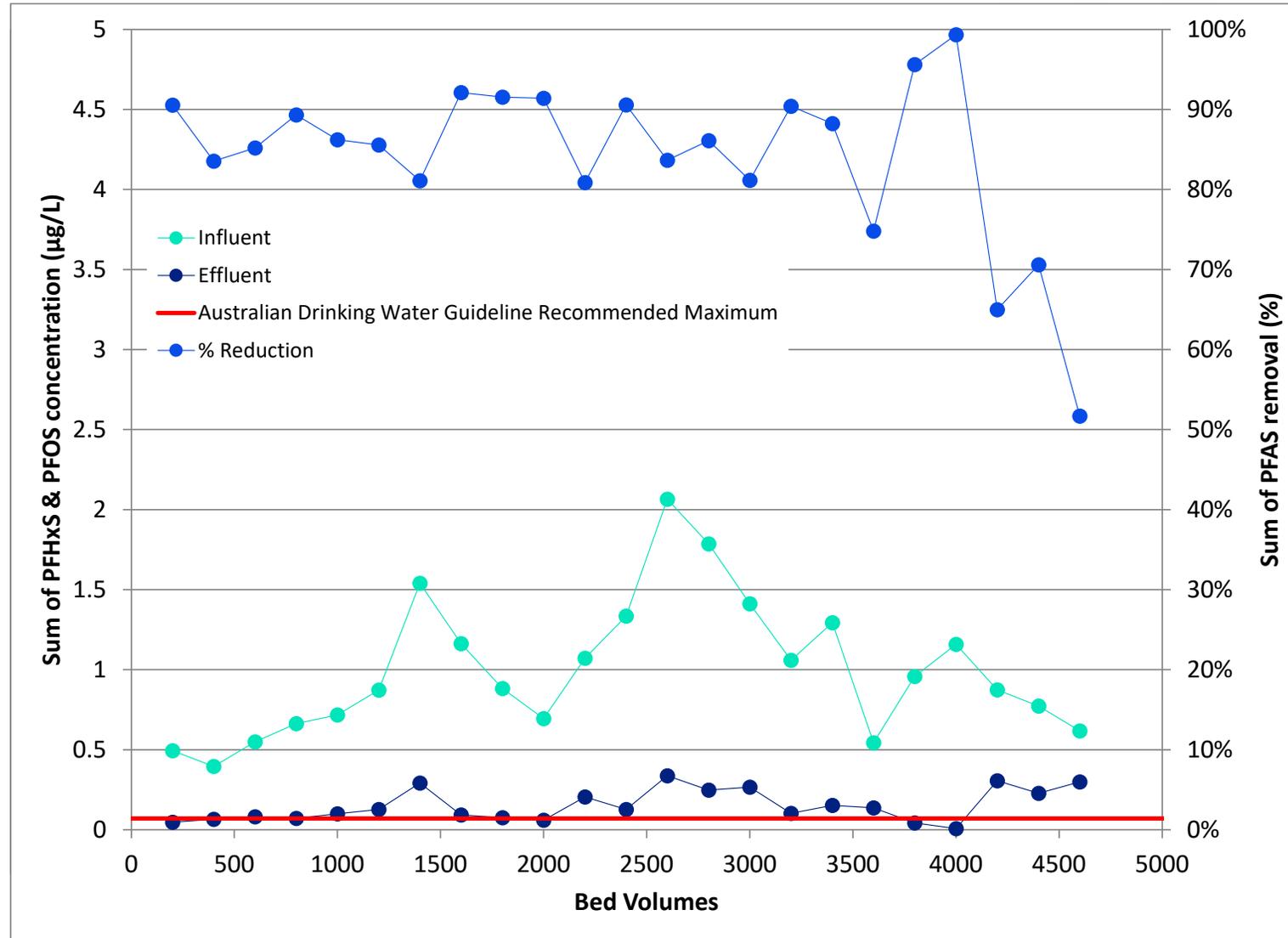
- ④ No pre-treatment of flows
- ④ 'Bed volume' defined by StormFilter (70L of media)
- ④ 336,000 litres of water (4800 bed volumes) treated
- ④ Operated & monitored in May & August 2021
- ④ Grab samples every 200 bed volumes
- ④ 24 sampling events collected & preserved
- ④ 24 samples analysed by University of NSW



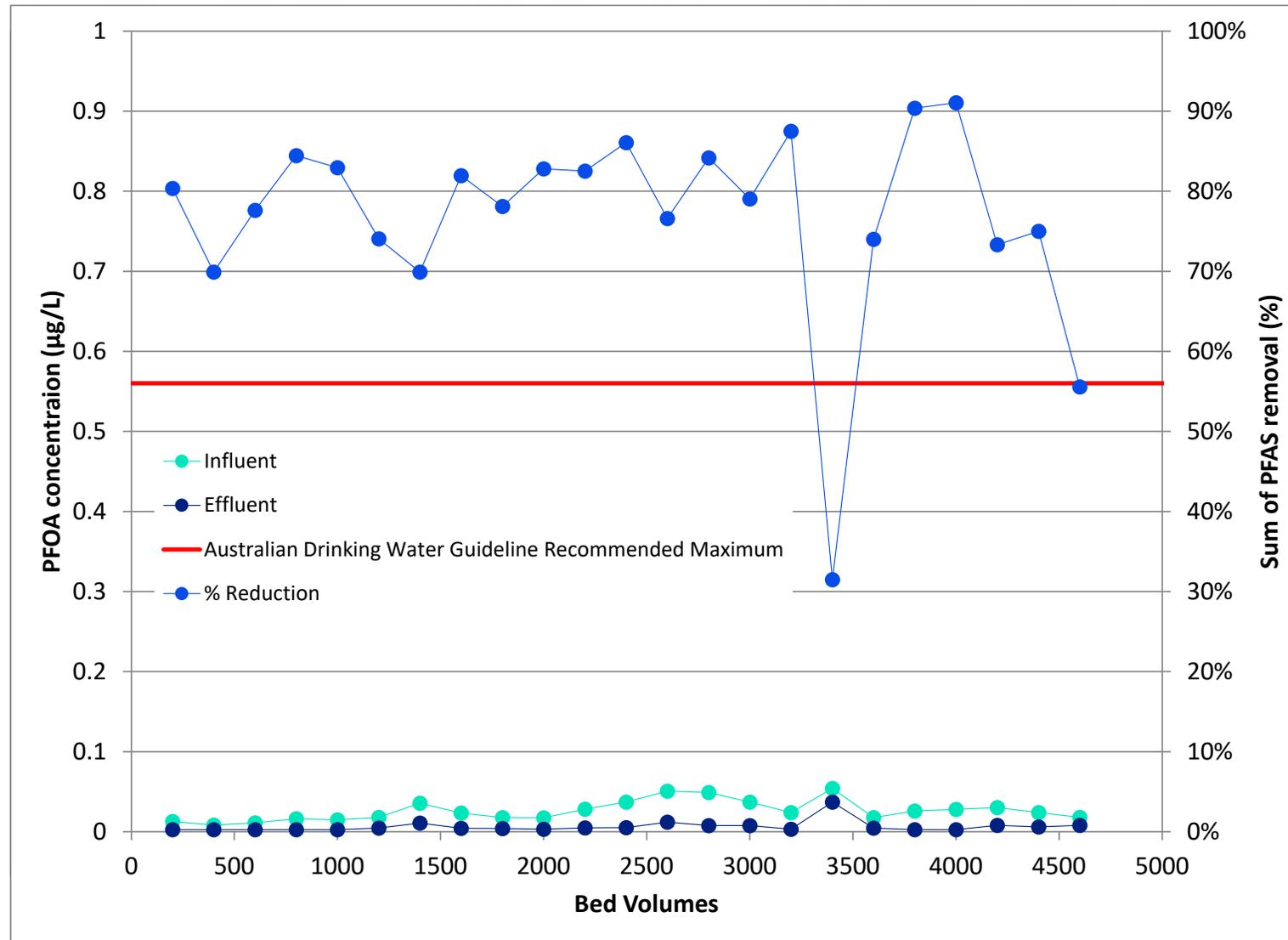
Study 1 Results – Sum of PFAS



Study 1 Results – Sum of PFOS & PFHxS

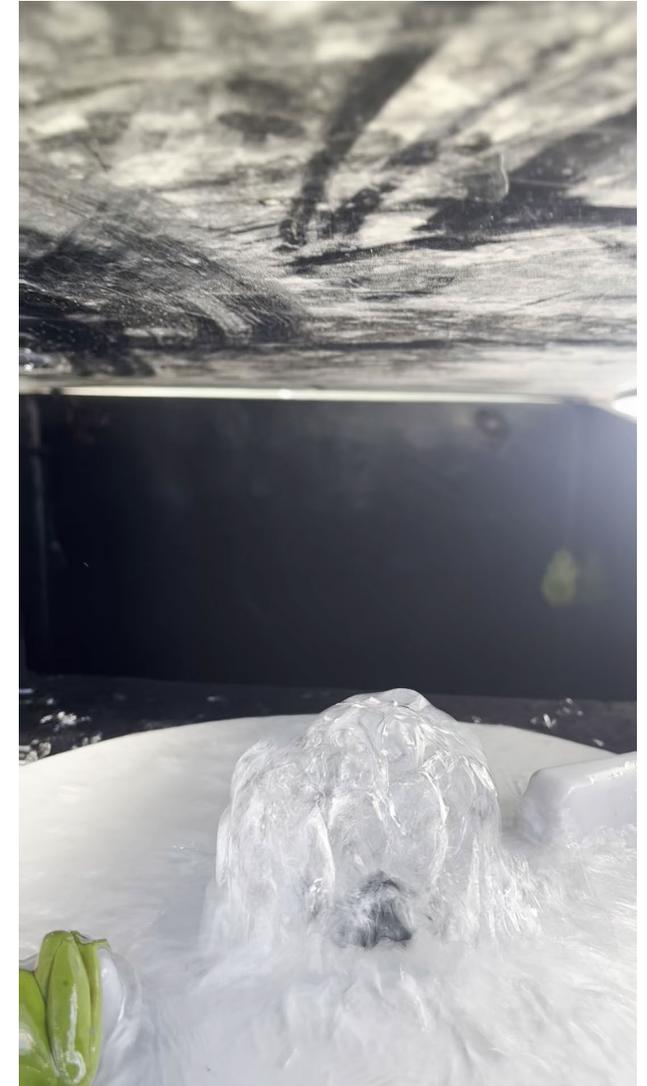


Study 1 Results – PFOA



Field-scale testing – study 2 (2022)

- ⦿ Pre-treatment of flows (by Jellyfish®)
- ⦿ 'Bed volume' defined by StormFilter (70L of media)
- ⦿ 41790 litres of water (597 bed volumes) treated
- ⦿ Operated & monitored in November & December 2022
- ⦿ Auto-samplers sampled every 25 minutes
- ⦿ 59 sampling events collected & preserved
- ⦿ 17 events analysed by ALS



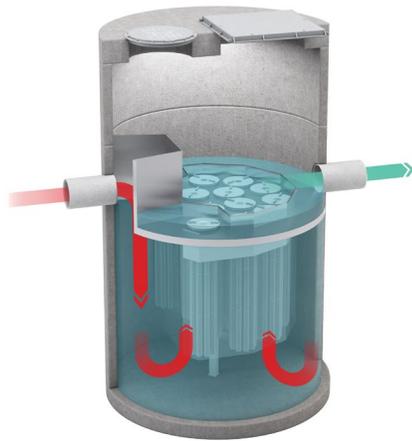
The background is a deep blue underwater scene. Numerous bubbles of various sizes are rising from the bottom, creating a sense of movement. Light rays filter down from the surface, creating a shimmering effect. The overall tone is serene and clean.

The Jellyfish[®]

(for pre-treatment)

What is Jellyfish ?

- ④ Membrane cartridge filtration
- ④ Up-flow hydraulics
- ④ Self cleaning functionality
- ④ Flexible configurations
- ④ Accessible & replaceable cartridges



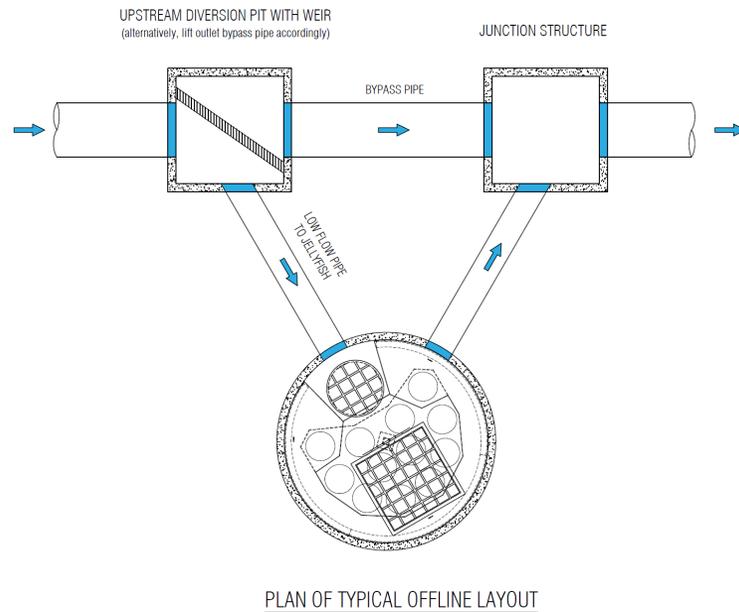
Application

- ⦿ Commercial, industrial & residential areas
- ⦿ Special projects (e.g. highways, airports)
- ⦿ Popular for sites with low driving head



Jellyfish – Configuration

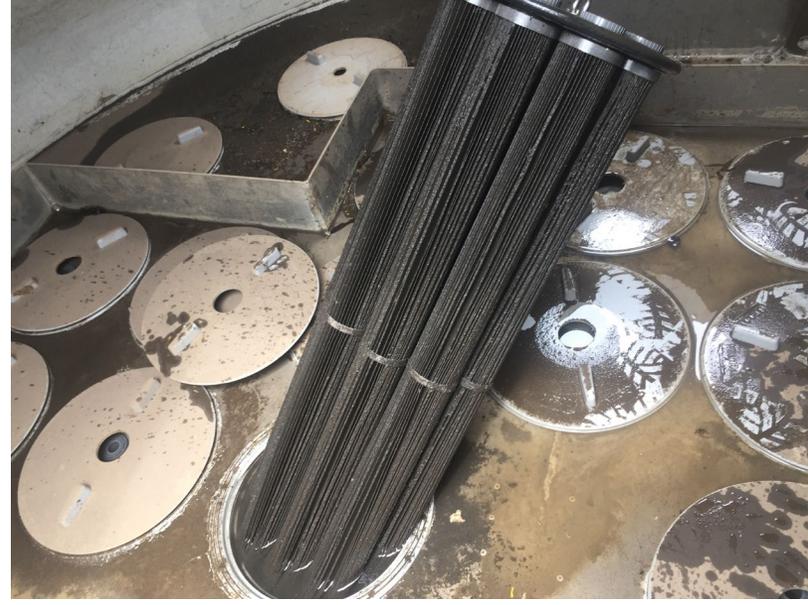
- ⦿ Precast concrete pits & tanks
- ⦿ Custom chambers
- ⦿ On-line or off-line



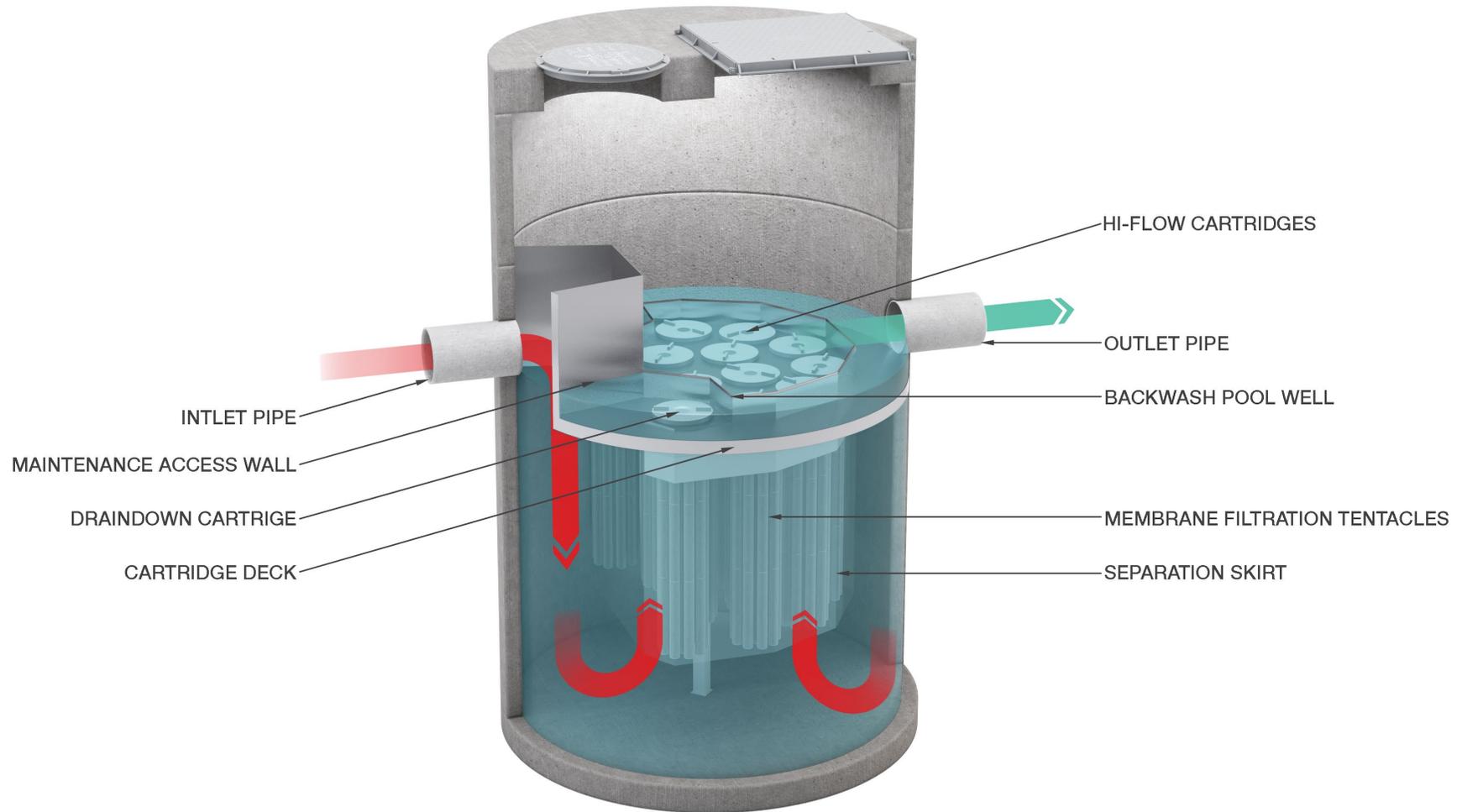
Model	High flow cartridges	Drain-down cartridges	467mm Head Flow rate (L/s)	306mm Head Flow rate (L/s)	229mm Head Flow rate (L/s)
JF-900-1-1	1	1	7.5	5.3	4.1
JF-900-2-1	2	1	12.5	8.6	6.6
JF-1200-1-1	1	1	7.5	5.3	4.1
JF-1200-2-1	2	1	12.5	8.6	6.6
JF-1500-3-1	3	1	17.5	12.0	9.1
JF-1500-4-1	4	1	22.5	16.3	11.7
JF-1500-5-1	5	1	27.5	18.7	14.2
JF-2300-6-1	6	1	32.5	22.0	16.7
JF-2300-7-2	7	2	40	27.3	20.8
JF-2300-8-2	8	2	45	30.6	23.3
JF-2300-9-2	9	2	50	34.0	25.8
JF-2300-10-2	10	2	55	37.3	28.4
JF-3300-11-2	11	2	60	40.7	30.9
JF-3300-12-2	12	2	65	44.0	33.4
JF-3300-13-3	13	3	72.5	49.3	37.5
JF-3300-14-3	14	3	77.5	52.6	40.0
JF-3300-15-3	15	3	82.5	56.0	42.5
JF-3300-16-3	16	3	87.5	59.3	45.1
JF-3300-17-3	17	3	92.5	62.7	47.6
JF-3300-18-3	18	3	97.5	66.0	50.1
JF-3300-19-4	19	4	105	71.3	54.2
JF-3300-20-4	20	4	110	74.6	56.7
JF-3300-21-4	21	4	115	78.0	59.2
JF-3300-22-4	22	4	120	81.3	61.8
JF-3300-23-4	23	4	125	84.7	64.3
JF-3300-24-4	24	4	130	88.0	66.8
JF-3300-25-5	25	5	137.5	93.3	70.9
JF-3300-26-5	26	5	142.5	96.6	73.4
JF-3300-27-5	27	5	147.5	100.0	75.9
JF-3300-28-5	28	5	162.5	103.3	78.6
JF-3300-29-5	29	5	167.5	106.7	81.0

Jellyfish – Case studies

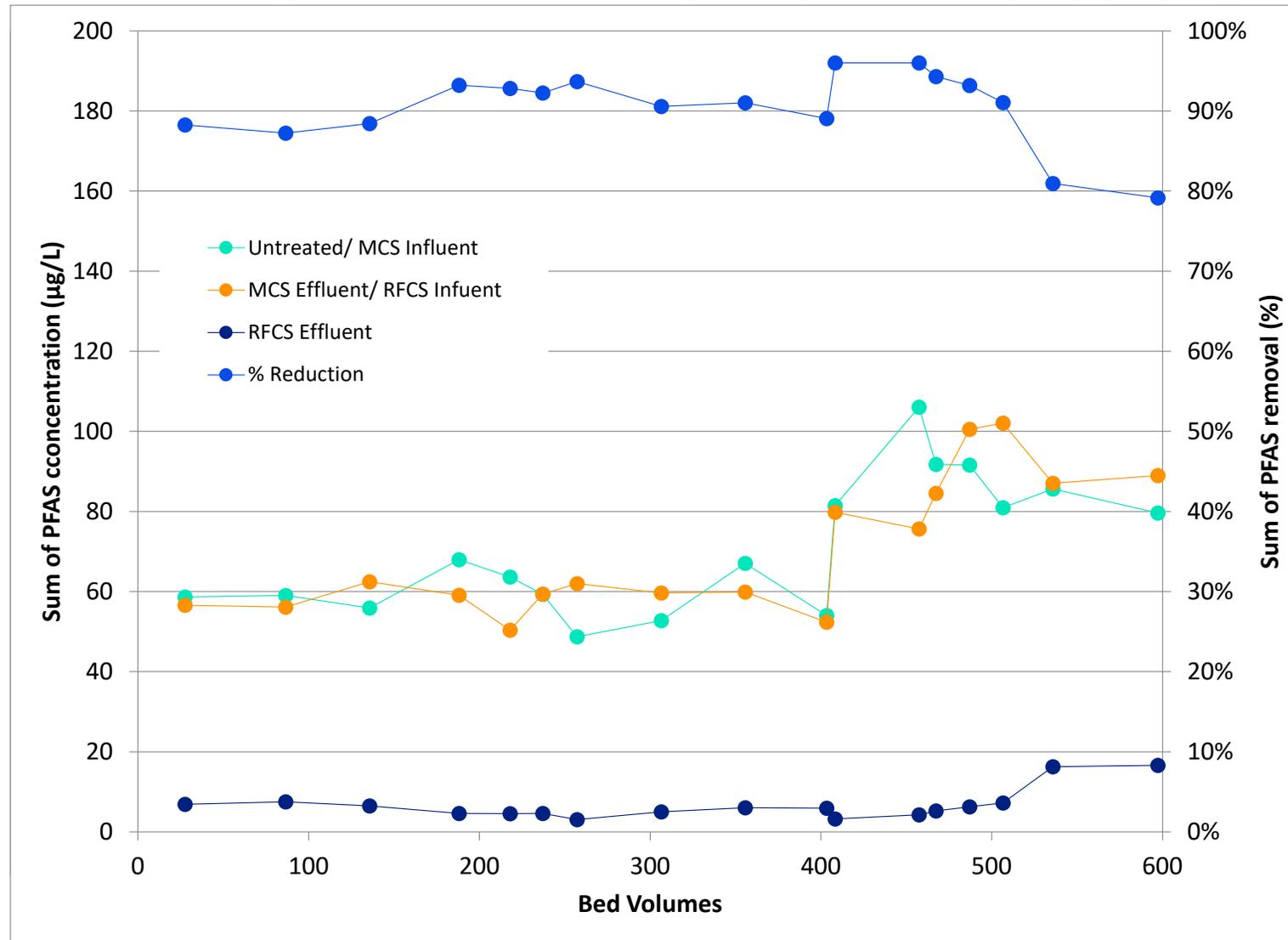
© Over 3300 installed in Australia since 2017



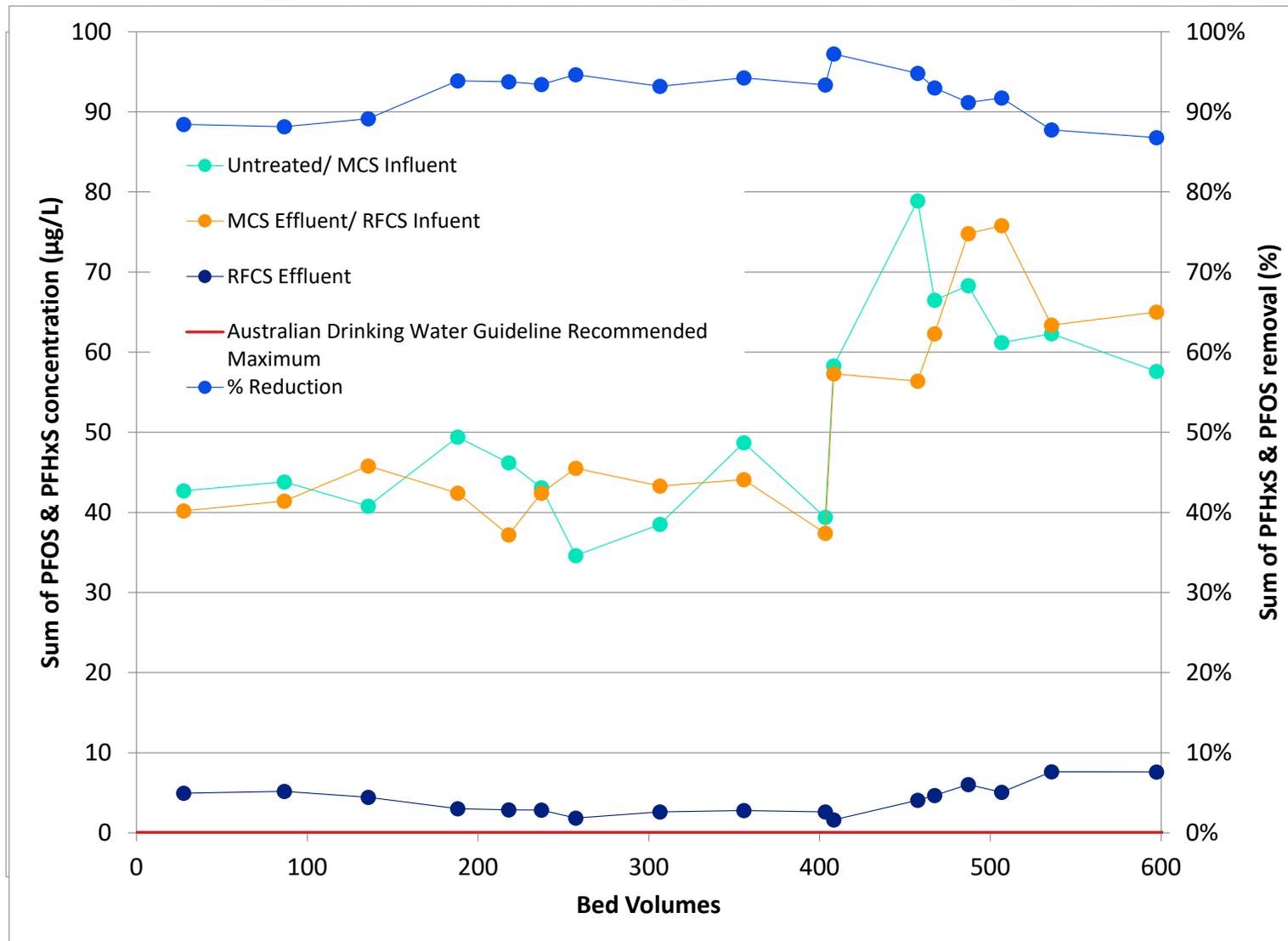
Jellyfish



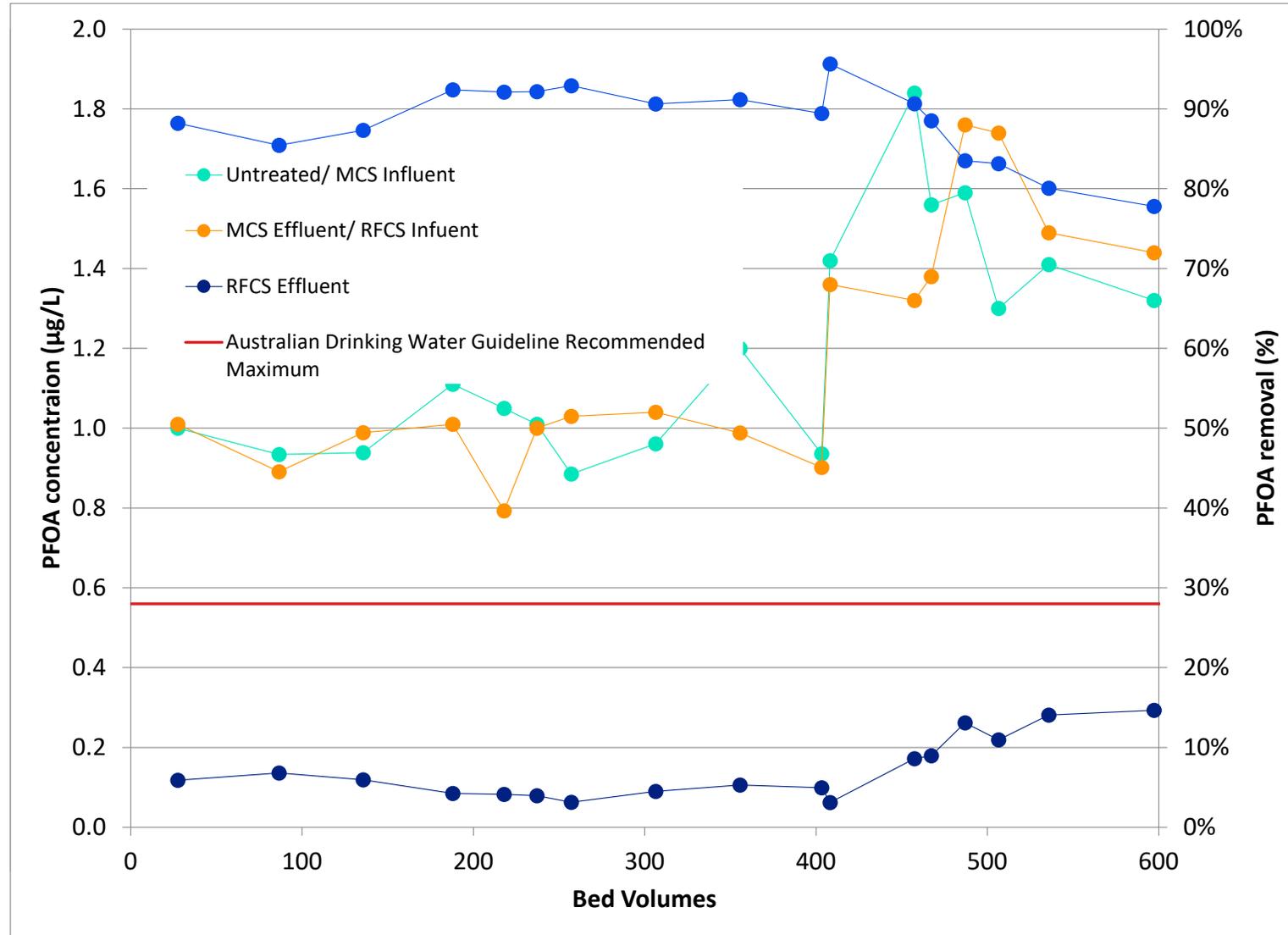
Study 2 Results – Sum of PFAS



Study 2 Results – Sum of PFOS & PFHxS



Study 2 Results – PFOA



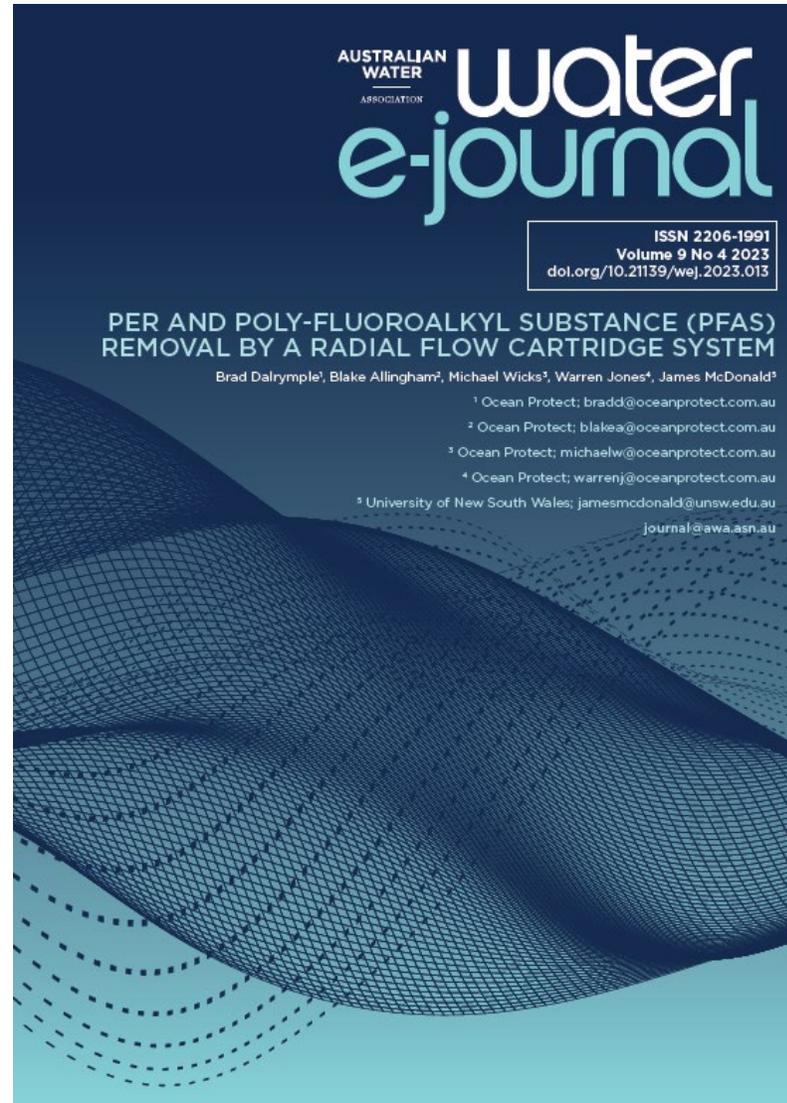
Study 1 Results Summary (for 'peak performance period', 4000 bed volumes)

PFASs	Mean concentration in influent (µg/L)	Mean concentration in effluent (µg/L)	Total load removal (µg)	% removal of PFAS
Sum of PFAS	1.43	0.20	343 283	87%
Sum of PFHxS and PFOS	1.03	0.13	250 463	87%
Sum of PFOA	0.03	0.01	39 992	76%
Sum of Long Chained PFASs and PFCAs	1.11	0.15	269 266	87%
Sum of Short Chained PFASs and PFCAs	0.26	0.05	59 027	82%

Study 2 Results Summary (for 'peak performance period', 467 bed volumes)

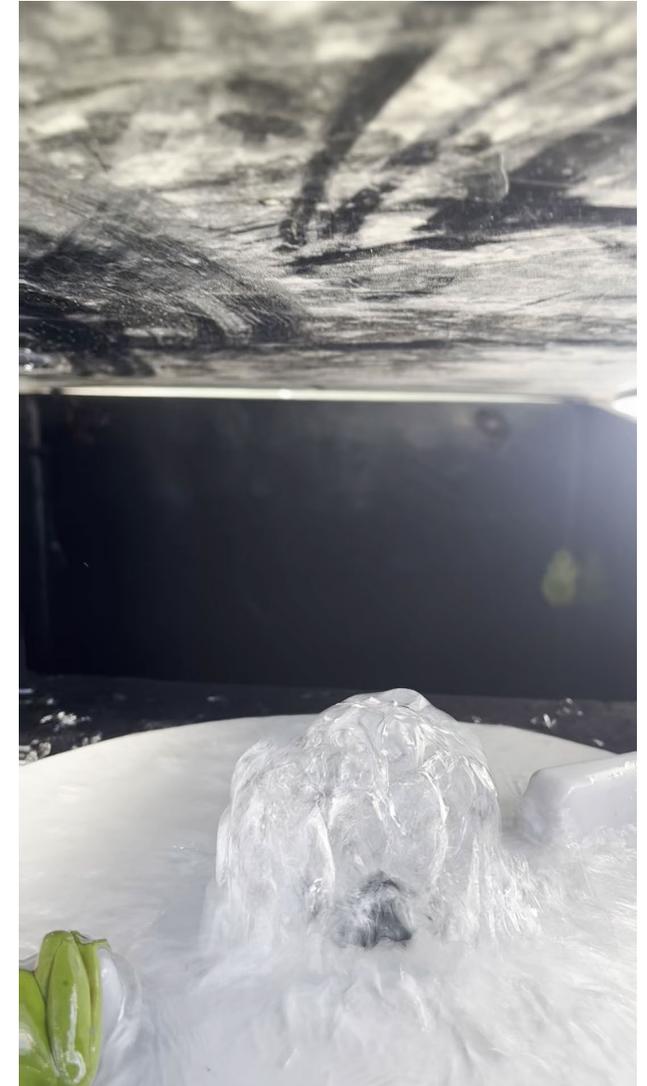
PFASs	Mean concentration in untreated water (µg/L)	Mean concentration in RCFS effluent (µg/L)	Total load removal (µg)	% removal of PFAS
Sum of PFAS	66.64	5.18	2 010 375	93%
Sum of PFHxS and PFOS	48.53	3.35	1 477 938	94%
Sum of PFOA	1.14	0.11	33 857	91%
Sum of Long Chained PFASs and PFCAs	51.46	3.57	1 566 485	94%
Sum of Short Chained PFASs and PFCAs	14.77	2.26	409 352	83%

Further info

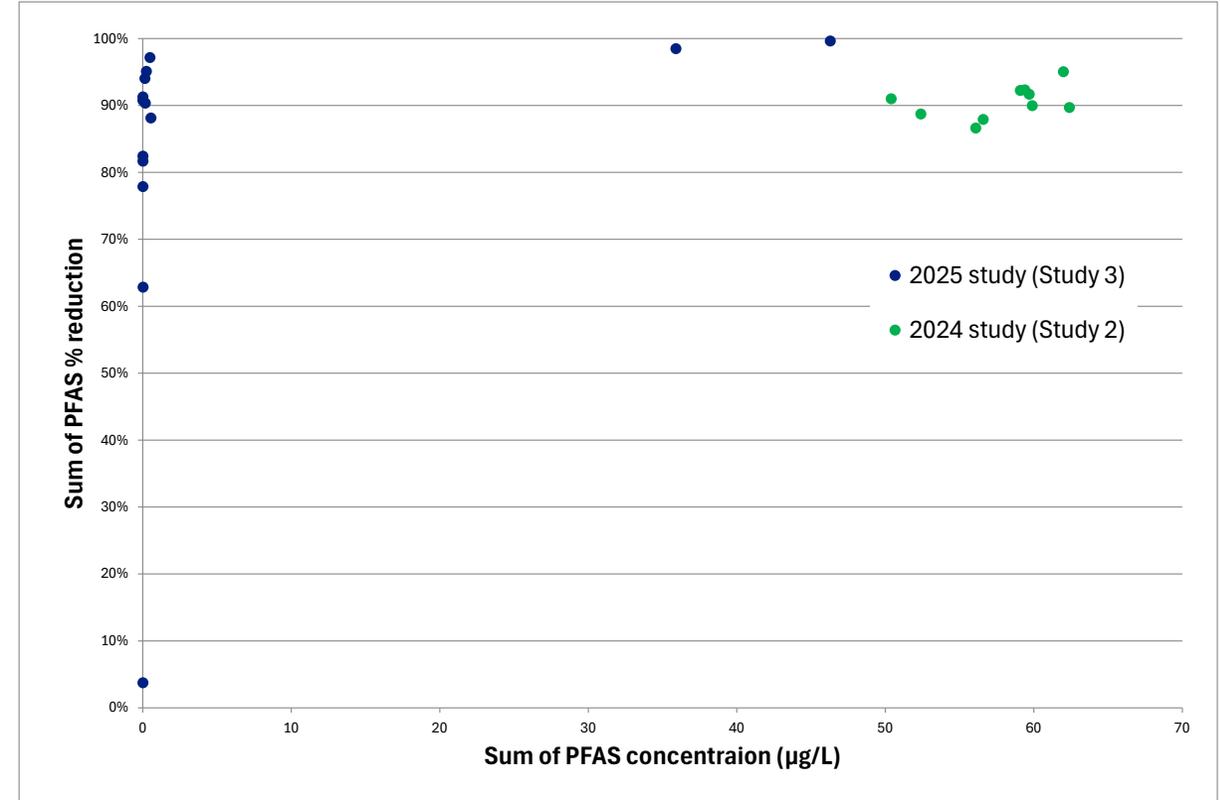
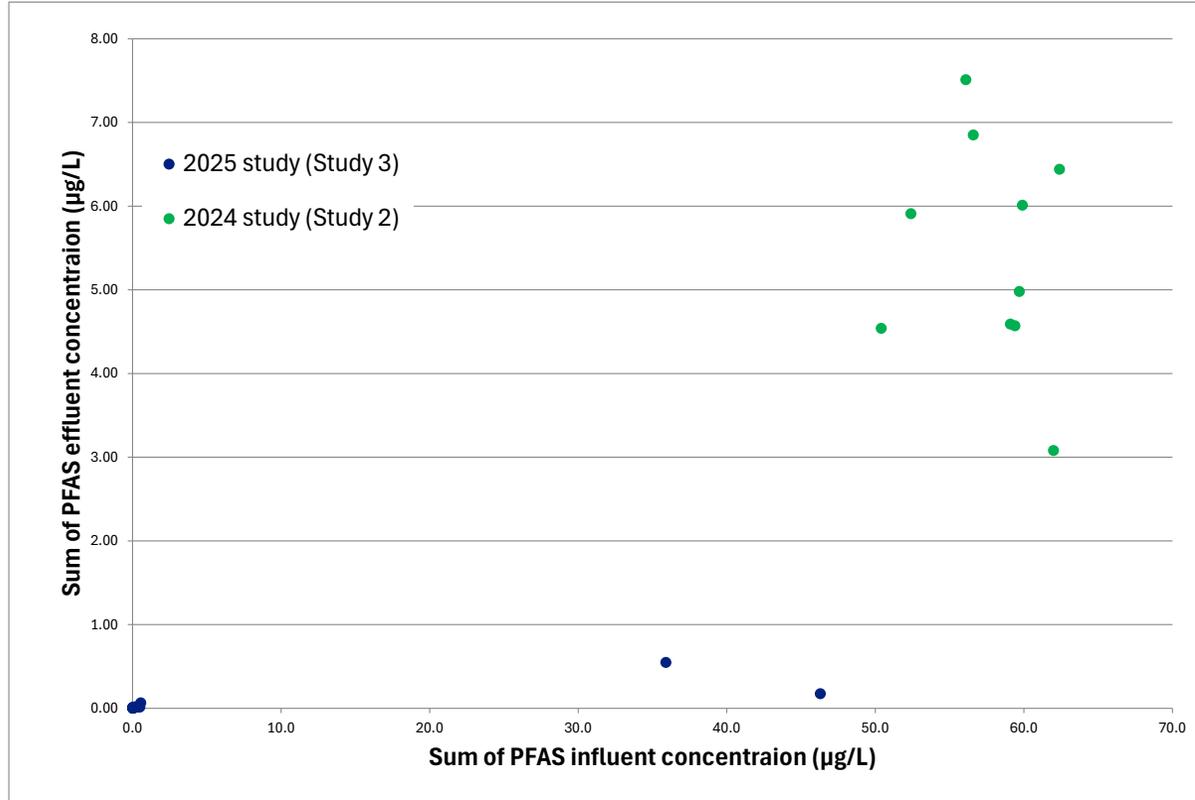


Field-scale testing – study 3 (2025)

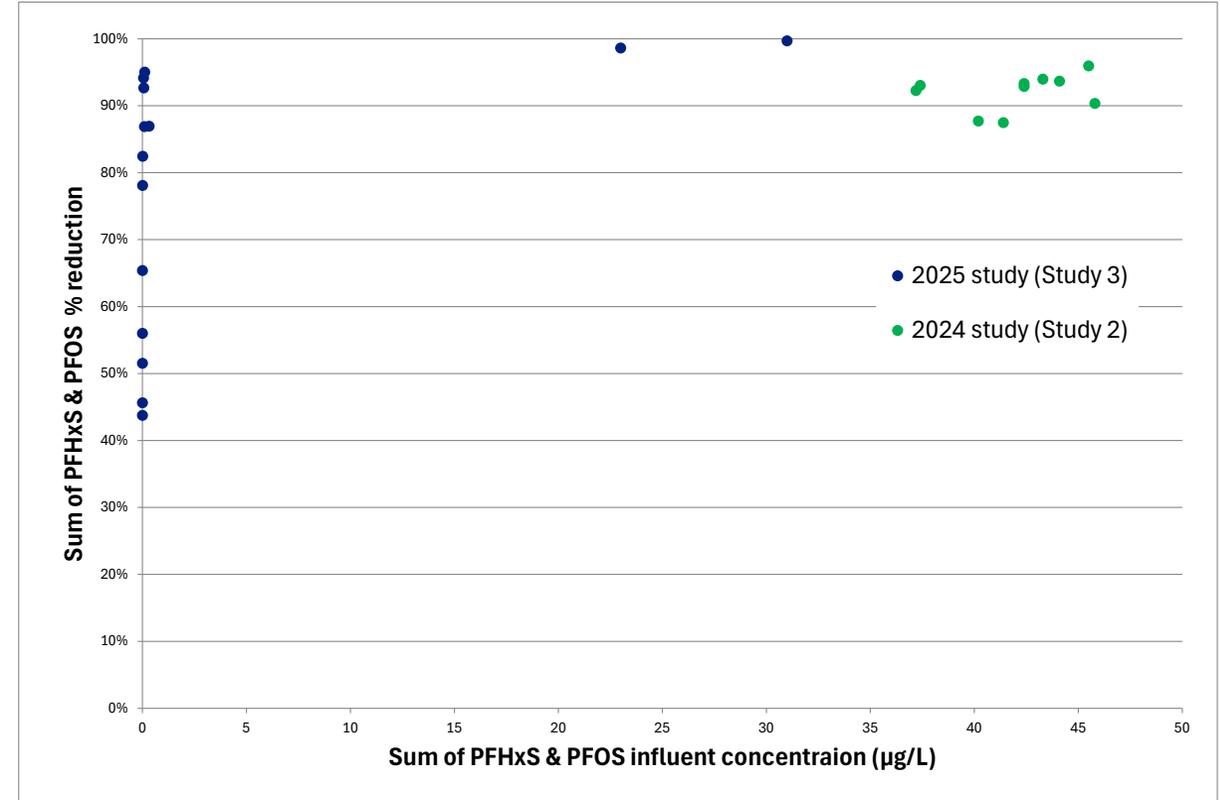
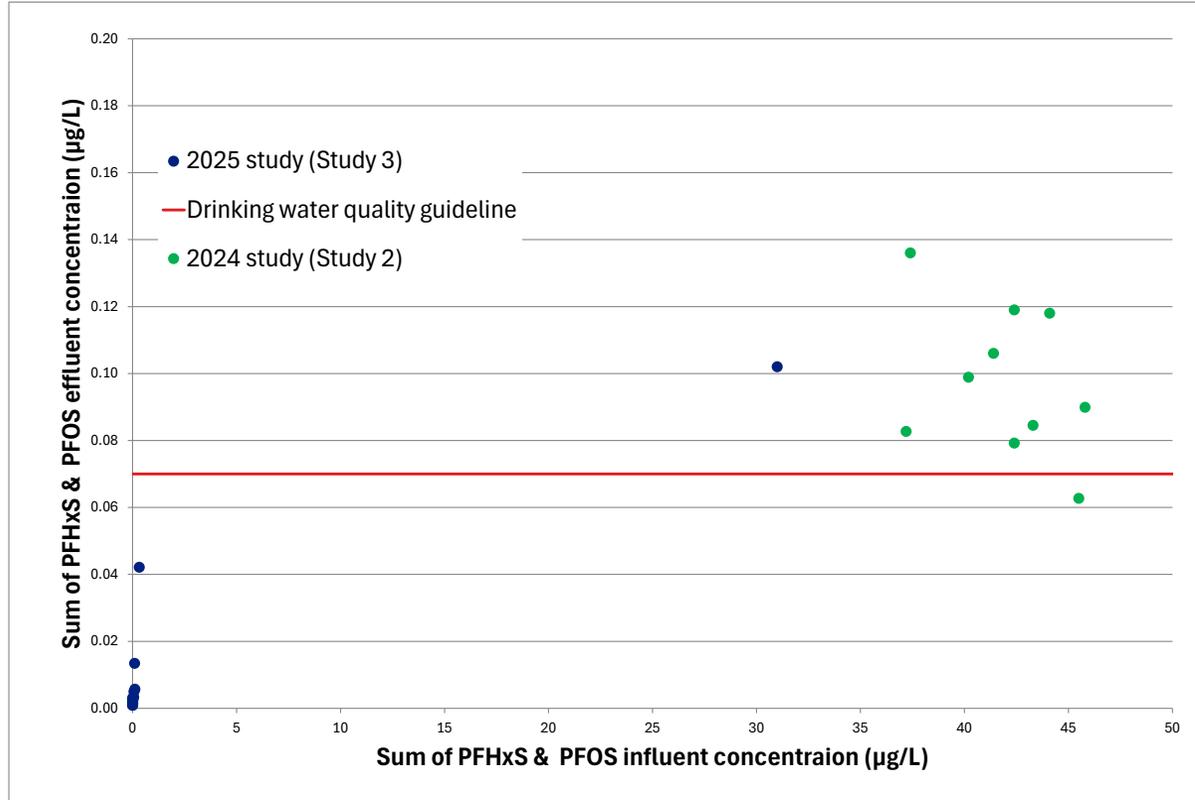
- ⦿ Pre-treatment of flows (by Jellyfish®)
- ⦿ 'Bed volume' defined by StormFilter (70L of media)
- ⦿ 3000 litres of water (42 bed volumes) treated
- ⦿ Operated & monitored in July 2025
- ⦿ Manually sampled
- ⦿ 28 sampling events collected & preserved
- ⦿ 14 events analysed by ALS



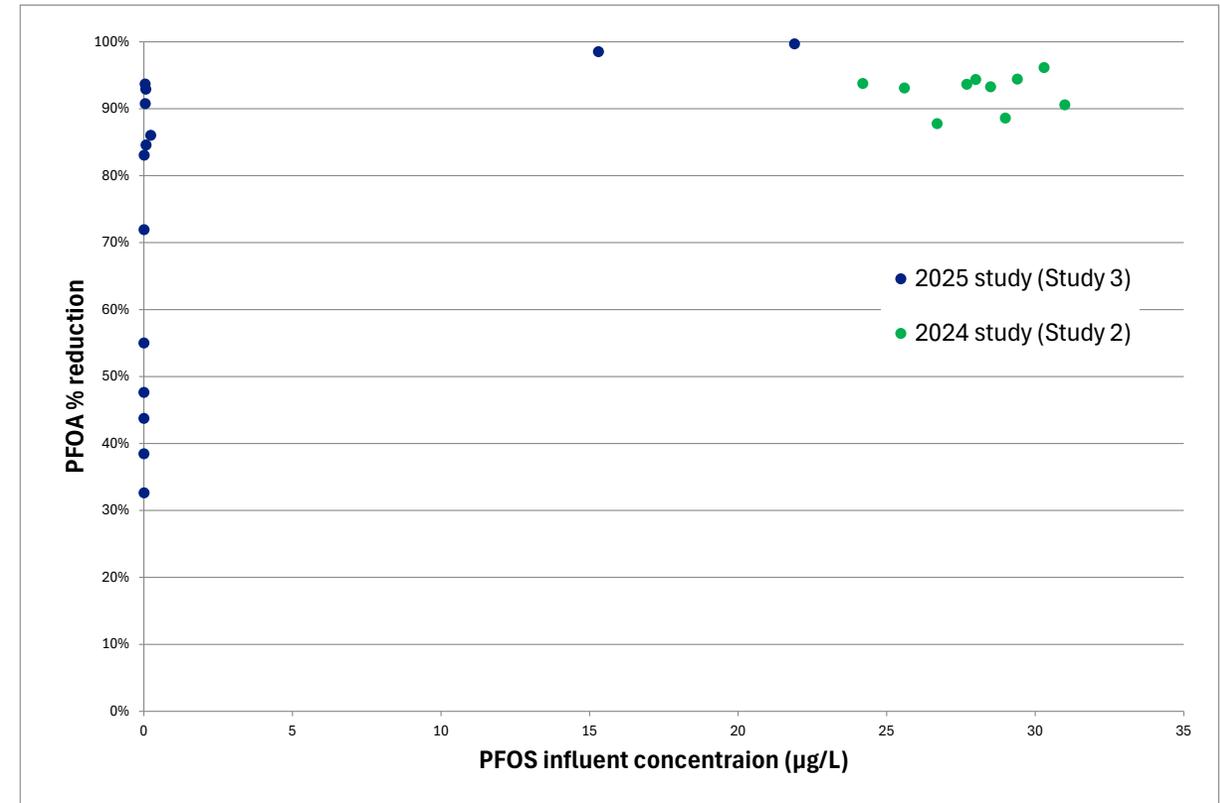
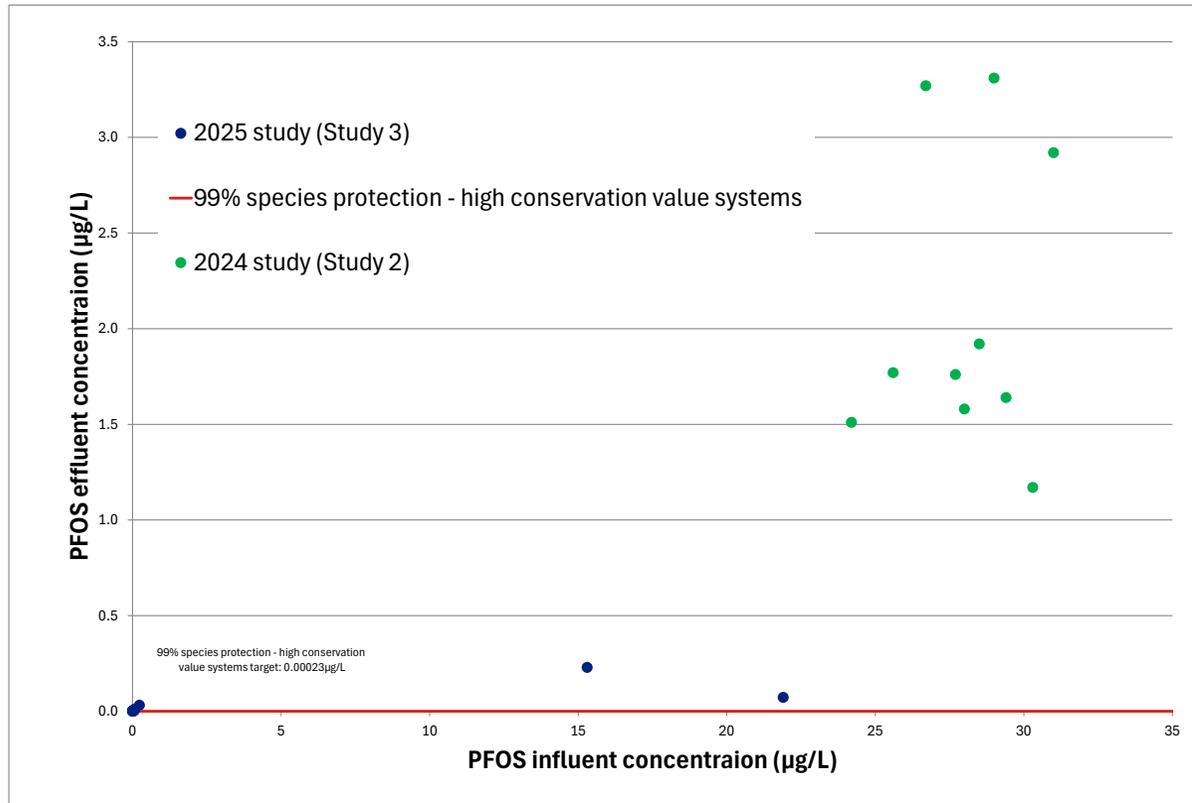
Study 3 Results – Sum of PFAS



Study 3 Results – Sum of PFOS & PFHxS



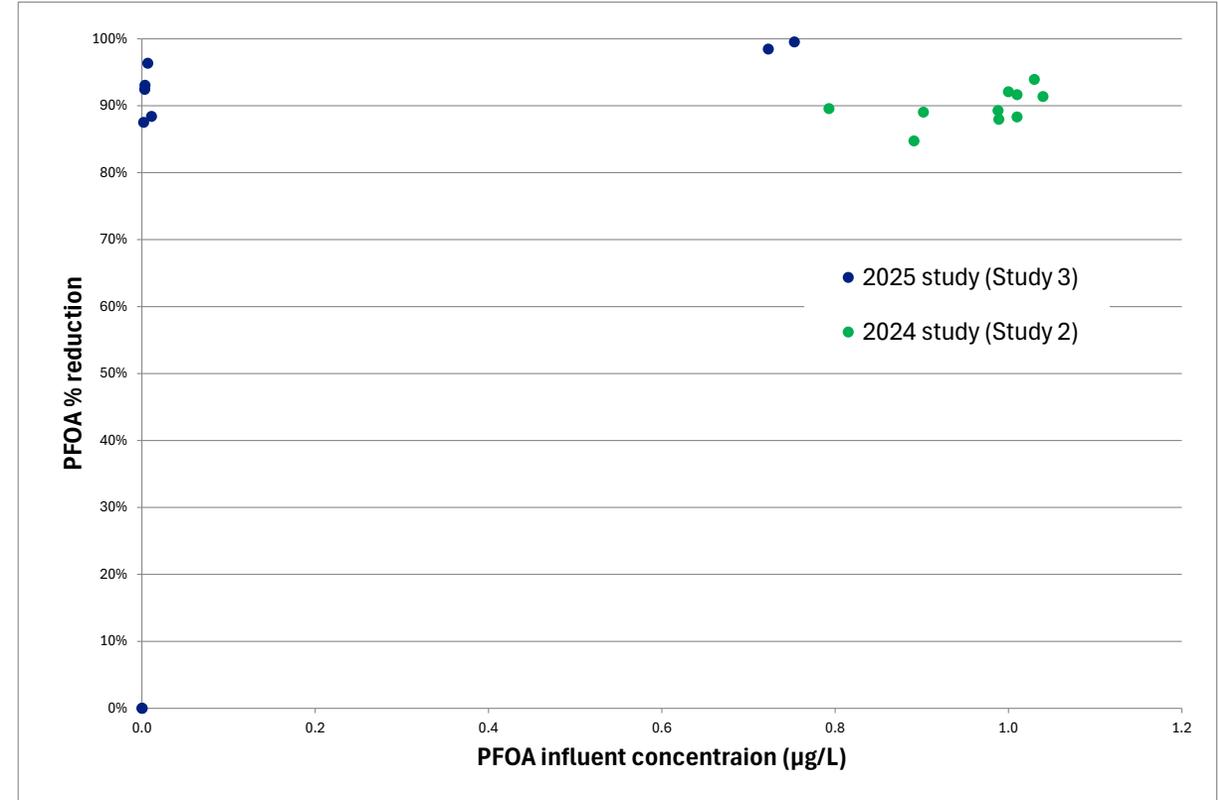
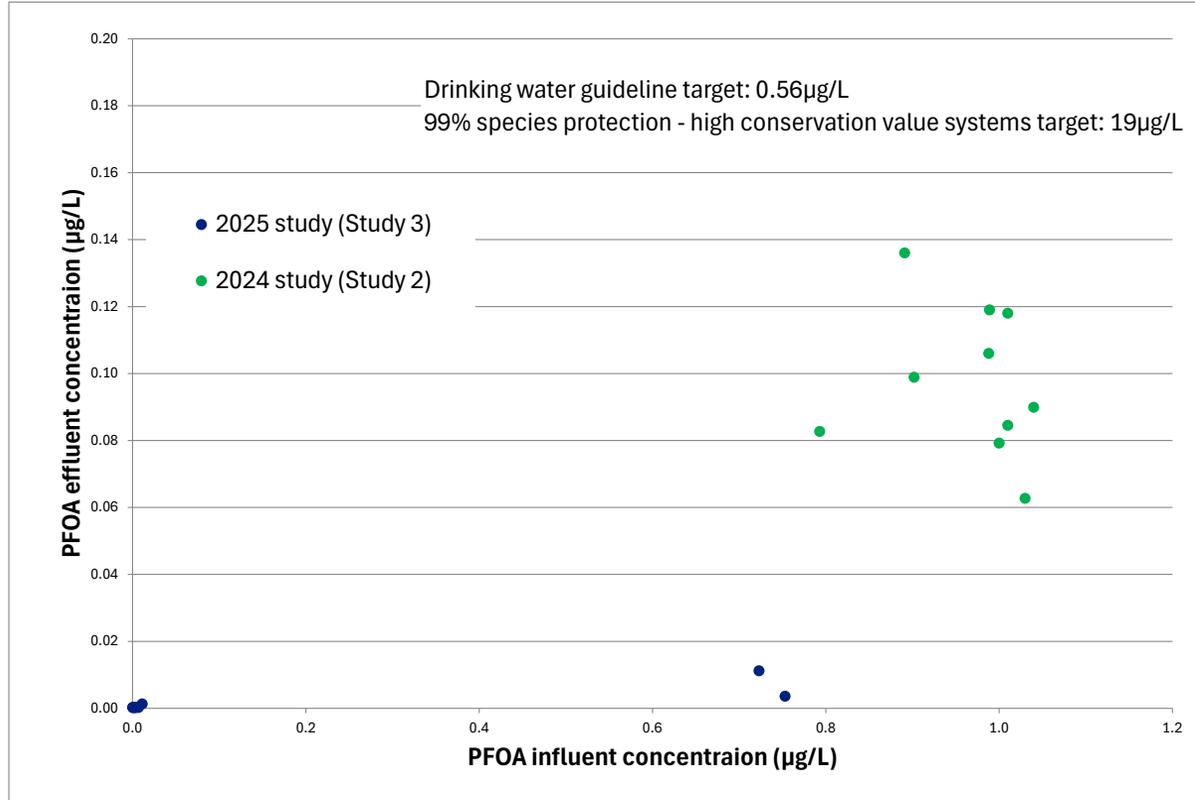
Study 3 Results – PFOS



Lowest effluent concentration = 0.0009 µg/L

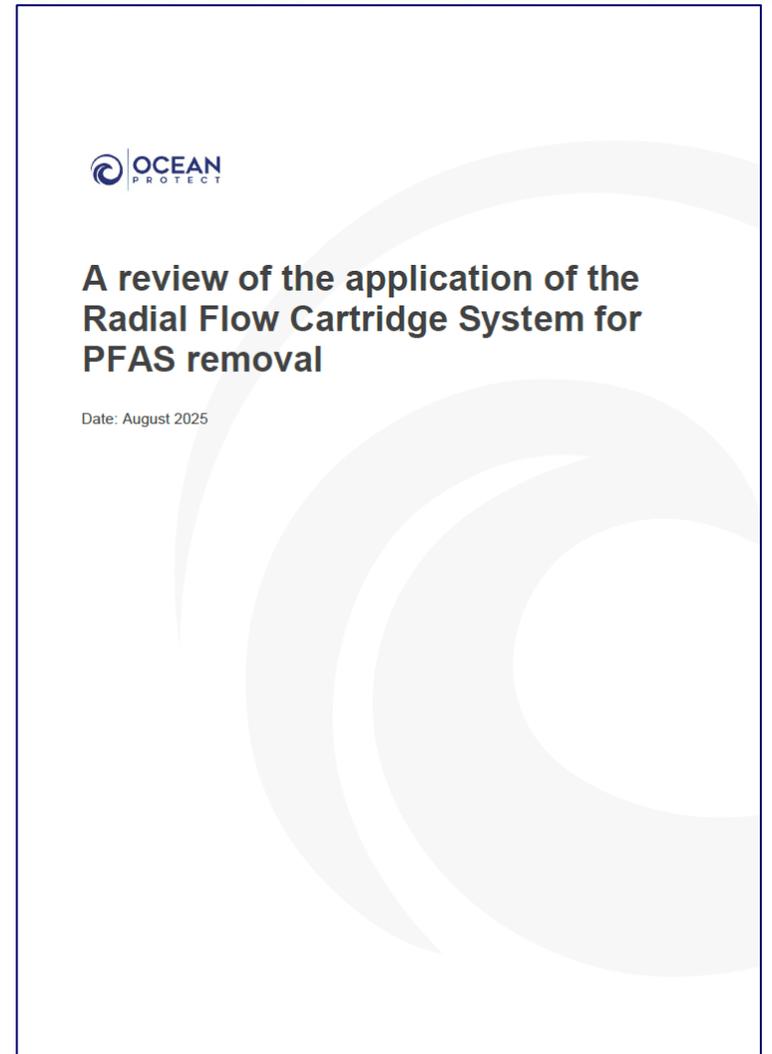
- Above the NEMP (2023) "Ecological water quality guideline" value for "99% species protection - high conservation value systems" for PFOS of 0.00023 µg/L.

Study 3 Results – PFOA



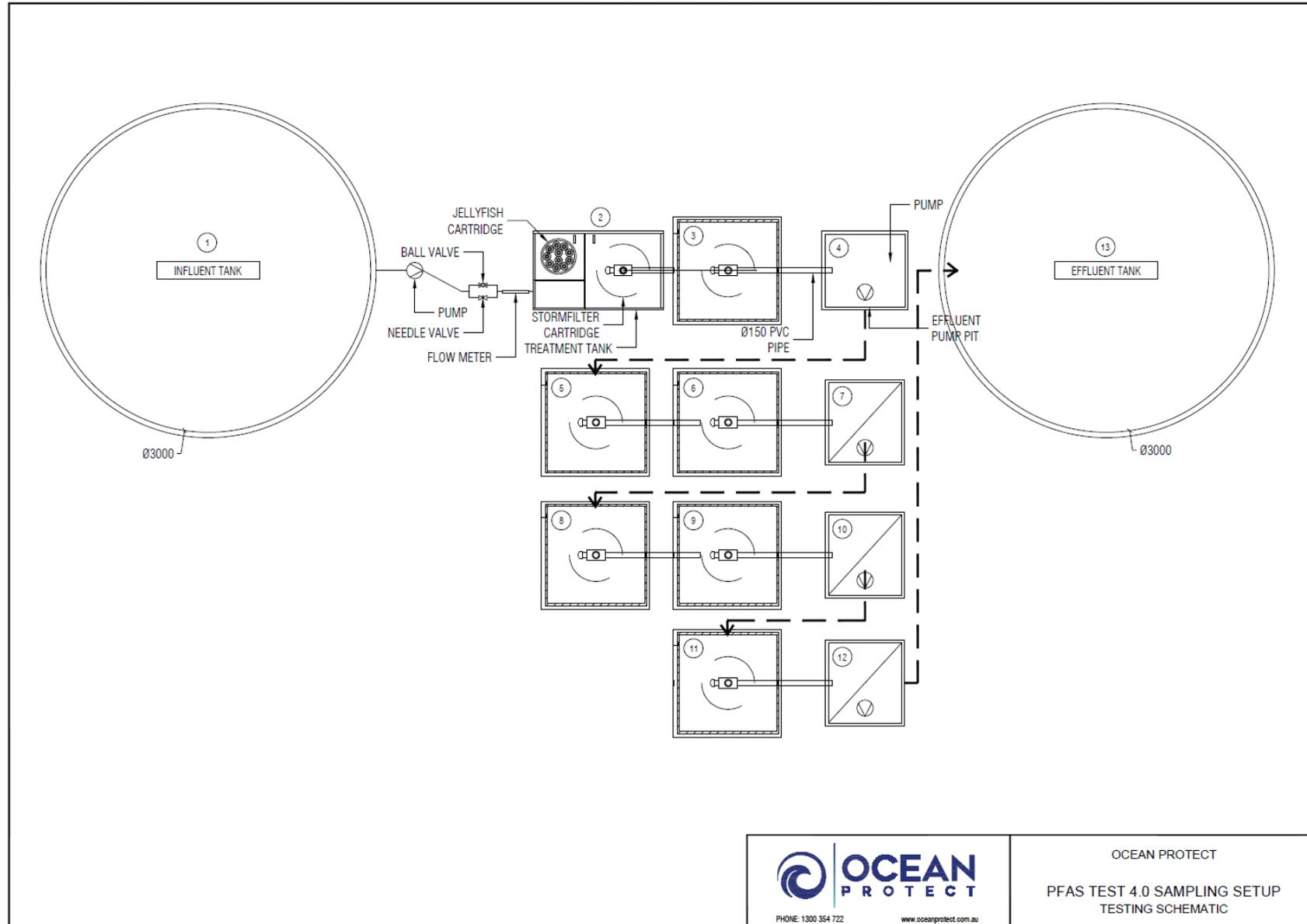
Summary of field study findings

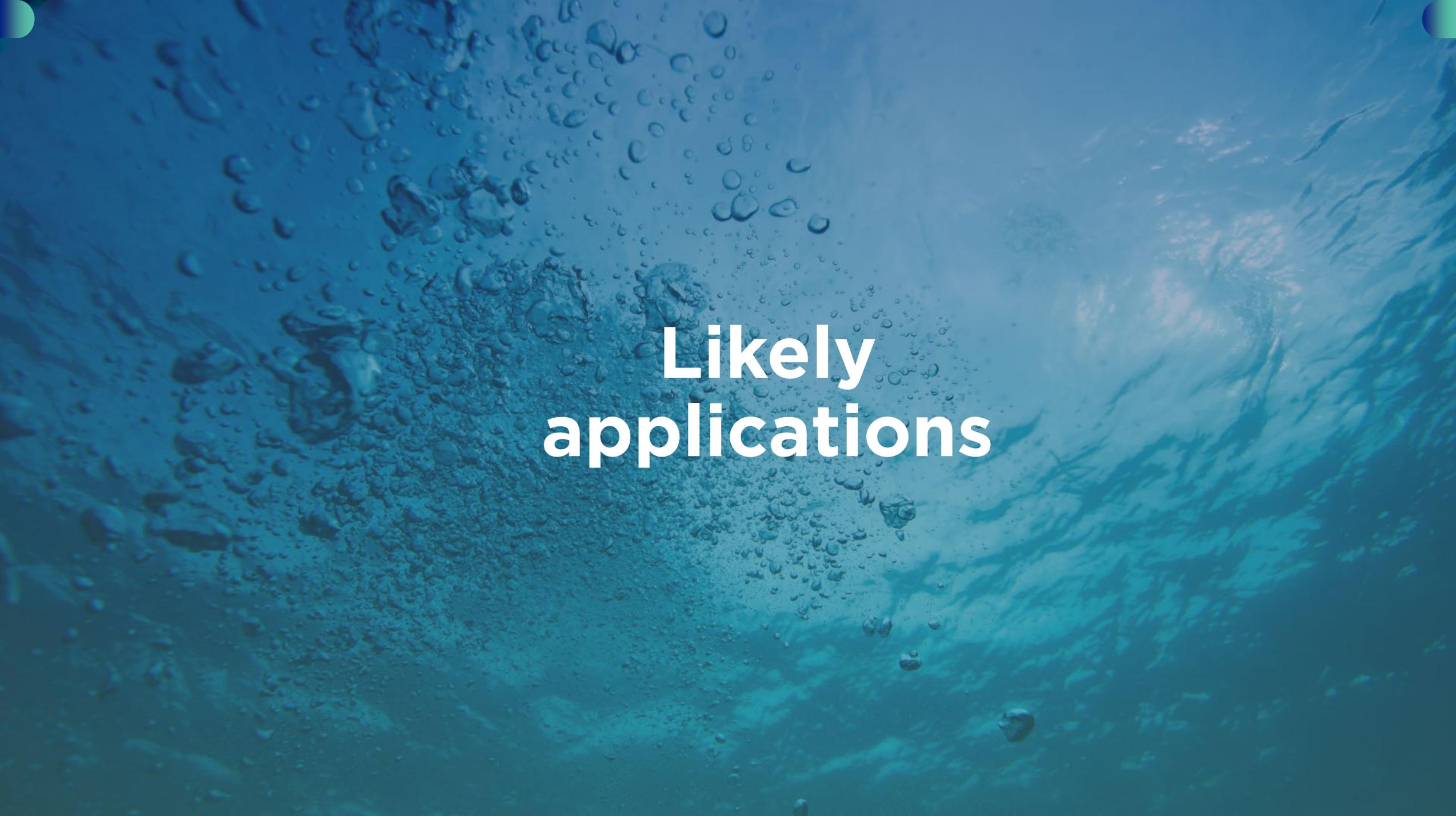
- ② All 3 field studies show high PFAS removal rates
- ② PFAS removal rates generally lower at lower influent concentrations
- ② Lowest effluent concentration observed for PFOS, Sum of PFHxS and Sum of PFAS observed was 0.0009 µg/L
 - Above the NEMP (2023) “Ecological water quality guideline” value for “99% species protection - high conservation value systems” for PFOS of 0.00023 µg/L.



Report available at:
www.oceanprotect.com.au/radflow-pfas-filter

Field-scale testing – study 4 (2026)



An underwater scene with numerous bubbles rising from the bottom and light rays filtering down from the surface. The water is a deep blue color.

Likely applications

Likely applications

- © Treatment of PFAS-contaminated surface waters
 - Military bases
 - Airports
 - Fire-training facilities



An underwater scene with a blue color palette. The water is filled with numerous bubbles of various sizes, some rising and some falling. Light rays are visible, creating a shimmering effect. The overall atmosphere is serene and deep.

Considerations

Key considerations

- ④ Incoming flow characteristics
 - PFAS concentrations/ loads & types
 - Solids concentrations/ loads
 - pH, fluoride, organic carbon, nitrogen
 - Flow rates, volumes
- ④ Site hydraulics
- ④ Water quality objectives
- ④ Operation & maintenance

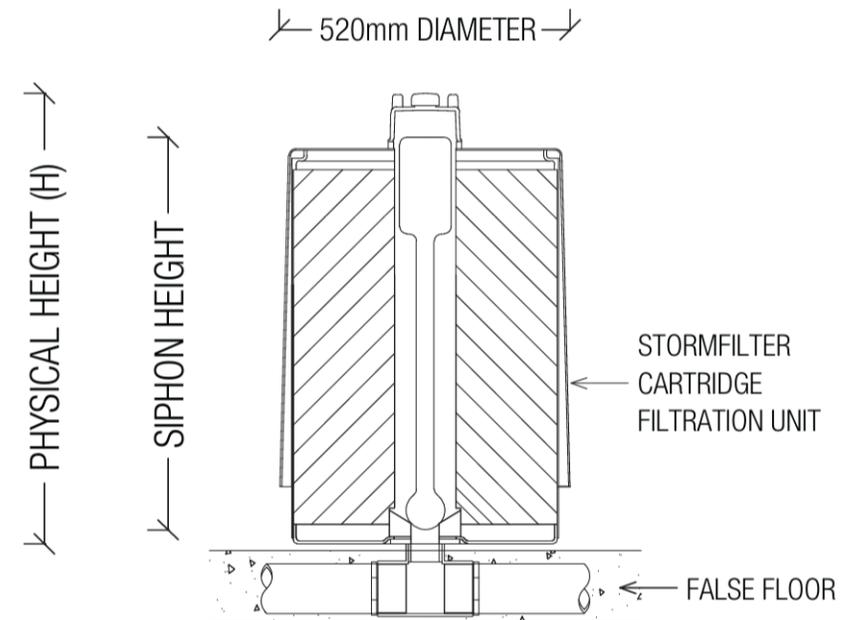


Cartridge dimensions

Cartridge name/ siphon height (mm)	690	460	310
Physical height (mm)	850	600	600
Typical weir height from outlet (mm)	920	690	540
Treatment flow rate (L/s) ¹	0.69	0.46	0.31
Approximate PFAS adsorptive capacity until end of “peak performance period” (grams) ²	3.02	2.01	1.34

1: Treatment flow rates apply a consistent peak flux of 0.66 L/s/m² – consistent with all laboratory and field-scale studies to date

2: From Dalrymple et al (2023)



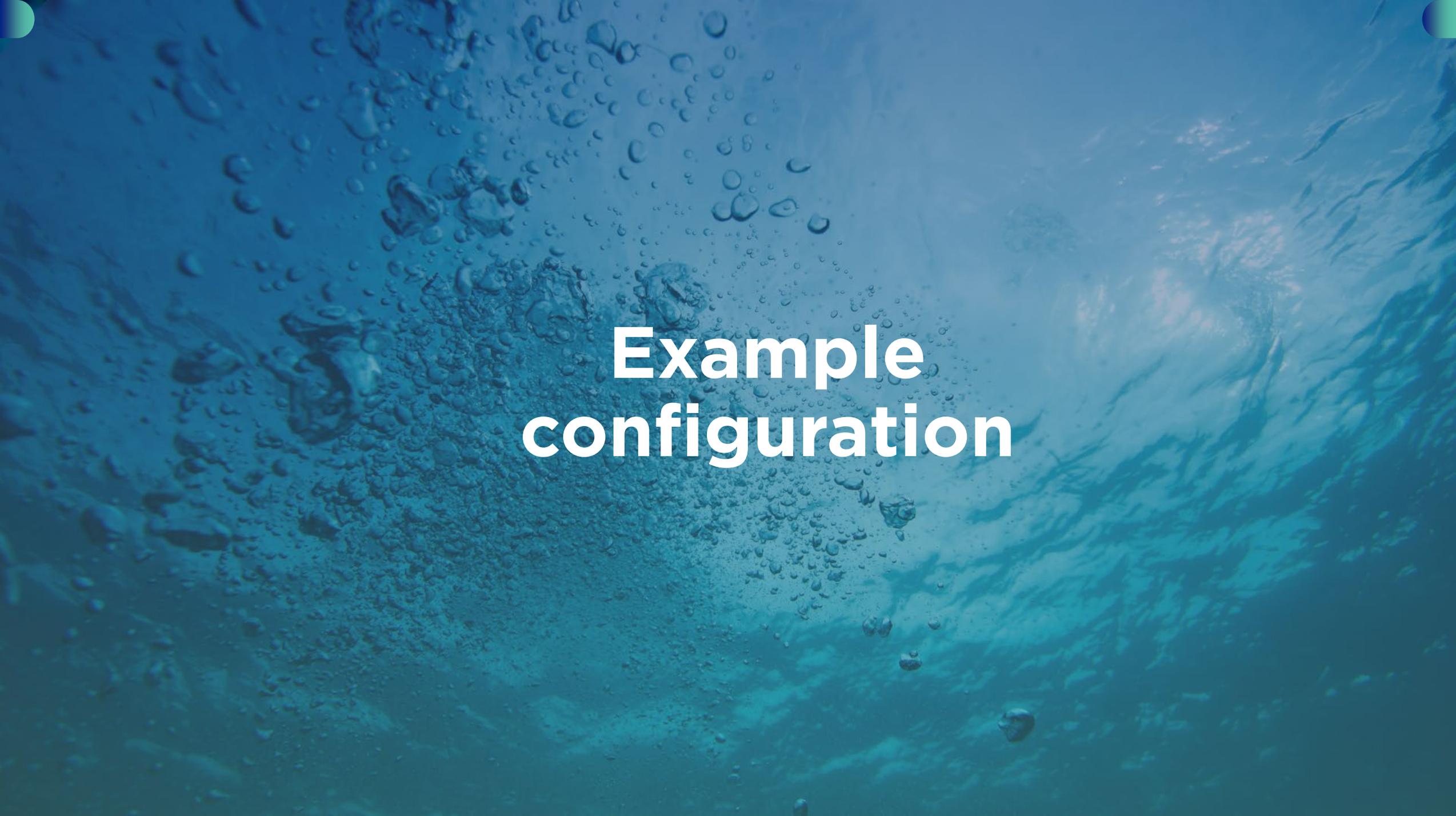
An underwater scene with a blue-green color palette. Numerous bubbles of various sizes are visible, rising from the bottom towards the surface. Light rays penetrate the water, creating a shimmering effect. The overall atmosphere is serene and clean.

Key advantages

Key advantages

- ④ Turn-key solution
- ④ Passive
- ④ Underground
- ④ Multiple 'pass' possible
- ④ Remote monitoring
- ④ Independently authored O&M guidance & SWMS's
- ④ Easy integration
- ④ Lower costs

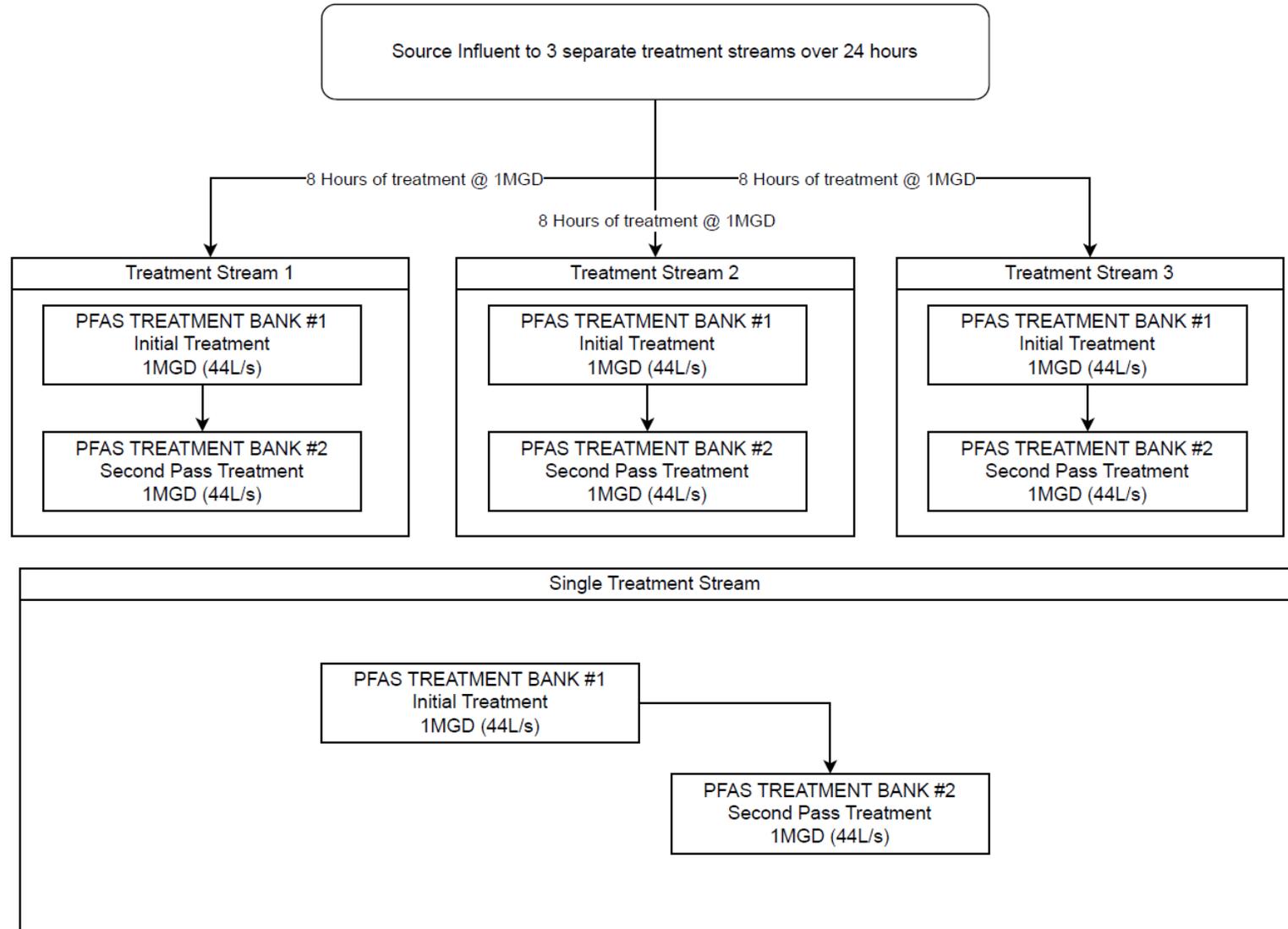


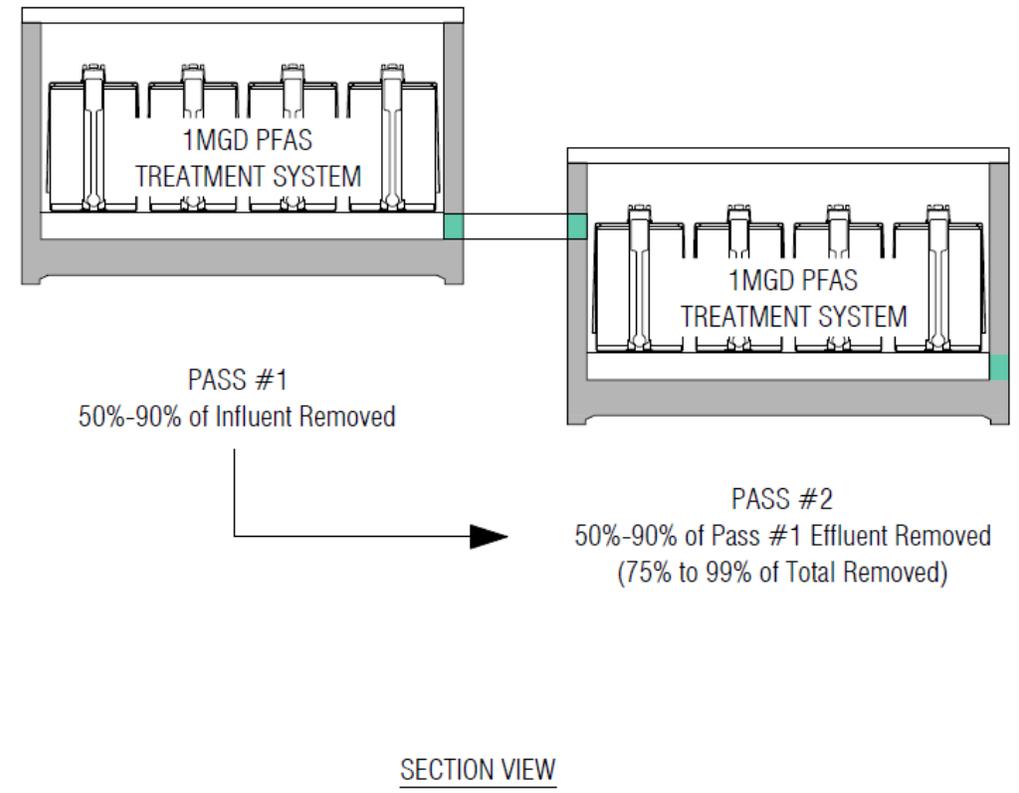
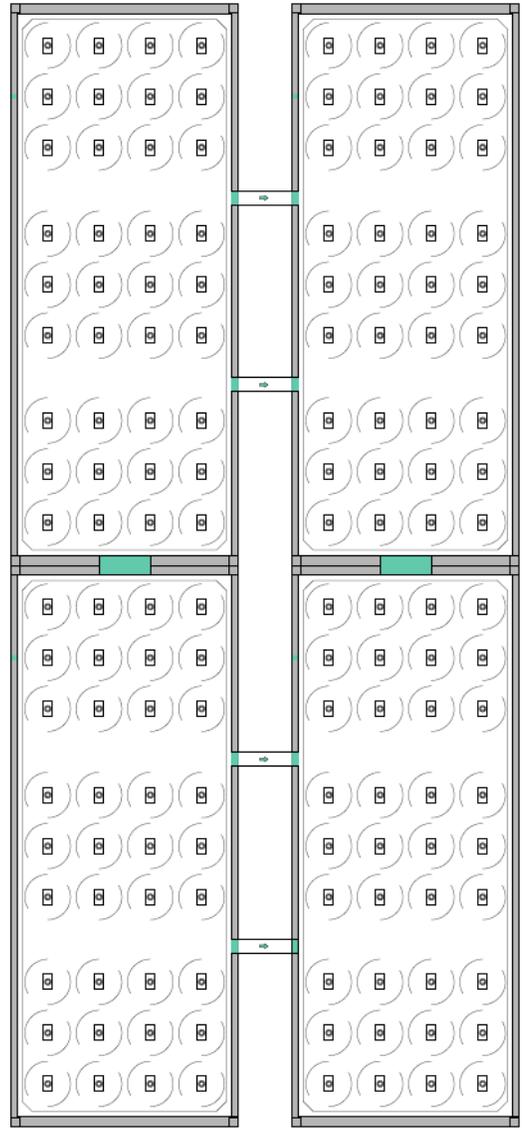
The background is an underwater scene with a blue color palette. It features numerous bubbles of various sizes rising from the bottom, and light rays filtering down from the surface, creating a shimmering effect. The overall atmosphere is serene and aquatic.

Example configuration

432 PFAS Filter cartridges

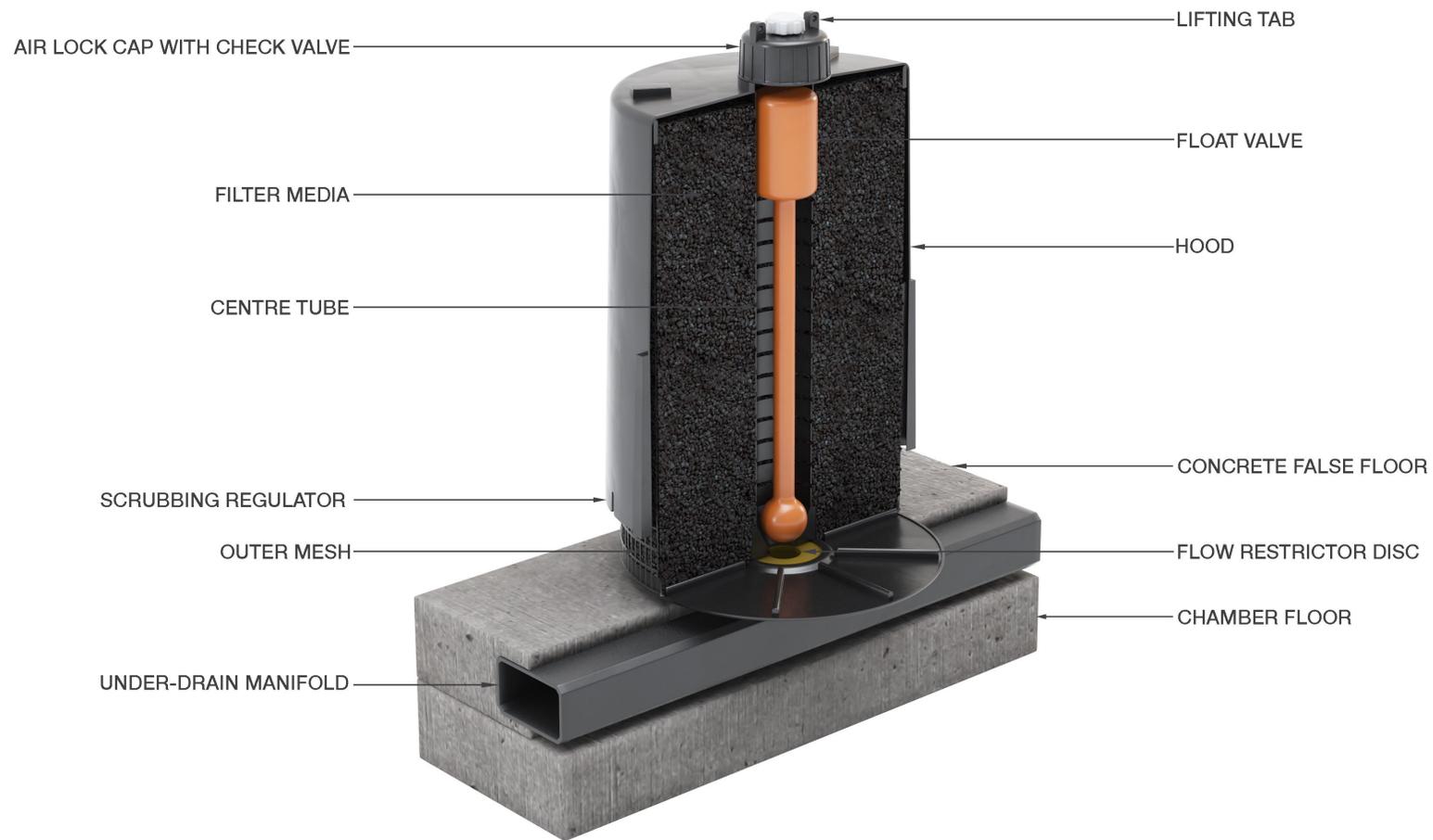
- 3 "streams"
- 2 "banks" per "stream"
- 72 cartridges/ bank





Example - Brisbane, QLD







www.oceanprotect.com.au

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