

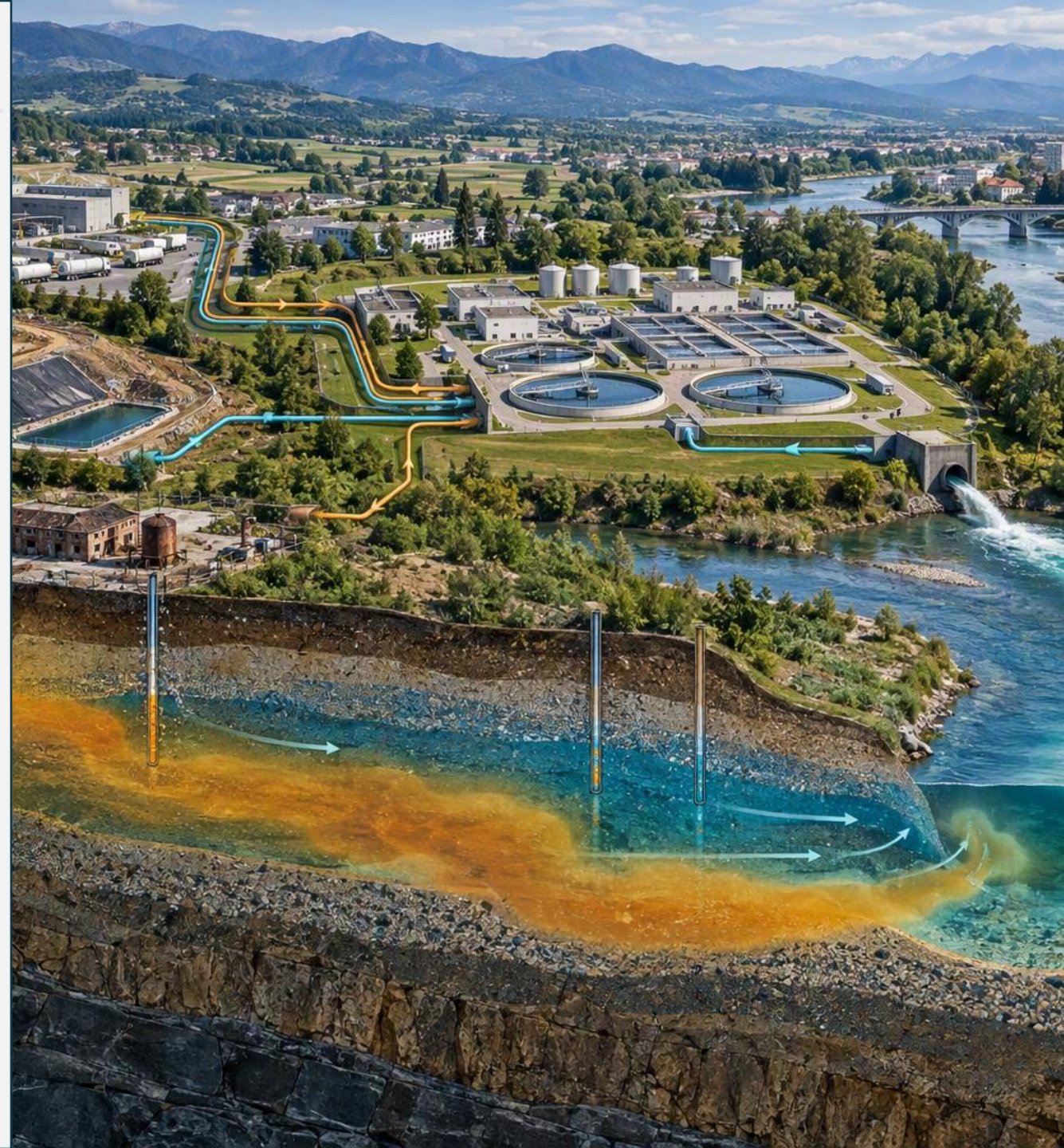
PFAS Management Under the Emerging EU Water and Wastewater Framework

From WWTP Monitoring to Conceptual Site Models

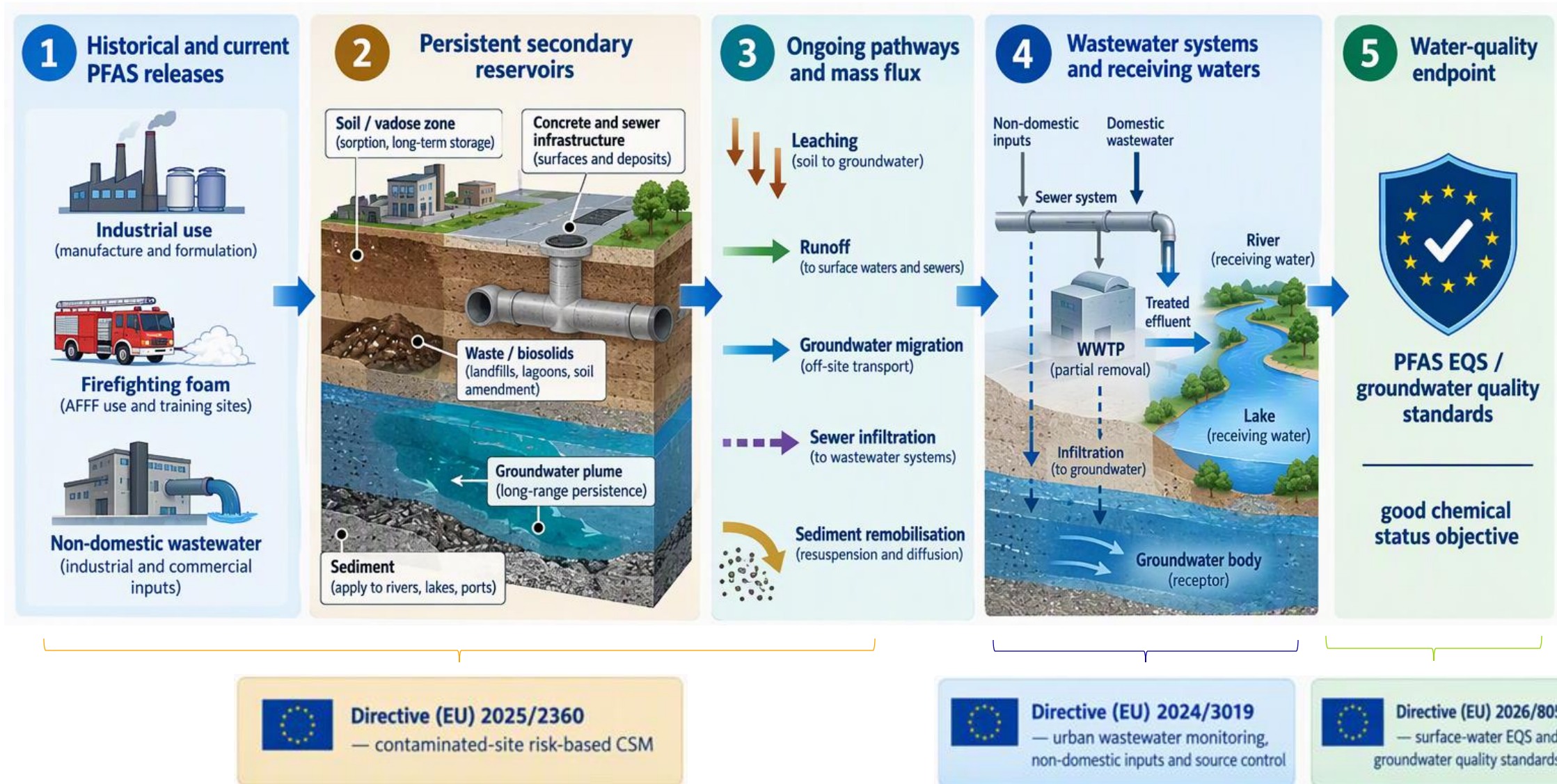


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Soil and Groundwater Management and Sustainable Remediation
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Stopping the release does not stop the PFAS flux



A historical release can remain a current source of PFAS loading.

Directive EU 2024/3019 — Urban wastewater

- Collecting systems and WWTPs
- PFAs monitoring
- Quaternary treatments
- Risk-based approach
- Receiving-water protection

Not a PFAS removal targets
No EPR PFAs obligations

1 July 2027 Transposition into national law
2033-2045 Q Treatments

Directive EU 2025/2360 — Supporting CSM

- Potentially contaminated sites
- Risk-based assessment
- Source–pathway–receptor logic
- Conceptual site models

No harmonised EU PFAS soil
clean-up value.

26 November 2028 Transposition into national
law

Directive EU 2026/805 — Water-quality endpoint

- Groundwater PFAS quality standards
- Surface-water PFAS EQS
- Biota EQS
- Chemical-status objectives

Receptor standards—not automatic
soil targets.

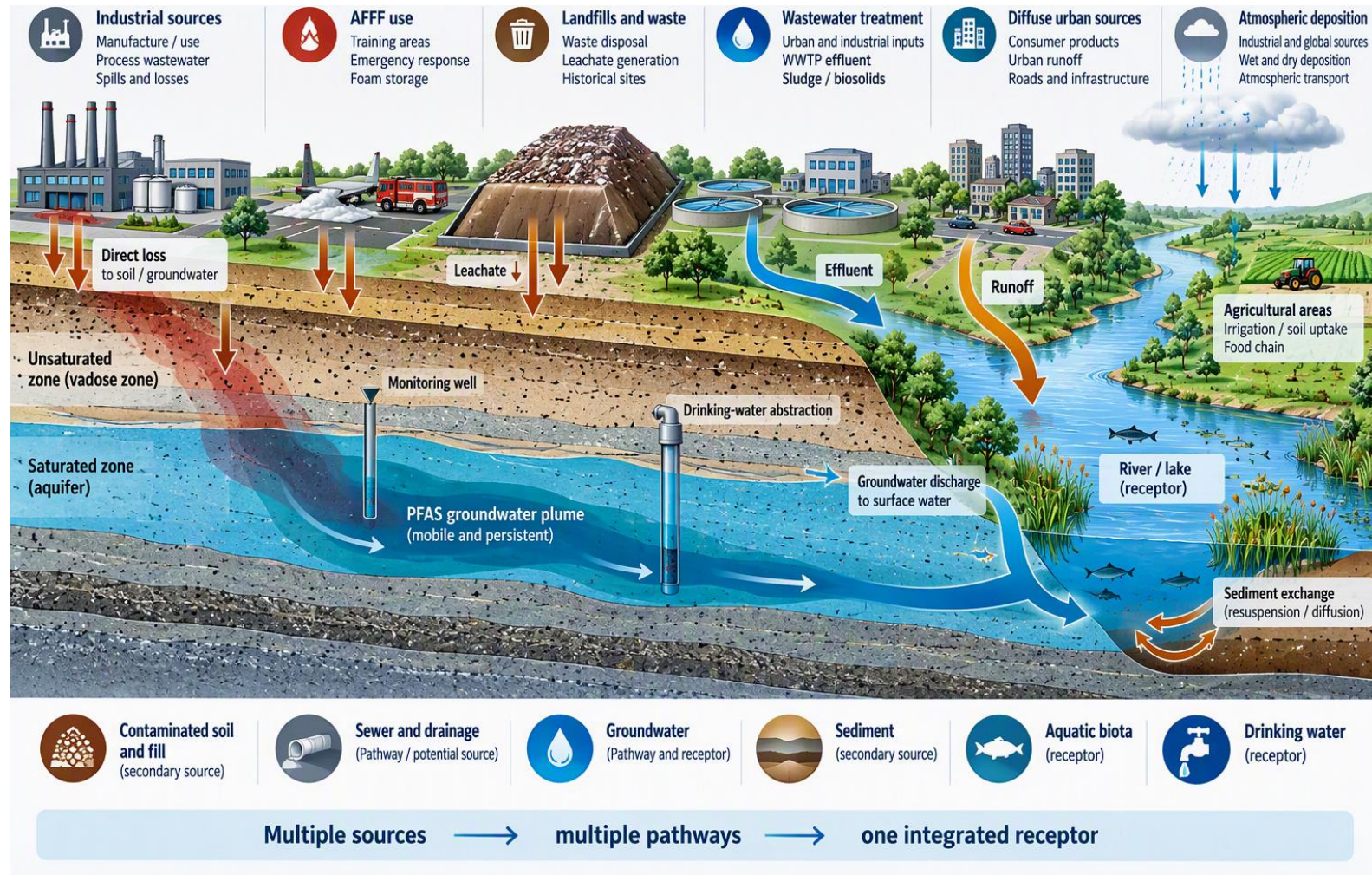
21 Decembre 2027 Transposition into national
law

PFAS Environmental standards

RECEPTOR	METRIC	STANDARD	ASSESSMENT BASIS	COMPONENTS / METHOD
GROUNDWATER	Σ PFAS	0.10 µg/L	Annual-average QS	Arithmetic sum of 20 PFAS; value imported from Directive (EU) 2020/2184
GROUNDWATER	Σ4 PFAS	0.0044 µg/L	Annual-average QS	PFHxS + PFOS + PFOA + PFNA; total concentration of substances/isomers
SURFACE WATER	Σ25 PFAS	0.0044 µg/L	AA-EQS (inland + other waters)	Σ(concentration × compound-specific RPF), expressed as PFOA equivalents
BIOTA	Σ25 PFAS	0.077 µg/kg wet wt	Biota EQS	Same potency-weighted PFOA-equivalent method; MAC-EQS is not applicable

The receptor integrates every source

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Water-body condition
reflects cumulative loading

WWTP effluent/sludge

Historical groundwater plume

Direct releases

Diffuse runoff / deposition

Sediment and bank exchange

WHAT MONITORING CAN SHOW

Concentration

Flow-normalised load

Temporal pattern

Treatment partitioning



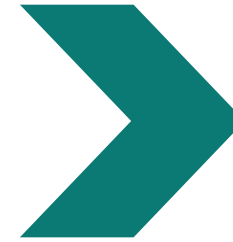
WHAT IT CANNOT PROVE ALONE

Exact source location

Release mechanism

Hydraulic connection

Relative receptor contribution



THE CSM QUESTION

Which source and pathway are controlling PFAS loading at the receptor?

PRIMARY RELEASE PROCESS

What first introduced PFAS?

Industrial use • AFFF application • wastewater discharge • waste placement • land application • emissions



SECONDARY SOURCE / RESERVOIR

Where is PFAS mass retained now?

Soil • porous materials • waste • sewer deposits • sediment • contaminated groundwater



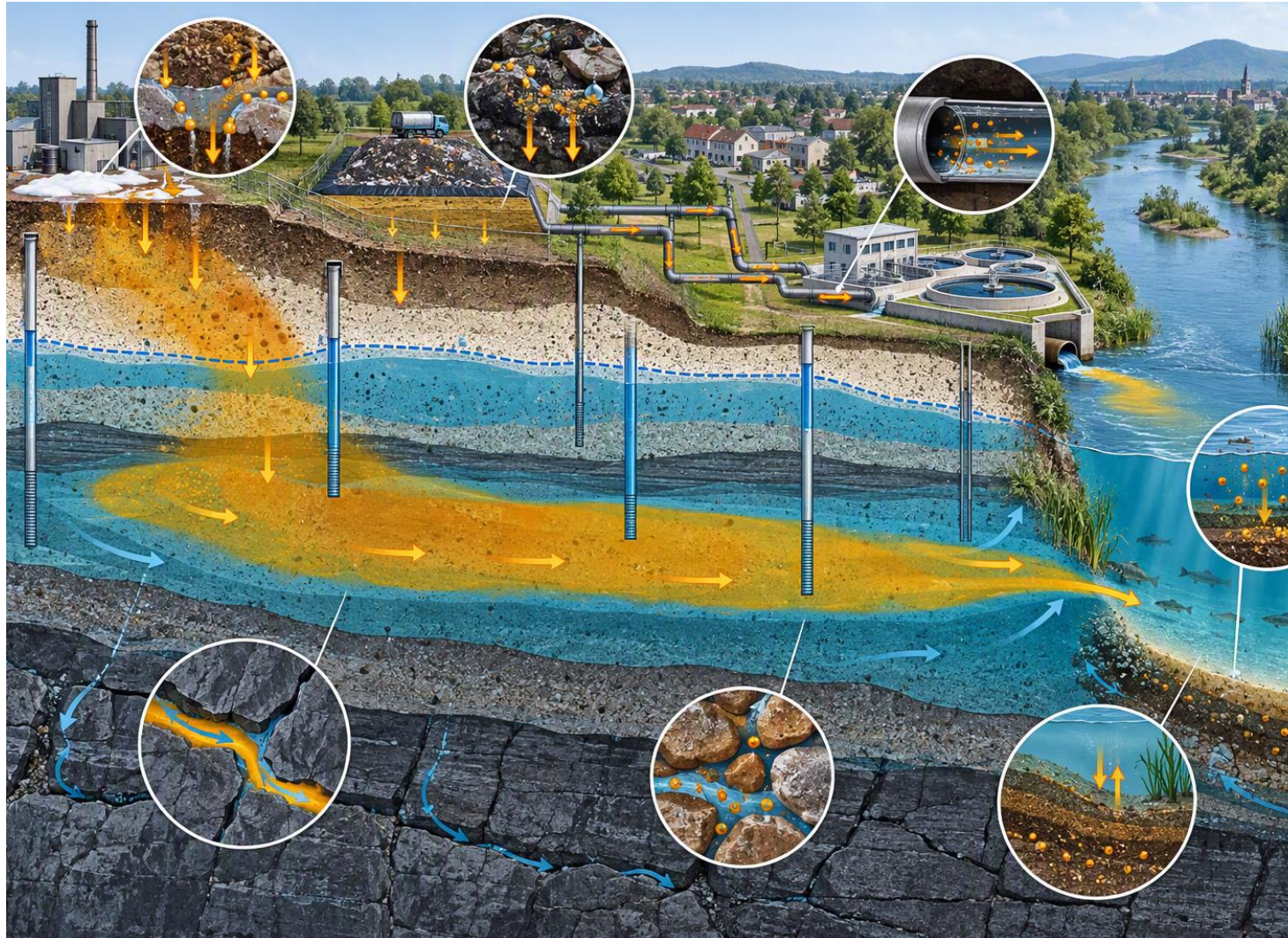
PATHWAY / CONDUIT

How does PFAS move?

Leaching • runoff • groundwater flow • sewers and drains • effluent • atmospheric deposition

Distributed sources

A release event can evolve into interacting subsurface reservoirs



Surface and infrastructure

Pavement • concrete • drains • shallow soil

Vadose zone

Retention on soil solids and air–water interfaces.

Capillary fringe

Fluctuating water levels can mobilise retained mass episodically.

Aquifer and matrix

Heterogeneity, low-permeability storage and back-diffusion prolong release.

Surface-water interface

Groundwater discharge and sediment exchange sustain receptor loading.

WHERE IS THE MASS?

Release history
Depth-discrete inventory
Porous materials and low-K storage

1

HOW DOES WATER MOVE?

Recharge and preferential flow
Hydraulic gradients
Seasonal and engineered controls

2

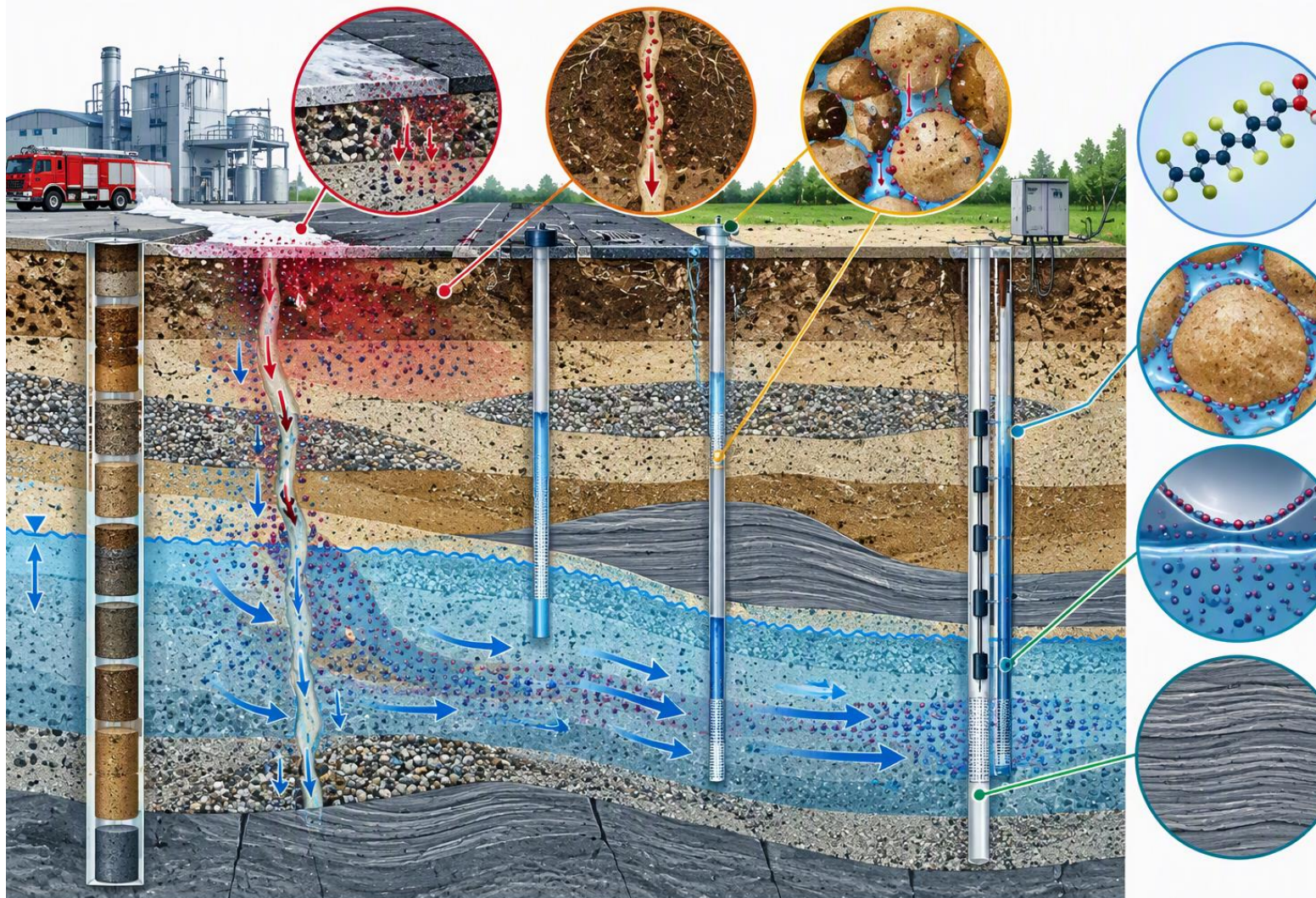
HOW MUCH MASS LEAVES?

Concentration $\times$ water flux
Source depletion or persistence
Loading to groundwater and receptors

3

A useful CSM must explain contaminant distribution and water movement together.

The vadose zone – multiple release pathways



Heterogeneous release history

Repeated spills, foam use, runoff and changing formulations

Preferential flow

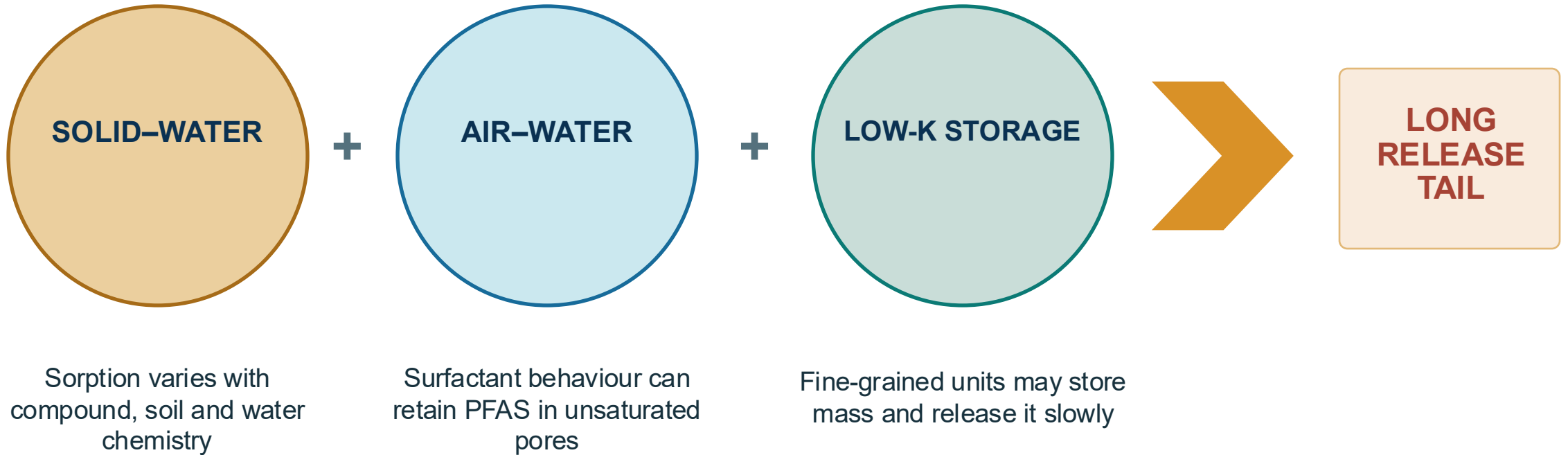
Macropores, fill contacts, fractures and drains bypass the matrix

Depth-discrete storage

Bulk shallow samples may miss deeper retained mass

Transient saturation

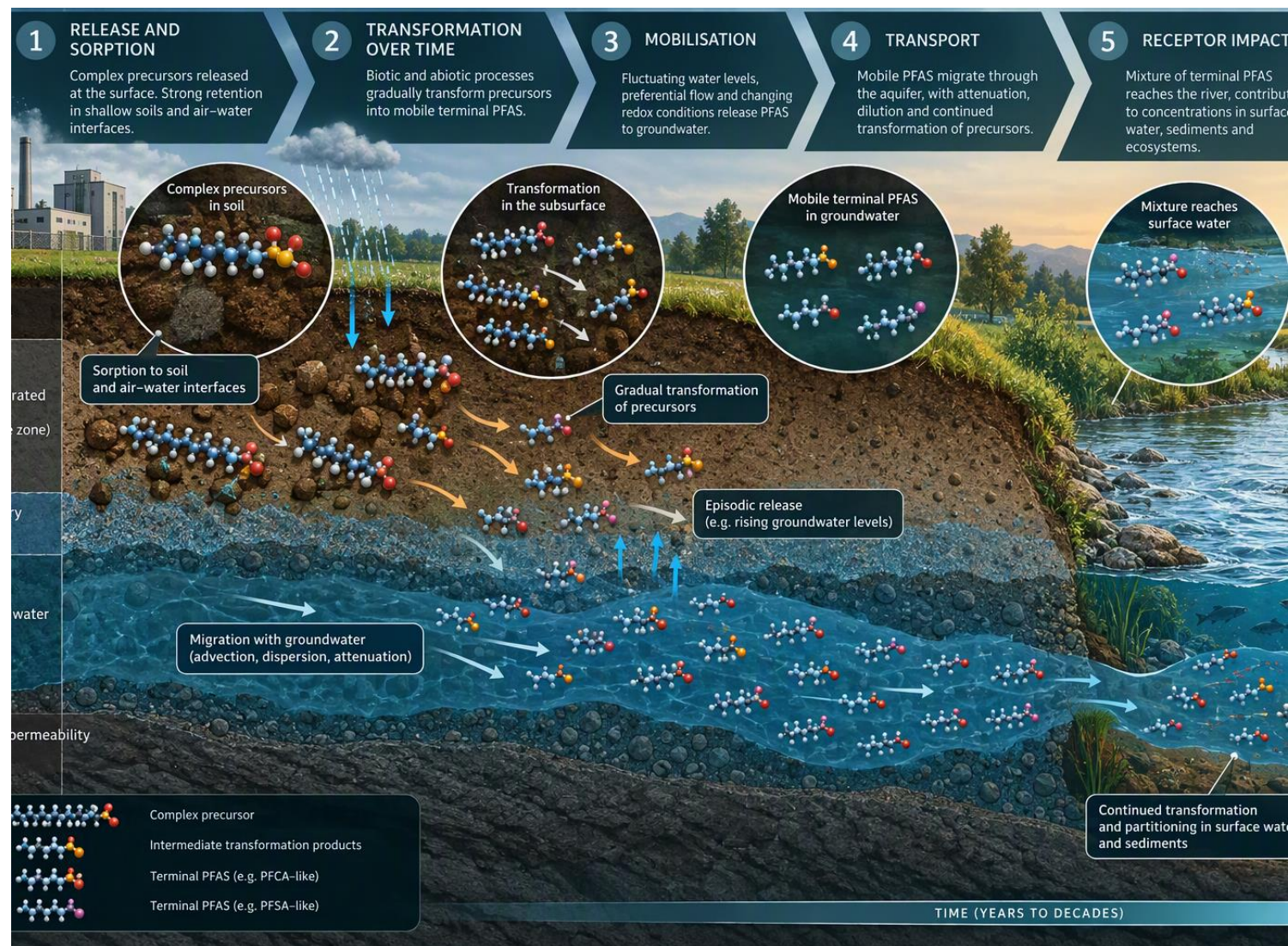
Recharge and water-table changes alter mobilisation



Retention can delay transport while preserving a source term for later mobilisation.

Precursors vs target PFAS

Targeted monitoring measures selected compounds, not the full future PFAS source term



Target analysis

Quantifies compounds included in the analytical list at sampling time.

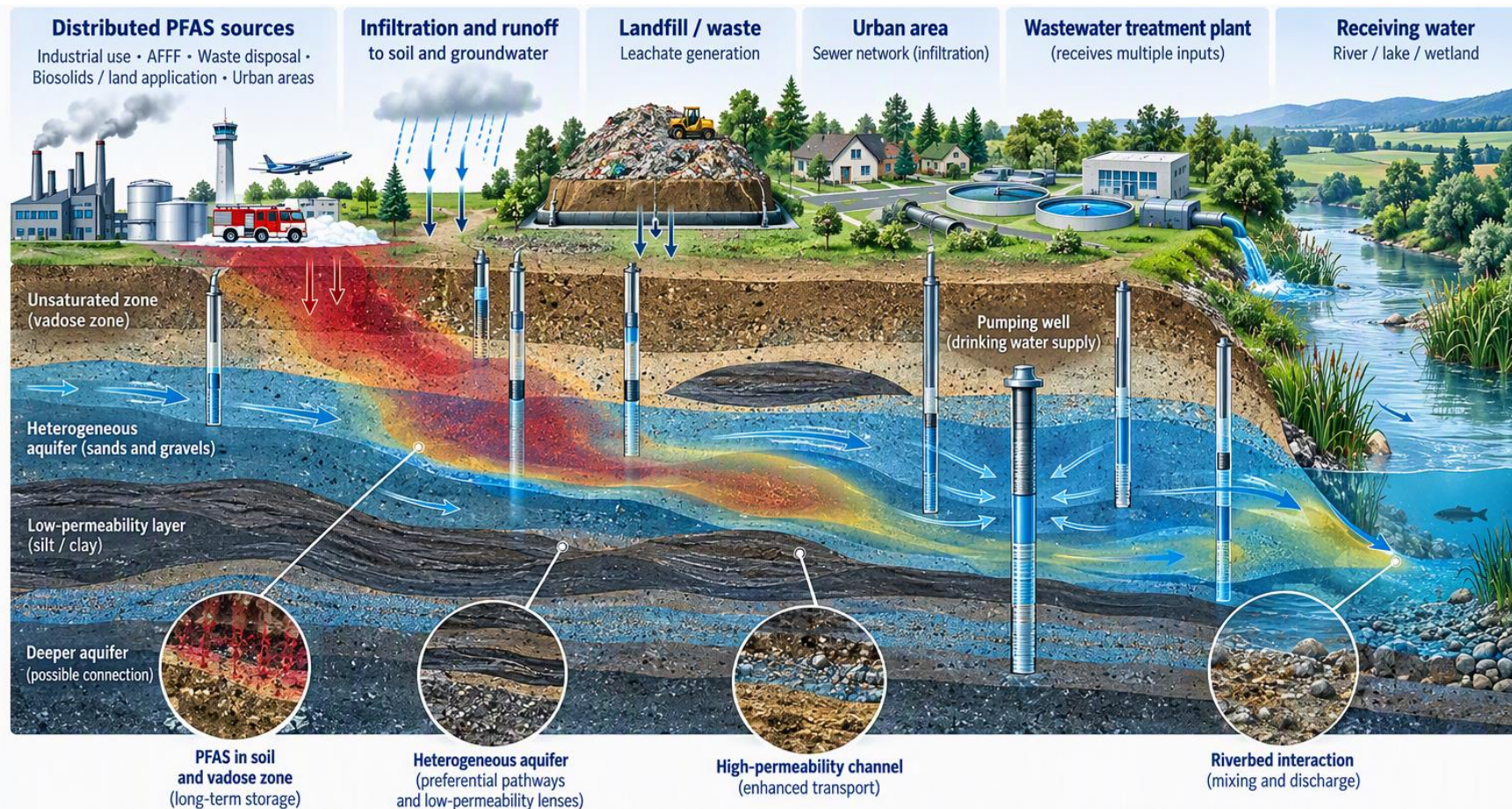
Precursor reservoir

Polyfluorinated compounds may remain outside a limited target list and transform over time.

Future terminal PFAAs

Transformation can generate persistent, mobile terminal compounds after the original release.

Measured now $\neq$ total fluorinated mass $\neq$ future PFAA load



Plume architecture

Vertical and lateral distribution may be strongly non-uniform

Hydraulic heterogeneity

A small part of aquifer thickness may carry much of the flow

Transient boundaries

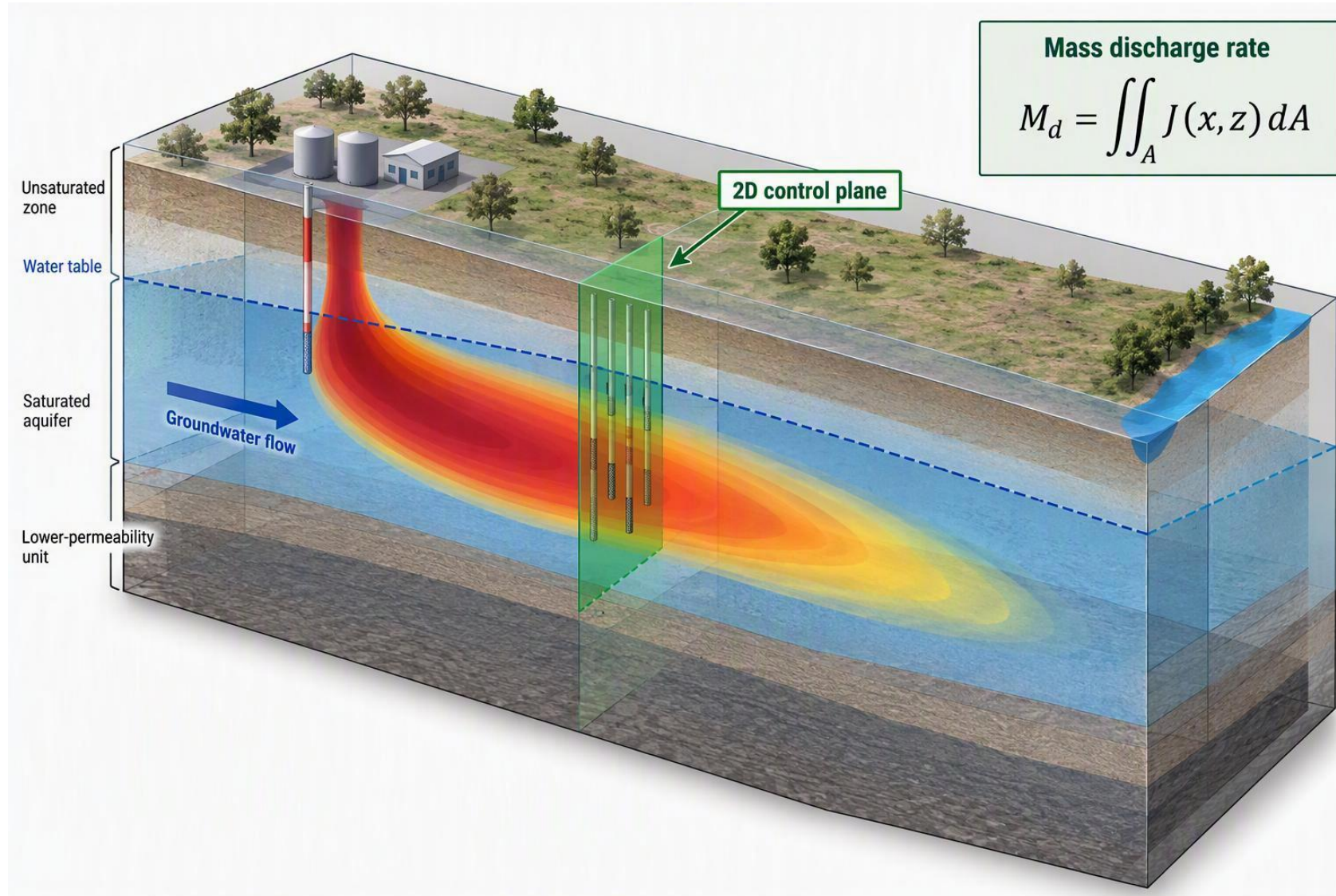
Pumping, river stage and recharge change gradients and discharge

Network design

Long screens can average concentrations and miss narrow pathways

Measuring PFAS mass and plume structure

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Better indicator of source strength

More meaningful measure of plume loading

Accounts for plume heterogeneity

Better remediation performance metric

Stronger link to receptor impacts

Example of application in a case study in New Mexico by Gray et al. 2025



Heads and gradients

Is groundwater gaining or losing at the river?

Discharge zones

Where does contaminated groundwater enter?

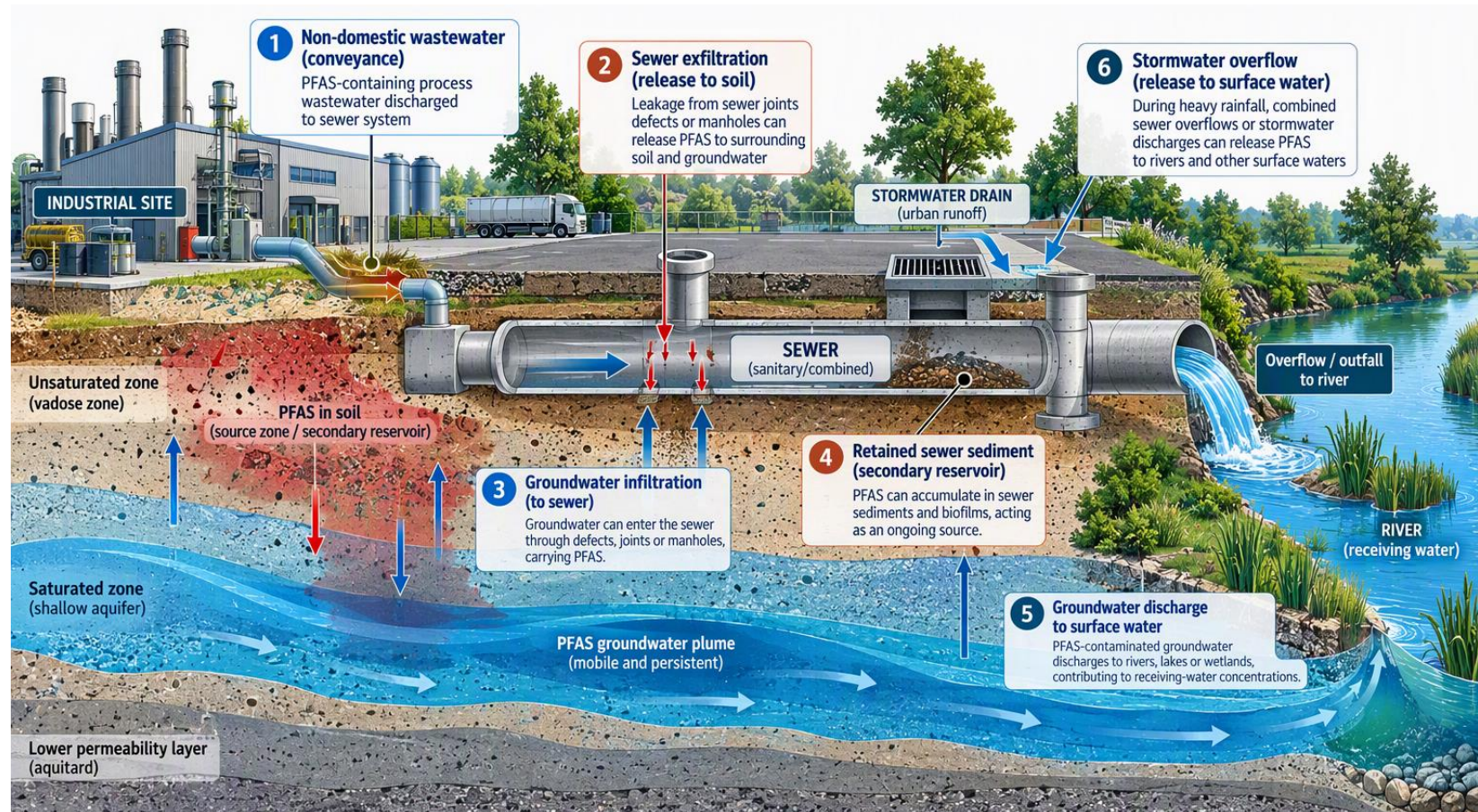
Temporal variability

How do river stage and recharge change flux?

Mixing and attenuation

What concentration and load reach the receptor?

A receptor sample shows the integrated outcome; it does not locate the contributing source zones.



Conduit

Carries non-domestic wastewater or contaminated runoff

Release mechanism

Exfiltration, defective joints, overflow or outfall

Secondary reservoir

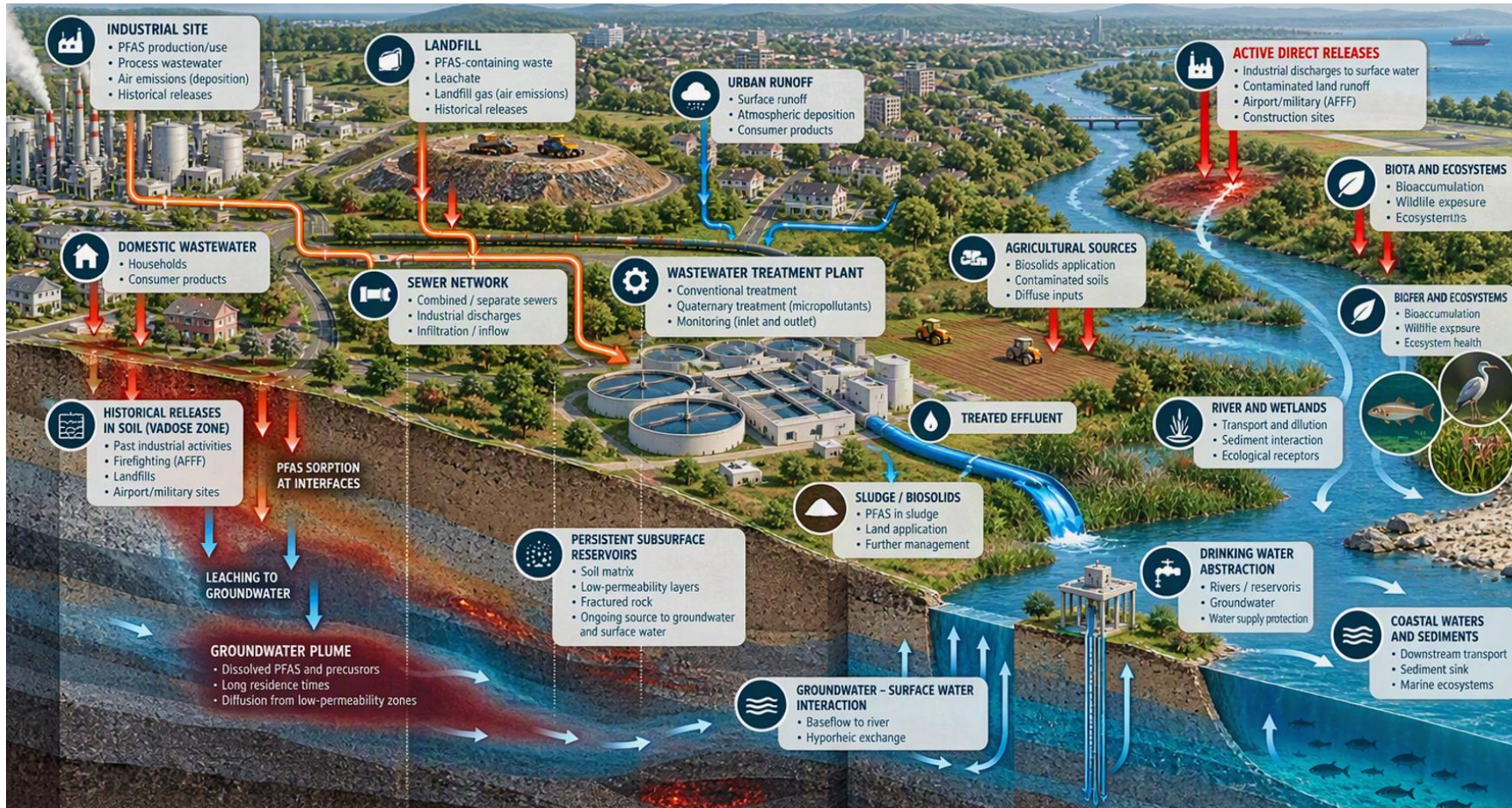
Sediment, deposits, residual water and impacted bedding

Receiving pathway

Groundwater infiltration can carry legacy PFAS into the sewer

Testable CSM – drives investigation and management plan

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1 HYPOTHESIS

State the suspected source, reservoir, pathway and receptor connection.

2 PREDICTION

Define what should be observed if that connection is correct.

3 DISCRIMINATING TEST

Collect the data that distinguish it from competing explanations.

4 UPDATE AND DECIDE

Retain, revise or reject the hypothesis, then prioritise action by mass contribution and receptor relevance.

Sample to discriminate between competing source–pathway hypotheses—not simply to add data points.

A testable PFAS CSM links a source–pathway hypothesis to a prediction that field evidence can confirm or reject.

01 **Current source control is necessary**

Directive 2024/3019 strengthens evidence and controls within the wastewater pathway.

02 **Historical does not mean inactive**

Secondary reservoirs can continue generating present-day PFAS flux.

03 **Hydrogeology determines contribution**

Source-zone inventory, pathway connectivity and water flux control receptor loading.

04 **The CSM connects evidence to action**

Prioritise mass contribution and receptor relevance—not concentration alone.

IDom

Thank you for your attention!

Three approaches to PFAS plume flux assessment

From source to receptor – linking point flux, control-plane discharge and receptor load

