

The Silent Legacy: A National Reckoning with PFAS at America's Airports

A Comprehensive National Assessment of PFAS-Contaminated Soils at U.S. Airports: Regulatory Frameworks, Scientific Principles, Economic Implications, and Strategic Management Pathways

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The Report is intended **solely for informational and educational purposes** to assist the aviation community in better understanding and managing PFAS-contaminated soils at airport facilities. The Report addresses a national-scale environmental challenge affecting virtually every airport across the United States in one way or another, whether through historical aqueous film-forming foam (AFFF) use, stormwater management, construction activities, or regulatory compliance obligations.

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A Note on the Spirit of This Resource

This Report was prepared with the sincere intention of assisting the aviation industry in understanding and addressing one of the most significant environmental challenges of our generation. PFAS contamination at airports is a national issue affecting virtually every airport facility across the country in some manner—whether through direct contamination, regulatory obligations, operational constraints, or financial impacts.

D31 Geo has invested substantial professional resources in developing this comprehensive resource and is providing it free of charge to support informed decision-making, strategic planning, and environmental stewardship across the aviation sector.

While these legal disclaimers are necessary to protect D31 Geo from liability for a complimentary educational resource, they should not obscure the core purpose: to help airport managers, executives, regulators, and other stakeholders navigate PFAS challenges more effectively.

We encourage readers to use this Report as a foundation for understanding, to seek qualified professional assistance for site-specific needs, and to engage collaboratively with regulatory agencies, industry peers, and technical experts in addressing this shared challenge.

The fight against PFAS contamination requires collective action, shared knowledge, and professional excellence. This Report is D31 Geo's contribution to that effort.

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Prologue: The Foam That Saved Lives, The Chemical That Stayed Forever

On a cold November morning in 1985, an airport fire chief in the Midwest stood beside a burning aircraft mockup, watching with satisfaction as a blanket of white foam smothered the flames in seconds. The aqueous film-forming foam—AFFF—was a marvel of chemical engineering, specifically designed to extinguish petroleum fires with unprecedented speed. It saved lives. It protected aircraft worth millions. It was mandated by federal regulation.

What that fire chief couldn't see—what nobody could see—was the invisible transformation occurring beneath his feet. The PFAS compounds in that foam were beginning a journey that would last not years, but generations. They were infiltrating the soil, migrating through sand and clay, hitchhiking on water molecules, accumulating in groundwater, and establishing a persistent chemical presence that would outlive every person standing at that training exercise.

Forty years later, that same airport is excavating 200,000 cubic yards of contaminated soil at a cost exceeding \$30 million. The fire chief has long since retired. The regulations that required AFFF have changed. But the PFAS remains, virtually unchanged, in concentrations that trigger some of the strictest environmental cleanup standards ever enacted in the United States.

This is not the story of one airport. This is the story of thousands.

Part I: The Architecture of Persistence

Chapter 1: The Molecular Bond That Refused to Break

To understand why PFAS contamination at airports represents such an intractable challenge, one must first understand the chemistry that makes these compounds unlike anything else in the environmental contamination lexicon.

The carbon-fluorine bond that defines per- and polyfluoroalkyl substances is among the strongest chemical bonds in organic chemistry. With a bond dissociation energy of approximately 536 kJ/mol, the C-F bond exceeds even the carbon-hydrogen bonds that form the backbone of organic life. This extraordinary stability—the very property that made PFAS ideal for firefighting foams—renders these compounds virtually immune to the biological, chemical, and photolytic processes that normally degrade organic contaminants in the environment.

Consider, by contrast, the fate of petroleum hydrocarbons spilled at an airport fueling station. Benzene, toluene, ethylbenzene, and xylenes—collectively known as BTEX compounds—are subject to aerobic and anaerobic biodegradation. Indigenous soil bacteria possess enzymatic pathways capable of cleaving carbon-carbon and carbon-hydrogen bonds, metabolizing these compounds into carbon dioxide, water, and biomass. Given sufficient time and appropriate conditions, petroleum contamination attenuates.

PFAS does not attenuate.

The perfluorinated carbon chain resists enzymatic attack. It resists oxidation. It resists reduction. It resists photolysis. In soil, in water, in sediment, in air—across virtually every environmental medium—PFAS persists. The half-life of PFOS in human serum is estimated at 5.4 years. The environmental half-life in groundwater and soil may extend to decades or longer. For practical regulatory purposes, PFAS contamination is considered permanent.

This permanence has profound implications for airport management. Unlike petroleum contamination, which diminishes over time through natural attenuation, PFAS contamination represents a liability in perpetuity. Every training exercise, every accidental discharge, every test of a hangar suppression system has contributed to a chemical burden that will outlast the operational lifespan of the airport itself.

Chapter 2: The Dual Nature—How PFAS Moves Through Airport Soils

PFAS molecules possess what chemists call an amphiphilic structure: a fluorinated carbon tail that repels both water and oils, attached to a functional head group—typically sulfonate or carboxylate—that attracts water. This molecular architecture creates behavior unlike traditional contaminants.

In the soil environment beneath an airport, PFAS exists in a state of dynamic equilibrium, partitioning between solid soil particles, porewater, and—in partially saturated zones—air-water interfaces. The distribution is governed by multiple factors: soil organic carbon content, mineral surface area, pH, ionic strength, moisture content, and the presence of co-contaminants.

In sandy soils typical of many airport infields and drainage areas, PFAS sorption is relatively weak. The compounds remain mobile, traveling vertically through infiltration and laterally along hydraulic gradients. Vertical migration profiles at airports have documented PFAS at depths exceeding twenty feet, far beyond the shallow surface soils where application occurred.

In clayey soils with higher organic matter content, PFAS sorption is stronger, yet still reversible. As precipitation infiltrates, as groundwater tables fluctuate, as construction activities disturb soil structure, PFAS desorbs and migrates. The process is slow but inexorable.

The practical consequence for airport managers is stark: PFAS contamination discovered during a runway reconstruction project today may have originated from a training exercise conducted thirty years ago, half a mile away, in a completely different operational area. The contaminant has migrated through interconnected soil and groundwater systems, following pathways shaped by geology, hydrology, and decades of airport development.

Chapter 3: The Inventory—Where PFAS Resides in Airport Infrastructure

The historical use of AFFF at U.S. airports was not confined to a single location or operation. It permeated the entire aviation safety apparatus, creating distributed sources across airport properties.

Fire Training Areas represent the most concentrated and well-documented PFAS source. For decades, airport fire departments conducted live-fire training exercises using jet fuel fires extinguished with AFFF. These activities occurred weekly or monthly, often in unlined burn pits or training pads. Foam was applied in quantities measured in hundreds or thousands of gallons per event. The PFAS infiltrated directly into underlying soils.

Investigations at former fire training areas consistently reveal PFAS concentrations in soil exceeding regulatory screening levels by orders of magnitude. Vertical profiles show contamination extending through the vadose zone into groundwater. Lateral migration has been documented along stormwater pathways, utility corridors, and preferential flow zones.

Hangar Fire Suppression Systems constitute a second major source category. Large hangars housing commercial aircraft, military aircraft, or high-value corporate jets were equipped with overhead foam deluge systems designed to flood the hangar floor with foam in the event of fire. These systems underwent periodic testing, and accidental discharges were not uncommon.

When foam escaped the hangar—through door thresholds, drainage systems, or floor cracks—it infiltrated soils around the hangar perimeter. Utility trenches, electrical conduits, and subsurface drainage infrastructure created pathways for lateral migration. The resulting contamination pattern is often complex and difficult to delineate.

Aircraft Rescue and Firefighting Response Zones include areas where foam was applied during actual emergencies, training drills conducted on active airfield surfaces, and crash sites. Unlike the concentrated releases at fire training areas, these applications were episodic and distributed across runways, taxiways, safety areas, and infield zones.

Over decades, however, even episodic applications accumulate. Stormwater runoff from treated surfaces carries PFAS into drainage swales, detention basins, and infiltration areas. Soil disturbance during construction redistributes contamination to new locations. The cumulative loading across an airport can rival or exceed that of the fire training area.

Stormwater Infrastructure itself becomes a secondary PFAS source. Detention basins that receive runoff from contaminated surfaces accumulate PFAS in sediments and underlying soils. Infiltration basins, designed to promote groundwater recharge, function as direct conduits for PFAS migration to aquifers. Unlined swales and ditches contribute to lateral spreading.

The sediments in these features often contain elevated PFAS concentrations even when the surrounding soils do not, reflecting decades of particle-bound transport. When airports undertake stormwater system retrofits—a common component of modern capital improvement programs—they encounter PFAS contamination in locations far removed from any historical foam use.

Utility Corridors and Construction Disturbance zones represent the most insidious category. Airports are in a constant state of evolution: runways are reconstructed, terminals expanded, utilities relocated, drainage systems upgraded. Each excavation, each backfill operation, each placement of imported fill material has the potential to redistribute PFAS-contaminated soils.

Soil reuse—a standard cost-saving measure in airport construction—has inadvertently spread contamination across airport properties. Fill materials excavated from one project area, stockpiled, and reused in another project may carry PFAS to previously uncontaminated zones. Utility trenches backfilled with permeable materials create high-conductivity pathways for subsurface migration.

The result is a contamination footprint that defies simple delineation. PFAS is not confined to a fenced-off "hotspot." It is distributed across operational areas critical to airport function—areas where earthwork, construction, and maintenance activities are routine and unavoidable.

Part II: The Regulatory Transformation

Chapter 4: From Advisory to Enforceable—The Federal Escalation

For most of its industrial history, PFAS existed in a regulatory limbo. The compounds were known to be persistent, known to bioaccumulate, but not subject to enforceable environmental standards. Airports conducting PFAS investigations in the 2000s and early 2010s operated under EPA health advisories—non-binding guidance values that carried no enforcement authority.

That era ended decisively in April 2024, when the U.S. Environmental Protection Agency finalized National Primary Drinking Water Regulations establishing Maximum Contaminant Levels for six PFAS compounds. The numerical limits—4 parts per trillion for PFOA and PFOS, 10 parts per trillion for PFHxS, PFNA, and HFPO-DA, and a Hazard Index of 1 for certain mixtures—represent some of the lowest enforceable drinking water standards ever promulgated in the United States.

To grasp the stringency of these standards, consider that 4 parts per trillion is equivalent to four drops of water in an Olympic-size swimming pool. Analytical detection at these levels requires sophisticated instrumentation and rigorous quality control. Compliance monitoring imposes substantial costs on water utilities.

For airports, the implications extend far beyond drinking water. Groundwater beneath airport properties—even groundwater not currently used for drinking water supply—is presumed to be a potential future drinking water source under federal and state regulatory frameworks. PFAS contamination of groundwater therefore triggers soil cleanup obligations designed to prevent further leaching and migration.

The regulatory logic is straightforward: if soil contains PFAS at concentrations sufficient to generate groundwater contamination above the MCL through leaching, that soil must be managed, treated, or isolated. The resulting soil screening levels, derived through leaching models and groundwater protection criteria, are extraordinarily low—often in the low milligrams per kilogram or even micrograms per kilogram range for fine-grained soils in contact with shallow groundwater.

The federal regulatory escalation did not stop with drinking water. In 2024, EPA designated PFOA and PFOS as hazardous substances under the Comprehensive Environmental Response,

Compensation, and Liability Act (CERCLA), commonly known as Superfund. This designation carries profound consequences:

- **Release Reporting:** Facilities must report releases of PFOA or PFOS exceeding the reportable quantity to federal, state, and local authorities.
- **Liability:** Parties responsible for PFAS releases may be held liable for cleanup costs, even if the releases occurred decades ago and were lawful at the time.
- **Cost Recovery:** Federal and state agencies may pursue cost recovery actions against responsible parties for investigation and remediation expenditures.

The CERCLA designation transforms PFAS from an environmental concern into a legal liability. Airport operators, even those who used AFFF in full compliance with FAA safety regulations, now face potential responsibility for contamination cleanup costs that may extend into tens or hundreds of millions of dollars.

Chapter 5: The State Patchwork—Navigating Fifty Jurisdictions

While federal regulation provides a national baseline, state-level PFAS regulation has evolved into a complex patchwork of standards, screening levels, and enforcement approaches that vary dramatically across jurisdictions.

Michigan established itself as an early leader in state PFAS regulation, adopting enforceable drinking water Maximum Contaminant Levels for seven PFAS compounds, with values ranging from 6 to 16 parts per trillion. The state developed comprehensive groundwater cleanup criteria and soil screening levels explicitly tied to groundwater protection. Michigan's regulatory framework is among the most technically sophisticated in the nation, incorporating speciation, mixture toxicity, and site-specific exposure pathways.

For airports in Michigan, this translates to aggressive investigation requirements, stringent cleanup expectations, and intense regulatory oversight. Soil management during construction must account for low-level PFAS contamination that would be inconsequential in less-regulated states.

New Jersey followed a similarly aggressive path, establishing MCLs of 13-14 parts per trillion for PFOA, PFOS, and PFNA. The state's regulatory program emphasizes prompt investigation, comprehensive characterization, and protective cleanup standards. New Jersey regulators have signaled willingness to pursue enforcement actions against parties responsible for PFAS contamination.

California approaches PFAS regulation through a risk-based framework that produces some of the most stringent cleanup levels in the nation. Groundwater screening levels for certain PFAS fall below 1 part per trillion in some scenarios. Soil cleanup criteria, derived from protection of groundwater and direct contact pathways, can reach into the low micrograms per kilogram range.

California airports face a regulatory environment where even low-level PFAS contamination triggers investigation, evaluation of remedial alternatives, and potential long-term monitoring or treatment obligations. The state's aggressive posture reflects both strong environmental advocacy and serious concerns about PFAS exposure through contaminated drinking water.

Vermont and Maine have taken distinctive approaches focused on agricultural soils and food chain pathways. Both states have identified PFAS contamination in agricultural lands resulting from biosolids application and have developed screening levels protective of crops and livestock. While these frameworks are not directly applicable to most airport soils, they reflect the breadth of PFAS regulation and the potential for future expansion into additional exposure pathways.

Massachusetts, New Hampshire, New York, Connecticut, Pennsylvania, Delaware, and Maryland have all established PFAS drinking water standards or groundwater cleanup criteria, generally in the 10-20 parts per trillion range for individual compounds or PFAS mixtures. These states represent a "second tier" of PFAS regulation—less aggressive than Michigan, New Jersey, or California, but substantially more restrictive than federal minimums.

Airports in these states should anticipate:

- Mandatory PFAS investigation during major construction projects
- Groundwater protection-based soil cleanup requirements
- Stormwater discharge monitoring and potential treatment obligations
- Long-term monitoring and institutional controls

By contrast, many states in the South, Central Plains, and Mountain West have not yet established PFAS-specific drinking water or groundwater standards. Airports in these "minimal regulation" jurisdictions might assume they face less stringent requirements—but this assumption is increasingly questionable.

Even in states without explicit PFAS standards, airports remain subject to:

- Federal drinking water MCLs (applicable to any current or potential drinking water source)
- CERCLA hazardous substance liability for PFOA and PFOS
- General environmental protection statutes authorizing cleanup of contamination that threatens water resources
- Landfill disposal restrictions driven by PFAS leachate concerns

Moreover, the regulatory trajectory is unmistakably toward greater stringency. States currently without PFAS standards are developing them. States with standards are tightening them. The regulatory environment of 2030 will be more restrictive than 2025, which is more restrictive than 2020.

For airport capital planning purposes, this means PFAS management strategies must anticipate future regulation, not merely comply with current standards.

Chapter 6: The Economic Algebra of Contaminated Soil

The intersection of widespread contamination, stringent regulatory standards, and limited disposal options creates an economic reality that is reshaping airport capital programs nationwide.

Consider the cost structure for a hypothetical runway reconstruction project at a medium-hub airport requiring excavation of 200,000 cubic yards of PFAS-contaminated soil:

Investigation and Characterization: Before a single cubic yard of soil is moved, the airport must delineate the contamination, profile the waste, and obtain regulatory approvals. This phase involves:

- Drilling and sampling: 40-60 soil borings at \$5,000-\$8,000 each = \$250,000-\$480,000
- PFAS laboratory analysis: 200-300 samples at \$400-\$600 each = \$80,000-\$180,000
- Groundwater monitoring wells: 10-15 wells at \$10,000-\$20,000 each = \$100,000-\$300,000
- Geotechnical characterization and waste profiling: \$100,000-\$200,000
- Regulatory consultation and reporting: \$75,000-\$150,000
- **Investigation Subtotal:** \$605,000-\$1,310,000

Soil Handling and Segregation: PFAS-contaminated soils cannot simply be loaded into trucks. They must be:

- Excavated under environmental oversight: \$8-\$15 per cubic yard
- Segregated by PFAS concentration and co-contaminant content: \$5-\$12 per cubic yard
- Stockpiled with stormwater controls and dust suppression: \$3-\$8 per cubic yard
- Sampled and profiled for waste acceptance: \$2-\$5 per cubic yard
- **Handling Subtotal** (200,000 cubic yards): \$3,600,000-\$8,000,000

Transportation and Disposal: Assuming a landfill 150 miles away willing to accept PFAS soils under restrictive conditions:

- Transportation: \$25-\$45 per ton (200,000 cy × 1.8 tons/cy = 360,000 tons) = \$9,000,000-\$16,200,000
- Tipping fees: \$80-\$150 per ton = \$28,800,000-\$54,000,000
- PFAS surcharges: \$15-\$30 per ton = \$5,400,000-\$10,800,000
- **Disposal Subtotal:** \$43,200,000-\$81,000,000

Construction Impacts: PFAS contamination imposes schedule delays, contractor risk premiums, and redesign costs:

- Schedule delays: 2-4 months at \$75,000-\$200,000 per month = \$150,000-\$800,000
- Contractor contingency and risk premiums: 5-15% of earthwork cost = \$2,000,000-\$5,000,000
- Design modifications and value engineering: \$200,000-\$500,000
- **Construction Impact Subtotal:** \$2,350,000-\$6,300,000

Long-Term Obligations: PFAS liability extends beyond construction completion:

- Groundwater monitoring: \$100,000-\$250,000 per year for 10-30 years = \$1,000,000-\$7,500,000
- Stormwater treatment and monitoring: \$50,000-\$150,000 per year = \$500,000-\$4,500,000
- Institutional controls and land use restrictions: \$50,000-\$100,000
- **Long-Term Subtotal:** \$1,550,000-\$12,100,000

Total Project Cost for PFAS Management: \$51,305,000-\$108,710,000

This range—\$51 million to \$109 million for a single runway reconstruction project—illustrates why PFAS has become a top-tier cost driver in airport capital programs. The midpoint estimate of approximately \$80 million exceeds the total cost of many runway reconstruction projects in the pre-PFAS era.

Scale this across the national airport system:

- Approximately 3,300 airports in the National Plan of Integrated Airport Systems
- Estimated 60-75% will require PFAS soil management over the next 20 years = 2,000-2,500 airports
- Average PFAS soil management cost per airport: \$5 million to \$50 million (varying by airport size and contamination extent)
- **National PFAS Soil Management Cost:** \$10 billion to \$125 billion over two decades

Even conservative estimates place the national cost above \$25 billion. More aggressive scenarios, accounting for regulatory tightening and disposal constraints, approach \$100 billion.

This is not speculative. This is the economic reality already manifesting at airports across the United States.

Part III: The Disposal Bottleneck

Chapter 7: When Landfills Say No

For half a century, contaminated soil management followed a simple model: excavate, load, haul to a municipal solid waste landfill, and move on to the next project. PFAS has destroyed that model.

The transformation began quietly. In 2019 and 2020, a handful of landfills in Michigan and the Northeast began imposing restrictions on PFAS-containing wastes: concentration limits, volume caps, surcharges. Airport projects experienced isolated disruptions—a landfill refusing a load, a tipping fee doubling mid-project—but these seemed like anomalies.

By 2022, the pattern had become systemic. Landfills across multiple states were restricting or refusing PFAS soils. The drivers were clear:

Leachate Treatment Constraints: Municipal solid waste landfills collect leachate—the liquid that percolates through waste and accumulates at the bottom of the landfill. This leachate is typically discharged to publicly owned treatment works (POTWs) for treatment before release to surface waters.

PFAS in landfill leachate poses an intractable problem. Conventional wastewater treatment processes—biological treatment, clarification, disinfection—do not remove PFAS. The compounds pass through the treatment plant largely unchanged and are discharged to rivers, lakes, or coastal waters.

As PFAS drinking water standards tightened, downstream water utilities began detecting PFAS in their source waters. Forensic investigations traced contamination back to POTW discharges. POTWs, in turn, identified landfill leachate as a major PFAS source.

The resulting regulatory and public pressure forced POTWs to demand that landfills reduce PFAS inputs. Landfills, lacking the ability to treat PFAS in leachate, responded by restricting PFAS waste acceptance.

Corporate Liability Concerns: Large waste management companies operate facilities across multiple states and are acutely aware of emerging PFAS liability. CERCLA hazardous substance designation for PFOA and PFOS means landfills accepting PFAS wastes may become responsible parties in future cleanup actions.

Corporate risk management increasingly favors restriction or refusal of PFAS wastes, even when immediate regulatory requirements do not compel such action. The long-term liability exposure is simply too great.

State Regulatory Actions: Several states have moved toward explicit restrictions on PFAS waste disposal:

- Maine enacted legislation restricting PFAS-containing products and wastes
- Michigan has considered PFAS waste acceptance limits at landfills
- Vermont, New Hampshire, and other states have imposed reporting requirements that function as de facto restrictions

Public Opposition: Communities near landfills have become increasingly vocal about PFAS. Public meetings feature residents demanding that landfill operators refuse PFAS wastes to protect local drinking water supplies. In several cases, public pressure has succeeded in halting PFAS waste acceptance even absent regulatory mandates.

The cumulative effect is a national disposal bottleneck. Airports planning major construction projects can no longer assume landfill disposal will be available, affordable, or reliable. The planning calculus has fundamentally shifted.

Chapter 8: The On-Site Imperative

As landfill options constrict, airports are being forced toward on-site PFAS soil management—an approach that carries its own technical, regulatory, and financial challenges.

Engineered Containment Cells represent the most straightforward on-site option. PFAS-contaminated soils are consolidated in a designated area, graded, and capped with low-permeability materials to minimize infiltration and leaching. The concept mirrors landfill design but on a smaller scale and without waste acceptance fees.

A typical airport containment cell includes:

- Geotechnical base preparation

- Compacted low-permeability liner or geosynthetic clay liner
- Placement and compaction of contaminated soils
- Drainage layer to capture and manage any leachate
- Low-permeability cap system
- Vegetative or paved cover
- Stormwater controls around the perimeter
- Long-term monitoring wells

Construction costs typically range from \$50 to \$150 per cubic yard—substantially less than off-site disposal, but still representing millions of dollars for large soil volumes. The trade-off is spatial: the airport must dedicate land to perpetual contaminated soil storage.

For large hub airports with thousands of acres, dedicating 10-20 acres to a containment cell may be acceptable. For small general aviation airports with limited land, on-site containment may be infeasible.

Soil Stabilization and Immobilization technologies use chemical amendments to bind PFAS to soil particles, reducing leachability and mobility. Common stabilizing agents include:

- Activated carbon or biochar
- Organoclays
- Proprietary polymer-based binders
- Colloidal silica

Laboratory studies have demonstrated that these amendments can reduce PFAS leaching by 60-90%, depending on soil type, PFAS speciation, and amendment dosage. Field-scale applications at airports remain limited but growing.

The critical limitation: stabilization does not destroy PFAS. It merely reduces mobility. If containment fails, if amendments degrade, if future excavation disturbs the stabilized soil, PFAS can remobilize. Regulators increasingly require long-term monitoring and institutional controls for stabilized soils.

Soil Washing physically separates PFAS from soil through water-based extraction and particle size separation. PFAS tends to concentrate on fine-grained soil particles (silts and clays) and organic matter. By separating these fractions from coarse-grained materials (sands and gravels), soil washing can reduce total PFAS mass by 60-85%.

The process generates two waste streams:

1. Clean or low-PFAS sand and gravel suitable for reuse or unrestricted disposal
2. PFAS-concentrated fines and wash water requiring treatment or specialized disposal

For airports with predominantly sandy soils and large excavation volumes, soil washing can be economically attractive, with costs ranging from \$150 to \$400 per ton. The technology is less effective for clayey soils or soils with high organic content.

Thermal Treatment offers the only technology capable of destroying PFAS at scale. High-temperature incineration (>1000°C) or thermal desorption systems can achieve >99.99% PFAS destruction through complete mineralization of the fluorinated carbon chain.

The barrier is cost: \$500 to \$1,500 per ton, making thermal treatment economically viable only for small volumes of highly contaminated soil or when regulatory mandates preclude other options. Mobile thermal treatment units have been deployed at some airport projects, but capacity remains limited and scheduling is challenging.

Thermal treatment also raises community concerns about air emissions, requiring extensive permitting, air quality monitoring, and public outreach.

Hybrid Approaches combine multiple technologies to optimize cost and performance:

- Excavate high-concentration soils from fire training areas for thermal treatment
- Soil wash moderate-concentration soils to reduce volume
- Stabilize low-concentration soils in place
- Consolidate residuals in an on-site containment cell

A large hub airport in the Midwest implemented such a hybrid strategy for a \$180 million runway reconstruction, ultimately managing 300,000 cubic yards of PFAS soil at a total cost of \$45 million—substantially less than off-site disposal would have cost, but still a major budget impact.

Part IV: The Co-Contamination Complexity

Chapter 9: PFAS Rarely Travels Alone

One of the most persistent misconceptions in airport PFAS management is that PFAS contamination exists in isolation. The operational reality is far more complex.

Airports are industrial facilities with decades of overlapping activities, each leaving its own chemical signature. PFAS contamination discovered during construction or investigation almost invariably co-occurs with other contaminants:

Petroleum Hydrocarbons from fuel handling, spills, and leaks are ubiquitous at airports. Jet fuel hydrant systems, fueling trucks, emergency generators, and ground support equipment all present opportunities for petroleum release. Over decades, these releases create widespread low-level total petroleum hydrocarbon (TPH) and BTEX contamination in soils around fueling areas, maintenance facilities, and aprons.

When PFAS-contaminated soils also contain petroleum hydrocarbons, several complications arise:

- Landfills may reject mixed wastes due to fire risk or odor concerns
- Soil washing efficiency declines due to organic loading

- Stabilization effectiveness may be reduced
- Regulatory frameworks may require evaluation under both PFAS and petroleum cleanup standards

Polycyclic Aromatic Hydrocarbons (PAHs) derive from incomplete combustion of jet fuel and diesel. Aircraft engines, auxiliary power units, ground support equipment, and historical burn pits all generate PAH residues that settle on airport surfaces and infiltrate soils.

PAHs are persistent, carcinogenic, and heavily regulated. Their presence alongside PFAS creates a dual liability: airports must address both classes of contaminants, often through different regulatory programs and technical approaches.

Chlorinated Solvents—trichloroethylene (TCE), perchloroethylene (PCE), and their degradation products—originate from aircraft maintenance, parts cleaning, and degreasing operations. These solvents are denser than water (DNAPLs—dense non-aqueous phase liquids) and tend to migrate downward through the subsurface.

The interaction between chlorinated solvents and PFAS is particularly problematic. Solvent plumes can alter subsurface chemistry, affecting PFAS mobility and partitioning. Co-contaminated soils often require specialized disposal or treatment, as neither landfills nor conventional treatment technologies handle both contaminant classes effectively.

Metals—particularly lead from historical aviation gasoline, chromium from industrial processes, and cadmium from paints and coatings—persist in airport soils and can limit management options. Soils contaminated with both PFAS and metals above hazardous waste thresholds may require disposal at Subtitle C hazardous waste facilities, dramatically increasing cost.

Deicing Agents introduce glycols and other organic compounds that alter soil chemistry and redox conditions. While glycols themselves are biodegradable, they create reducing conditions that can affect the behavior of metals and other co-contaminants. Some deicing formulations historically contained PFAS-based surfactants, adding another layer of complexity.

Polychlorinated Biphenyls (PCBs) from electrical transformers, capacitors, and hydraulic fluids represent one of the most costly co-contaminants. PCBs are extraordinarily persistent, bioaccumulative, and stringently regulated. Even low-level PCB contamination can render soils non-compliant with landfill waste acceptance criteria.

The regulatory framework for PCBs under the Toxic Substances Control Act (TSCA) is entirely separate from PFAS regulation under the Safe Drinking Water Act and CERCLA. Airports managing PFAS-PCB co-contaminated soils must navigate dual regulatory pathways, often requiring separate permits, disposal facilities, and cleanup standards.

Chapter 10: The Case Studies—Patterns Across the Nation

The abstract chemistry and regulatory frameworks of PFAS contamination become concrete in the lived experience of airport managers navigating investigations, construction delays, budget

overruns, and community concerns. The following case studies—composites drawn from multiple real-world airport projects, anonymized to protect confidentiality—illustrate recurring patterns.

Case Study Alpha: Large Hub in a Strict Regulatory State

A major commercial service airport in the Great Lakes region undertook runway reconstruction requiring excavation of 600,000 cubic yards of soil. Pre-construction investigation revealed PFAS contamination from a former fire training area, multiple hangar foam discharges, and stormwater infiltration across the runway safety area.

Soil concentrations ranged from non-detect to 850 mg/kg total PFAS in the former FTA, with widespread low-level contamination (0.1-5 mg/kg) across the runway corridor. Co-contaminants included TPH, PAHs, and localized PCBs near an old electrical substation.

The state's aggressive PFAS program required:

- Comprehensive soil and groundwater characterization
- Risk-based cleanup levels protective of groundwater (derived from a 4 ppt MCL)
- Documentation of disposal pathways
- Long-term monitoring

The airport's disposal strategy:

- Contacted 8 regional landfills; 5 declined PFAS soils outright
- 3 offered conditional acceptance with strict concentration limits and surcharges
- High-concentration FTA soils (>50 mg/kg) were excluded from all landfill acceptance criteria

The airport implemented a hybrid approach:

- Constructed a 15-acre on-site engineered containment cell for 120,000 cubic yards of high-PFAS soils (cost: \$18 million)
- Soil-washed 200,000 cubic yards of moderate-PFAS soils, producing 50,000 cubic yards of PFAS-concentrated fines for containment and 150,000 cubic yards of clean sand for reuse (cost: \$32 million)
- Disposed 280,000 cubic yards of low-PFAS soils at the accepting landfill (cost: \$56 million, including transportation and surcharges)

Total PFAS soil management cost: \$106 million Construction delay: 7 months Long-term monitoring obligation: 30 years

Case Study Beta: Medium Hub, Unexpected Discovery

A medium hub airport in the Mid-Atlantic region began taxiway reconstruction without pre-construction PFAS investigation—a decision reflecting the project's initiation before PFAS awareness became widespread. Three weeks into excavation, contractors encountered foam-like residues and stained soils along a utility corridor.

Emergency sampling revealed PFAS (PFOA+PFOS) concentrations up to 180 mg/kg, with TPH and PAH co-contamination. The utility corridor aligned with a historical drainage pathway from a former hangar foam system.

Construction halted for 11 weeks while the airport:

- Characterized the contamination extent
- Segregated excavated soils by PFAS concentration
- Negotiated landfill acceptance
- Revised construction sequencing

Complications:

- The primary landfill refused mixed PFAS-TPH-PAH waste mid-project due to a corporate policy change
- The airport had to haul soils 220 miles to an alternate facility willing to accept mixed waste at a premium tipping fee
- PCB contamination discovered near transformer pads required separate disposal at a TSCA-approved facility

Total PFAS-related cost impact: \$14.2 million Construction delay: 11 weeks Contractor delay claims: \$2.1 million Regulatory penalties for unauthorized stockpiling: \$85,000

Lesson learned: The airport implemented mandatory pre-construction PFAS screening for all future earthwork projects and established a standing agreement with two backup disposal facilities.

Case Study Gamma: General Aviation Airport, Limited Resources

A general aviation airport serving corporate and recreational aviation discovered PFAS during a hangar redevelopment project. The airport, with an annual budget of \$3 million and no dedicated environmental staff, faced contamination it could not afford to manage through traditional disposal.

PFAS concentrations ranged from non-detect to 45 mg/kg in soils beneath the hangar apron, with impacts extending along a stormwater swale. Estimated volume: 8,000 cubic yards.

The airport's constrained options:

- Off-site disposal estimates: \$3.2-\$6.8 million (exceeding the entire hangar redevelopment budget)
- No land available for large-scale containment
- No access to soil washing or thermal treatment facilities

The airport, working with state regulators, implemented an innovative approach:

- In-place stabilization using activated carbon amendment for 6,000 cubic yards (cost: \$420,000)

- Excavation and off-site disposal for 2,000 cubic yards of highest-concentration soils (cost: \$680,000)
- Stormwater infiltration controls to prevent continued migration (cost: \$180,000)
- Deed restrictions and institutional controls limiting future excavation (cost: \$25,000)
- 20-year groundwater monitoring program (present value cost: \$850,000)

Total cost: \$2.15 million—still a major burden for a small airport, but achievable through a combination of FAA grant funding, state environmental assistance, and phased implementation.

The project illustrates that PFAS contamination affects airports of all sizes, and solutions must be scaled to institutional capacity and financial resources.

Part V: The Path Forward

Chapter 11: Strategic Frameworks for Airport PFAS Management

The technical, regulatory, and economic realities of PFAS contamination demand a fundamental shift in how airports approach environmental management. PFAS cannot be addressed as an isolated, project-specific issue. It requires integration into institutional strategy, capital planning, operational protocols, and risk management frameworks.

The Five-Pillar Strategy

Based on analysis of successful PFAS programs at airports nationwide, a strategic framework emerges with five interdependent pillars:

Pillar 1: Proactive Investigation and Characterization

Airports must shift from reactive PFAS discovery during construction to proactive, systematic characterization across the entire property. This requires:

- Developing a comprehensive PFAS Investigation Master Plan identifying all potential source areas, migration pathways, and receptors
- Implementing a phased sampling program prioritizing areas with highest impact potential (fire training areas, hangars, stormwater basins, utility corridors)
- Integrating PFAS sampling into all site investigations, including those triggered by petroleum releases or other contamination
- Establishing a centralized PFAS database tracking all sampling results, creating institutional knowledge independent of staff turnover

The investment in proactive characterization—typically \$500,000 to \$2 million for a medium-to-large airport—prevents far more costly surprises during construction and supports informed capital planning.

Pillar 2: Integration with Capital Planning and Design

PFAS must become a standard consideration in the airport capital improvement program, not an afterthought discovered during construction. This integration requires:

- PFAS risk assessment for every proposed earthwork project, conducted during preliminary engineering
- PFAS contingency line items in project budgets, typically 10-30% of estimated earthwork cost depending on contamination likelihood
- Design modifications to minimize soil disturbance in known or suspected PFAS areas (e.g., directional drilling for utilities, foundation systems that reduce excavation depth, stormwater designs that avoid infiltration basins in contaminated zones)
- Pre-construction PFAS sampling and waste profiling integrated into project schedules, allowing 6-12 months for characterization and disposal planning before breaking ground

Capital planners must recognize that PFAS can transform a \$20 million runway reconstruction into a \$60 million project. Projects must be scoped and budgeted accordingly.

Pillar 3: Soil Management Hierarchy and Decision Framework

Airports should adopt a hierarchical approach to PFAS soil management, evaluating options in order of preference:

1. **Avoidance:** Modify designs to avoid disturbing PFAS-contaminated soils wherever feasible. This is almost always the lowest-cost option.
2. **Minimization:** Where disturbance is unavoidable, minimize excavation depth, footprint, and volume. Design optimization can often reduce soil volumes by 20-40%.
3. **Segregation:** Separate high-PFAS from low-PFAS soils during excavation. High-PFAS materials may require on-site containment or treatment; low-PFAS materials may be acceptable for reuse or landfill disposal.
4. **Reuse:** Where regulatory and geotechnical requirements allow, reuse PFAS-contaminated soils on-site in locations where leaching risk is minimal (e.g., beneath pavement, above the water table, in areas with institutional controls).
5. **On-Site Management:** Construct engineered containment cells or implement in-place stabilization for soils that cannot be reused or disposed off-site.
6. **Treatment:** For soils where containment is infeasible and disposal is unavailable, evaluate soil washing, thermal treatment, or other technologies based on PFAS concentration, co-contaminants, and volume.
7. **Off-Site Disposal:** Pursue landfill disposal only after confirming acceptance, profiling waste, and establishing backup options. Recognize that this pathway is increasingly constrained and costly.

This hierarchy reflects both economic optimization and regulatory acceptance. Regulators generally support approaches that minimize waste generation and long-term liability.

Pillar 4: Regulatory Engagement and Compliance

Successful PFAS programs maintain proactive, transparent relationships with regulatory agencies. This requires:

- Early notification to state environmental agencies when PFAS is discovered or anticipated
- Regular progress briefings demonstrating good-faith effort and technical competence
- Submission of comprehensive work plans before initiating major investigations or remedial actions
- Responsiveness to agency comments and data requests
- Documentation of decision-making rationale, especially for risk-based decisions or departures from standard approaches

Regulators are more likely to support flexible, cost-effective approaches when airports demonstrate technical rigor and environmental stewardship. Adversarial relationships, by contrast, tend to produce prescriptive, expensive outcomes.

Pillar 5: Long-Term Stewardship and Adaptive Management

PFAS contamination persists for decades. Management programs must likewise persist, requiring:

- Long-term groundwater and soil monitoring programs, with data reviewed quarterly and trends evaluated annually
- Institutional controls (deed restrictions, land use covenants, groundwater use restrictions) where PFAS remains in place above cleanup standards
- Periodic re-evaluation of remedial approaches as new technologies emerge or regulatory standards evolve
- Succession planning ensuring institutional knowledge transfers across staff changes
- Financial assurance mechanisms (reserve funds, escrow accounts, or third-party guarantees) supporting multi-decade monitoring and maintenance obligations

The concept of "closure" familiar from petroleum contamination sites does not apply to PFAS. Airports must plan for perpetual stewardship.

Chapter 12: The Innovation Frontier—Technologies in Development

The technical challenges posed by PFAS contamination have catalyzed a wave of research and development in treatment technologies, analytical methods, and remedial approaches. While many technologies remain experimental, several show promise for eventual airport-scale deployment.

Advanced Oxidation and Reduction Processes

Electrochemical oxidation uses electrical current to generate reactive species capable of cleaving C-F bonds. Laboratory studies demonstrate >90% PFAS destruction in aqueous systems, and pilot-scale systems are being tested for soil leachate and groundwater treatment.

The technology faces scalability challenges: high energy consumption, electrode fouling, and generation of toxic byproducts require management. Capital costs for full-scale systems remain prohibitive for most airport applications, but ongoing development may reduce costs to competitive levels within 5-10 years.

Plasma treatment applies high-energy plasma to decompose PFAS in water or soil slurries. Early results show excellent destruction efficiency but extremely high energy requirements. The technology may find niche applications for small volumes of highly contaminated material but is unlikely to become a primary remedial approach.

Bioremediation Strategies

While PFAS was long considered non-biodegradable, recent research has identified bacterial strains capable of limited defluorination under specialized conditions. These organisms cleave terminal fluorine atoms, potentially transforming long-chain PFAS into shorter-chain analogs or, in some cases, into non-fluorinated compounds.

The mechanisms remain poorly understood, rates are extremely slow, and field-scale effectiveness is unproven. However, the discovery that biological PFAS transformation is possible—even if highly limited—has opened a new research direction. Augmented bioremediation, combining specialized bacterial cultures with co-substrates and optimized geochemical conditions, may eventually provide a low-cost, in-situ treatment option.

Expectations should remain modest. Bioremediation is unlikely to achieve the rapid, comprehensive cleanup typical of petroleum hydrocarbon or chlorinated solvent bioaugmentation. It may, however, supplement other approaches or provide long-term polishing after primary treatment.

Sorption Enhancement Technologies

Research into novel sorbents seeks materials capable of irreversibly binding PFAS at high capacity. Candidates include:

- Modified activated carbons with enhanced surface chemistry
- Metal-organic frameworks (MOFs) offering tunable pore structures
- Biochar derived from specific feedstocks and pyrolysis conditions
- Ion exchange resins tailored to PFAS functional groups

If successful, these materials could enable more effective soil stabilization, more efficient water treatment, and potentially reversible PFAS sequestration allowing later recovery and destruction.

The challenge is transitioning from laboratory demonstrations to cost-effective, field-deployable applications. Many advanced sorbents perform exceptionally in controlled conditions but lose effectiveness in complex environmental matrices containing competing organic matter, salts, and co-contaminants.

Phytoremediation and Natural Attenuation Enhancement

Certain plant species demonstrate capacity to uptake and translocate PFAS from soil and groundwater into above-ground biomass. Willows, poplars, and some grasses have shown promise in greenhouse studies.

Phytoremediation, if proven viable at field scale, could offer a low-cost, low-impact approach for managing low-level PFAS contamination across large areas. Harvested biomass containing concentrated PFAS could then be managed through thermal destruction or other treatment technologies.

Significant uncertainties remain: uptake rates, long-term effectiveness, ecological impacts, and public acceptance of harvesting contaminated biomass. Phytoremediation is unlikely to address high-concentration source areas but might contribute to site-wide PFAS mass reduction over decades.

Part VI: The Human Dimensions

Chapter 13: Communication, Transparency, and Trust

The technical and regulatory complexities of PFAS contamination exist within a human context shaped by community concerns, media attention, and institutional accountability. How airports communicate about PFAS—to regulators, to neighboring communities, to tenants and airlines, to employees, to elected officials—profoundly influences both practical outcomes and institutional reputation.

The Transparency Imperative

Experience across multiple airport PFAS programs demonstrates that transparency generally produces better outcomes than opacity. When airports proactively disclose PFAS contamination, explain investigation plans, and provide regular updates, they build credibility that pays dividends during challenging phases of investigation or remediation.

By contrast, when PFAS contamination becomes public through regulatory filings, media investigations, or community discovery, airports face immediate credibility deficits. Questions arise: What did you know? When did you know it? Why didn't you tell us?

Recommended communication practices include:

- Public notification when PFAS is discovered above screening levels in environmental media
- Establishment of a dedicated PFAS information webpage with investigation reports, sampling data, remedial plans, and FAQs
- Community meetings at major milestones (completion of investigation, selection of remedial alternative, initiation of construction)
- Responsiveness to information requests from neighboring residents, community organizations, and media
- Plain-language summaries of technical reports, avoiding jargon while maintaining accuracy

Transparency does not mean releasing every data point immediately. Airports should coordinate with legal counsel and communications professionals to ensure disclosures are accurate,

complete, and appropriately contextualized. But the default should be toward disclosure, not withholding.

Addressing Community Health Concerns

PFAS contamination triggers legitimate health concerns among community members, particularly those relying on private wells or living near airports. Airports should respond to these concerns with empathy and fact-based information.

Recommended approaches:

- Offering private well sampling to residents within a defined radius of known contamination, with laboratory analysis provided at airport expense
- Providing bottled water or point-of-use treatment systems to residents whose wells exceed drinking water standards, regardless of legal liability
- Connecting concerned residents with independent health professionals who can provide individual risk counseling
- Avoiding dismissive or minimizing language ("the contamination is probably safe," "you don't need to worry") in favor of straightforward acknowledgment ("PFAS has been detected above drinking water standards, and we are taking steps to address it")

Health communication requires particular care because the science of PFAS toxicology remains evolving. While regulatory standards provide clear benchmarks for environmental management, they do not always align with individual risk perception. Some community members will remain concerned even when contamination is below regulatory thresholds. Airports should acknowledge these concerns without either validating unfounded fears or dismissing legitimate questions.

Internal Communication and Workforce Safety

Airport employees—particularly those in operations, maintenance, and ARFF roles—have direct exposure pathways to PFAS through their work. They deserve clear, accurate information about potential exposures and protective measures.

Recommended practices:

- Training programs for ARFF personnel on PFAS sources, exposure pathways, and protective equipment
- Provision of appropriate personal protective equipment for employees working in known PFAS-contaminated areas
- Medical surveillance programs for employees with historical or ongoing PFAS exposure
- Inclusion of employee representatives in PFAS planning and decision-making processes

Workforce communication should emphasize that historical AFFF use was mandated by regulation, that employees followed appropriate safety protocols based on then-current understanding, and that the airport is committed to protecting employee health going forward.

Chapter 14: The Liability Landscape—Allocating Responsibility

PFAS contamination raises profound questions of responsibility and cost allocation. Airports used AFFF because federal regulations required it. AFFF manufacturers produced formulations containing PFAS that were, at the time, considered safe and effective. Equipment suppliers designed foam systems to specifications incorporating PFAS-based products. Regulators mandated performance standards achievable only through PFAS chemistry.

Who bears responsibility for the resulting environmental contamination and cleanup costs?

The Manufacturer Litigation

Hundreds of lawsuits—including cases filed by airports, water utilities, states, and individuals—seek to hold PFAS manufacturers liable for contamination costs. The legal theories vary:

- Products liability (PFAS-containing products were defectively designed or inadequately warned)
- Negligence (manufacturers knew or should have known of PFAS hazards but failed to disclose them)
- Nuisance (PFAS contamination constitutes a public or private nuisance)
- Strict liability (PFAS contamination constitutes an abnormally dangerous activity)

Several manufacturers have reached significant settlements:

- 3M agreed to a \$10.3 billion settlement with public water systems
- DuPont, Chemours, and Corteva agreed to a \$1.185 billion settlement with water systems
- Multiple consent decrees require manufacturers to fund monitoring and treatment at specific contaminated sites

These settlements provide substantial cost recovery for some affected parties but do not resolve all liability questions. Many airports remain in ongoing litigation.

Government Immunity and the Regulatory Compliance Defense

Airports frequently argue that they should not bear cleanup liability for contamination resulting from compliance with federal regulations. The Federal Aviation Administration mandated AFFF use through Part 139 certification requirements. How can airports be held responsible for following legally required safety protocols?

This "regulatory compliance defense" has achieved mixed success. Some courts have found it persuasive, reasoning that entities compelled by regulation to use a product should not face liability for resulting contamination. Other courts have rejected the defense, noting that regulatory compliance does not automatically shield parties from environmental cleanup obligations under CERCLA or state environmental laws.

The legal landscape remains unsettled, and resolution may ultimately require legislative action clarifying liability allocation for contamination resulting from mandated safety practices.

Insurance Coverage Disputes

Many airports maintain comprehensive general liability insurance policies that potentially provide coverage for environmental cleanup costs. However, insurers frequently deny PFAS claims based on pollution exclusions, known-loss doctrines, or other policy provisions.

Resulting coverage litigation adds another layer of complexity and expense to PFAS management. Airports must simultaneously pursue cleanup, defend against third-party claims, litigate with manufacturers, and battle with insurers over coverage—often across multiple policy periods and multiple carriers.

The Equitable Solution

From a policy perspective, the most equitable approach to PFAS liability allocation would recognize:

- Manufacturers developed and profited from PFAS products while possessing superior knowledge of their persistence and potential harms
- Airports and other AFFF users acted in good faith, following legally mandated safety protocols
- The costs of PFAS cleanup are enormous and should be shared across parties based on responsibility, capacity to pay, and societal benefit

Federal legislation establishing a PFAS cleanup fund—potentially financed through manufacturer contributions, general appropriations, and user fees—could provide a path forward that reduces litigation costs, accelerates cleanup, and allocates burdens more fairly than protracted legal battles.

Absent such legislation, the liability landscape will remain contentious, uncertain, and inefficient.

Part VII: A Retrospective and a Prospective

Chapter 15: What We Learned Too Late

The PFAS crisis at airports is, fundamentally, a failure of foresight. The chemical stability that made PFAS valuable for firefighting—the very property that allowed it to extinguish fuel fires so effectively—also ensured its environmental persistence. This was not unknowable. It was known, or should have been known, by entities with the expertise to evaluate long-term environmental implications.

Internal documents from PFAS manufacturers reveal that concerns about environmental persistence and bioaccumulation were recognized as early as the 1970s. Studies documented PFAS in wildlife, in human blood serum, in environmental samples far from production facilities. The warning signs were present.

Yet regulatory frameworks failed to respond. AFFF containing PFAS continued to be mandated for aviation safety. Disposal practices assumed PFAS would behave like other organic contaminants, degrading over time. Manufacturers continued production and distribution. Airports continued use.

The lesson extends beyond PFAS. It speaks to systemic challenges in how society evaluates emerging chemicals, balances short-term benefits against long-term environmental costs, and assigns responsibility for unintended consequences.

The Precautionary Principle Revisited

The precautionary principle holds that when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically. In the context of PFAS, a precautionary approach would have demanded:

- Comprehensive environmental fate and transport studies before widespread deployment
- Long-term monitoring of PFAS in environmental media and biological systems
- Development and approval of fluorine-free alternatives before mandating PFAS-based foams
- Restrictions on disposal practices pending understanding of environmental persistence

None of these precautions were systematically implemented. Society proceeded with large-scale AFFF deployment based on short-term performance benefits, deferring questions about long-term environmental consequences.

The cost of this failure is now measured in billions of dollars, widespread contamination of water resources, and decades of environmental remediation.

Lessons for Future Chemicals Policy

The PFAS experience should inform how society evaluates and regulates emerging chemicals:

- Persistence and bioaccumulation should be evaluated rigorously before chemicals achieve widespread use
- Regulatory approval should require demonstration of environmental safety, not merely demonstration of use-specific performance
- Alternatives should be developed and proven before locking industries into dependence on chemicals with questionable environmental profiles
- Liability frameworks should be established ex ante, clarifying responsibility for long-term environmental costs
- Monitoring systems should detect environmental accumulation early, triggering precautionary responses before contamination becomes widespread

These reforms face political and economic headwinds. Chemical manufacturers argue that excessive precaution stifles innovation. Industries relying on specialized chemicals resist restrictions that might compromise performance. Regulators face resource constraints limiting their capacity for comprehensive chemical assessment.

Yet the alternative—the path we actually took with PFAS—has proven far more costly. The precautionary investments that might have prevented widespread PFAS contamination would have been trivial compared to the remediation costs now being incurred.

Chapter 16: The Next Decade—Regulatory, Technical, and Economic Trajectories

The PFAS landscape of 2035 will differ substantially from that of 2025. Based on current regulatory trajectories, technological development, and economic forces, several trends appear likely:

Regulatory Tightening

PFAS regulation will continue to expand and intensify:

- Additional PFAS compounds will be added to drinking water standards, potentially including short-chain PFAS and emerging replacements
- Federal soil screening levels and groundwater cleanup criteria will be established, reducing state-to-state variability
- CERCLA hazardous substance designation will likely extend beyond PFOA and PFOS to encompass additional long-chain PFAS
- RCRA hazardous waste listing for certain PFAS remains possible, fundamentally altering disposal pathways
- Air emission standards for thermal treatment and industrial PFAS sources will emerge as treatment capacity scales up

Airports planning today for 2030 construction projects should assume regulatory standards more stringent than current requirements.

Disposal Pathway Constriction

Landfill acceptance of PFAS-contaminated soils will continue to decline:

- More states will adopt explicit restrictions on PFAS waste disposal
- Existing landfills will reach capacity or implement volume caps on PFAS waste
- Leachate treatment requirements will force landfills to choose between expensive upgrades or waste refusal
- Corporate liability concerns will drive additional restrictions

By 2030, off-site landfill disposal may be unavailable or economically infeasible for most airport PFAS soils. On-site management—containment, stabilization, treatment—will transition from alternative to norm.

Treatment Technology Maturation

Several emerging technologies will mature toward commercial viability:

- Soil washing systems optimized for PFAS removal will become more widely available, with costs declining through scale and competition

- Advanced thermal treatment systems may achieve cost reductions through improved energy efficiency and higher throughput
- Electrochemical oxidation technology may transition from laboratory-scale to pilot- and full-scale applications
- Novel sorbents and stabilization amendments will offer improved performance and reduced costs

However, none of these technologies will achieve the low costs typical of traditional contaminated soil management. PFAS treatment will remain expensive, reinforcing the economic pressure toward avoidance and minimization.

Funding Mechanisms and Cost Distribution

The scale of PFAS cleanup costs will force development of new funding mechanisms:

- Federal appropriations for airport PFAS remediation may expand, potentially through dedicated programs similar to those supporting asbestos removal or underground storage tank cleanup
- Manufacturer settlement funds will provide partial cost recovery for some airports but will not cover total national costs
- State environmental assistance programs will grow to support smaller airports lacking resources for comprehensive PFAS management
- Insurance markets may develop specialized PFAS liability and cleanup cost coverage, albeit at high premiums

Despite these developments, airports will bear substantial direct costs for PFAS management, requiring integration into long-term capital planning and financial forecasting.

Litigation Resolution

The current wave of PFAS manufacturer litigation will largely resolve within the next decade:

- Additional manufacturer settlements will provide cost recovery to airports and water systems
- Courts will clarify liability allocation frameworks, reducing uncertainty about responsibility
- Legislative action may establish federal cost-sharing programs or liability caps, bringing finality to protracted legal disputes

However, second-generation litigation—claims by landfills, POTWs, and downstream water users against airports and other AFFF users—may be just beginning. Airports should anticipate ongoing legal exposure even as manufacturer litigation concludes.

Epilogue: The Accounting We Owe

In 1985, that Midwest fire chief watching foam smother a training fire was doing his job—protecting lives, protecting property, complying with federal safety regulations. He had no reason to question the environmental implications of the foam he was using. The science of PFAS environmental fate was absent from fire service training. The regulatory frameworks that would later govern PFAS contamination did not yet exist.

In 2025, his successors face a different reality. They know PFAS persists. They know it migrates. They know it contaminates. They know it triggers some of the strictest environmental standards ever implemented. They know it will cost billions to address.

The difference between 1985 and 2025 is knowledge. We know now what we did not know then—or what we should have known but chose not to examine.

The question before the aviation sector, the regulatory community, and society more broadly is: What do we do with that knowledge?

We can continue the status quo: airport-by-airport investigations, project-by-project crises, regulatory actions driven by isolated discoveries, manufacturer litigation proceeding through decades of legal maneuvering, communities discovering contamination through media reports rather than proactive notification.

Or we can choose a different path: systematic characterization, integrated planning, transparent communication, equitable cost distribution, coordinated development of treatment technologies, and regulatory frameworks that recognize both environmental protection imperatives and institutional realities.

The cost of PFAS contamination at airports is no longer avoidable. It exists. It must be paid, in money and in long-term stewardship obligations.

The question is whether we pay it intelligently, efficiently, and fairly—or whether we pay it through the inefficiencies of crisis management, the waste of duplicative investigations, the expense of protracted litigation, and the erosion of public trust that accompanies secrecy and delay.

This document represents a small contribution toward the former path: a comprehensive, technically grounded, and operationally relevant resource synthesizing the science, regulation, economics, and practice of PFAS management at airports. It is written in the hope that airport managers, regulators, engineers, and policymakers will use it not merely to comply with requirements, but to lead—to demonstrate that the aviation sector, having contributed to a national environmental challenge, is capable of responding with competence, transparency, and commitment to both operational excellence and environmental stewardship.

The foam has been in the ground for forty years. It will remain there for generations to come. How we manage that reality—the strategies we adopt, the resources we commit, the values we express through our choices—will define the environmental legacy of American aviation in the twenty-first century.

Appendix A: Regulatory Reference Tables

Table A-1: Federal PFAS Drinking Water Standards (Final Rule, 2024)

PFAS Compound	MCLG (ppt)	MCL (ppt)	Compliance Date
PFOA	0	4	April 2029
PFOS	0	4	April 2029
PFHxS	10	10	April 2029
PFNA	10	10	April 2029
HFPO-DA (GenX)	10	10	April 2029
Mixture (PFHxS, PFNA, HFPO-DA, PFBS)	—	Hazard Index = 1	April 2029

Table A-2: State PFAS Regulatory Frameworks (Representative Examples, 2025)

State	Drinking Water MCL	Groundwater Standard	Soil Screening Level	Regulatory Posture
Michigan	6-16 ppt (7 compounds)	Protective of MCLs	GW protection-based	Very Strict
New Jersey	13-14 ppt (3 compounds)	Case-specific	Risk-based	Very Strict
California	Notification levels 5-13 ppt	<1 ppt risk-based	Case-specific	Very Strict
Massachusetts	20 ppt (PFAS6 sum)	Case-specific	Under development	Strict
Vermont	20 ppt (PFAS5 sum)	Protective of MCL	Agricultural focus	Strict
New York	10 ppt (PFOA/PFOS)	Protective of MCL	Under development	Strict
Pennsylvania	Adopting EPA MCLs	Under development	Risk-based	Moderate
Colorado	PFAS6 approach	Protective of MCL	Under development	Moderate
Texas	None (federal default)	Case-specific	Risk-based	Minimal
Florida	Under development	Under development	None	Minimal

Table A-3: PFAS Soil Management Cost Ranges (2025)

Management Approach	Cost Range (per ton or per cubic yard)	Notes
Investigation and Characterization	\$3-\$8 per cubic yard	Includes drilling, sampling, analysis
Excavation and Handling	\$8-\$25 per cubic yard	Segregation, stockpiling, profiling
Off-Site Disposal (MSW Landfill)	\$100-\$250 per ton	Includes transport, tipping fees, surcharges

Management Approach	Cost Range (per ton or per cubic yard)	Notes
Off-Site Disposal (Industrial)	\$200-\$500 per ton	Higher containment standards
On-Site Containment Cell	\$50-\$150 per cubic yard	Engineered design, construction, monitoring
Soil Stabilization	\$50-\$150 per ton	Amendment application, mixing, placement
Soil Washing	\$150-\$400 per ton	Process cost, residual management
Thermal Treatment	\$500-\$1,500 per ton	High destruction efficiency, energy intensive
Long-Term Monitoring	\$100,000-\$250,000 per year	Groundwater, soil, stormwater

Table A-4: PFAS Co-Contaminants Common at Airports

Contaminant Class	Primary Sources	Interaction with PFAS	Management Implications
Petroleum Hydrocarbons (TPH, BTEX)	Fueling, spills	May suppress PFAS sorption	Limits landfill acceptance; affects treatment
Polycyclic Aromatic Hydrocarbons (PAHs)	Combustion, asphalt	Co-sorbs to soil; persistent	May require thermal treatment
Chlorinated Solvents (TCE, PCE)	Maintenance, degreasing	DNAPL behavior; complex plumes	Requires specialized disposal/treatment
Metals (Pb, Cr, Cd)	Fuels, paints, coatings	Competes for sorption sites	May trigger hazardous waste classification
Deicing Agents (Glycols)	Aircraft/pavement deicing	Alters redox conditions	Affects treatment chemistry
Polychlorinated Biphenyls (PCBs)	Electrical equipment	Separate regulatory framework	Very restrictive disposal requirements

Appendix B: Technical Guidance Documents

B-1: PFAS Soil Sampling Protocols for Airport Environments

Objective: Establish standardized procedures for collecting soil samples representative of PFAS contamination at airports while minimizing cross-contamination and ensuring data quality.

Equipment and Materials:

- Stainless steel or PFAS-free plastic sampling equipment (no Teflon-coated tools)
- High-density polyethylene (HDPE) sample containers
- Dedicated equipment for PFAS sampling (no reuse from other investigations)
- Decontamination supplies free of PFAS-containing surfactants

- Chain-of-custody documentation
- Personal protective equipment (nitrile gloves, not latex)

Sampling Locations:

Fire Training Areas:

- Surface samples (0-6 inches) across burn pit footprint
- Subsurface samples at 2-foot intervals to depth of 10 feet or groundwater
- Downgradient samples along stormwater pathways
- Background samples upgradient of historical use areas

Hangar Areas:

- Surface samples at foam discharge points and drainage inlets
- Subsurface samples at utility penetrations and suspected preferential pathways
- Samples beneath floor slabs where accessible
- Perimeter samples around hangar footprint

Stormwater Features:

- Sediment samples from basin bottoms and inlet/outlet structures
- Underlying soil samples beneath sediment accumulation zones
- Lateral samples along swale alignments
- Samples at groundwater interface where infiltration occurs

ARFF Response Areas:

- Surface samples at documented or suspected foam application locations
- Infield samples along historical drainage pathways
- Samples at stormwater collection points
- Runway/taxiway shoulder samples where appropriate

Sample Depth Strategy: PFAS vertical migration often exceeds expectations based on traditional contaminant behavior. Recommended depth strategy:

- Surface interval: 0-6 inches (highest concentration zone)
- Shallow subsurface: 2-4 feet (vadose zone migration)
- Intermediate depth: 6-10 feet (extended vadose zone, potential perched water)
- Deep samples: to groundwater or 20 feet, whichever is shallower
- Groundwater interface samples where applicable

Quality Assurance/Quality Control:

- Field duplicates: 1 per 20 samples
- Equipment blanks: 1 per day of sampling
- Field blanks: 1 per day when composite sampling

- Trip blanks: 1 per cooler of samples
- Matrix spike/matrix spike duplicate: as required by laboratory

Laboratory Analysis:

- Method: EPA 1633 or state-approved equivalent
- Analyte list: Minimum 40 PFAS compounds including PFOA, PFOS, PFHxS, PFNA, PFBS, PFHxA, and emerging short-chain compounds
- Detection limits: <1 ng/g (ppt) for soil, appropriate for comparison to regulatory screening levels
- Turnaround time: Standard 15-20 business days; expedited available for construction-critical projects

Documentation:

- Photographic documentation of sampling locations
- Boring logs with soil classification
- GPS coordinates (sub-meter accuracy)
- Field observations of foam residues, staining, odors
- Historical information from airport personnel
- Weather conditions and recent precipitation

Safety Considerations:

- PFAS sampling does not generally require specialized PPE beyond standard construction site safety equipment
- Avoid Teflon-containing materials in clothing or equipment
- Wash hands before eating/drinking even when wearing gloves
- Follow airport-specific safety protocols for airfield access

B-2: PFAS Waste Profiling for Landfill Acceptance

Purpose: Develop comprehensive waste profiles enabling airports to negotiate landfill acceptance and demonstrate regulatory compliance.

Required Analytical Data:

PFAS Analysis:

- Full EPA 1633 analyte suite (40+ compounds)
- Total PFAS concentration (sum of all detected compounds)
- Individual compound concentrations for PFOA, PFOS, PFHxS, PFNA, PFBS
- PFAS speciation (short-chain vs. long-chain distribution)

PFAS Leachability (where required by receiving facility):

- Synthetic Precipitation Leaching Procedure (SPLP) per EPA Method 1312

- Target analytes: Same as soil analysis
- Comparison to landfill-specific acceptance thresholds or groundwater standards

Co-Contaminant Screening:

- Total Petroleum Hydrocarbons (DRO/GRO)
- BTEX (benzene, toluene, ethylbenzene, xylenes)
- Polycyclic Aromatic Hydrocarbons (PAH-16)
- Volatile Organic Compounds (VOCs) including chlorinated solvents
- RCRA-8 metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver)
- PCBs (if historical electrical infrastructure present)

Physical Characterization:

- Soil classification (USCS)
- Moisture content
- Presence of debris, free liquids, or odorous materials
- Organic content
- pH

Waste Segregation Strategy:

Airports should segregate excavated soils into categories based on anticipated disposal pathways:

Category 1 - High PFAS (>50 mg/kg total PFAS):

- Typically fire training area hotspots
- Usually excluded from landfill acceptance
- Managed through on-site containment or specialized treatment

Category 2 - Moderate PFAS (5-50 mg/kg total PFAS):

- May be acceptable to some landfills with conditions
- Candidates for soil washing or stabilization
- Volume reduction through treatment may enable disposal

Category 3 - Low PFAS (0.1-5 mg/kg total PFAS):

- Most likely category for landfill acceptance
- May require SPLP demonstration
- Possible reuse in certain on-site applications

Category 4 - Non-Detect or Minimal PFAS (<0.1 mg/kg total PFAS):

- Unrestricted disposal or on-site reuse
- Minimal special handling requirements

Landfill Inquiry Process:

1. Identify candidate landfills within economically viable haul radius (typically <200 miles)
2. Request PFAS waste acceptance criteria in writing
3. Provide preliminary waste profile data
4. Negotiate acceptance conditions, volume limits, pricing
5. Obtain written confirmation of acceptance valid through project duration
6. Establish contingency agreements with backup facilities

Documentation Package:

Submit comprehensive waste profile to receiving landfill including:

- Project narrative describing source of soils, excavation areas, airport operations
- Summary of PFAS analytical results with statistics (mean, median, range, 95th percentile)
- Co-contaminant analytical results
- Waste segregation plan
- Estimated tonnage and delivery schedule
- Handling and transportation plan
- Generator certification and liability acknowledgment

Acceptance Conditions to Anticipate:

Most landfills accepting PFAS soils impose conditions such as:

- PFAS concentration thresholds (e.g., <10 mg/kg PFOA+PFOS)
- SPLP limits (e.g., <70 ppt total PFAS in leachate)
- Co-contaminant restrictions (especially PCBs, high TPH, chlorinated solvents)
- Daily tonnage limits (e.g., maximum 500 tons PFAS soil per day)
- Total project tonnage caps
- Moisture content limits (e.g., <25% by weight)
- Prohibition on free liquids or containerized waste
- Premium tipping fees (\$20-\$100 per ton above standard rates)
- Special delivery scheduling or dedicated disposal cells
- Right to refuse loads based on field inspection or verification sampling

Contingency Planning:

Because landfill acceptance can change during project execution, airports should:

- Maintain pre-qualified backup disposal facilities
 - Design on-site stockpile areas capable of holding 30-60 days of excavation volume
 - Establish decision trees for soil management if primary disposal becomes unavailable
 - Budget contingencies of 25-40% for disposal cost escalation
 - Include contractual provisions addressing disposal pathway changes
-

Appendix C: Case Study Details

C-1: Large Hub Airport Runway Reconstruction - Complete Project Chronicle

Background: A major commercial service airport in the Great Lakes region initiated reconstruction of its primary runway (10,000 feet × 150 feet) including associated safety areas, lighting, and drainage infrastructure. The project was originally budgeted at \$85 million with an 18-month construction timeline.

Pre-construction environmental review identified a former fire training area approximately 1,500 feet from the runway centerline and multiple historical hangar locations along the runway. Airport environmental staff recommended PFAS investigation; project management elected to proceed with limited sampling to maintain schedule.

Initial PFAS Discovery (Month 3): Shallow soil samples collected during utility corridor excavation revealed PFAS (PFOA+PFOS) concentrations of 12-85 mg/kg across a 200-foot section of the corridor. Concentrations correlated with a historical stormwater swale that had received runoff from the fire training area.

Work stopped in the affected area. Emergency characterization began.

Expanded Investigation (Months 4-6): Comprehensive soil investigation included:

- 127 soil borings across runway corridor, safety areas, and stormwater features
- 483 soil samples analyzed for PFAS suite, TPH, PAHs, metals
- 12 groundwater monitoring wells installed
- PFAS detected across 65% of project area, with highest concentrations in:
 - Former FTA: 450-850 mg/kg total PFAS
 - Stormwater basin sediments: 85-320 mg/kg total PFAS
 - Runway safety area soils: 2-45 mg/kg total PFAS
 - Utility corridors: 5-180 mg/kg total PFAS

Co-contaminants included:

- TPH (DRO): 500-3,200 mg/kg in multiple locations (historical fuel spills)
- PAHs: 12-67 mg/kg in infield soils (jet exhaust deposition)
- PCBs: 1.2-8.7 mg/kg near transformer pad (below TSCA threshold but above landfill acceptance)

Regulatory Coordination (Months 5-8): State environmental agency required:

- Soil Management Plan addressing segregation, profiling, disposal
- Groundwater Monitoring and Mitigation Plan
- Stormwater Pollution Prevention Plan with PFAS-specific controls
- Public notification of investigation results

Disposal Pathway Evaluation (Months 6-9): Airport and consultant contacted 11 landfills in Michigan, Ohio, Indiana, and Illinois:

- 6 declined PFAS soils outright due to leachate concerns or corporate policies
- 3 offered conditional acceptance with strict limits:
 - Landfill A (Ohio): PFOA+PFOS <15 mg/kg, no PCBs, TPH <500 mg/kg, 200 ton/day limit, \$165/ton tipping fee + \$45/ton PFAS surcharge
 - Landfill B (Indiana): Total PFAS <25 mg/kg, SPLP <100 ppt, 500 ton/day limit, \$142/ton + \$35/ton surcharge
 - Landfill C (Michigan): PFOA+PFOS <10 mg/kg, no co-contaminants above residential soil standards, 100 ton/day limit, \$188/ton + \$55/ton surcharge
- 2 offered acceptance for non-PFAS soils only

Analysis revealed that:

- Only 28% of project soils (approximately 168,000 cubic yards) met most lenient landfill criteria
- 35% of soils (210,000 cubic yards) exceeded all landfill acceptance thresholds
- 37% of soils (222,000 cubic yards) were in intermediate range, potentially manageable through treatment

Soil Management Strategy (Months 9-11):

Airport adopted multi-pathway approach:

Pathway 1 - On-Site Containment Cell:

- Designed for 120,000 cubic yards of high-PFAS soils (>50 mg/kg) and PCB-containing materials
- Located in underutilized airport property 2,800 feet from runway
- Engineered features:
 - 18-inch compacted clay liner (permeability $<1 \times 10^{-7}$ cm/sec)
 - Leachate collection system with sump and monitoring
 - Contaminated soil placement and compaction
 - 24-inch clay cap with vegetative cover
 - Perimeter fence and institutional controls
 - 30-year groundwater monitoring program
- Cost: \$18.3 million (\$153 per cubic yard)

Pathway 2 - Soil Washing:

- Mobile soil washing system deployed on-site for 200,000 cubic yards of moderate-PFAS soils
- Process:
 - Soils screened to remove debris and >2-inch particles
 - Attrition scrubbing to liberate PFAS from sand/gravel
 - Hydrocyclone separation of fines (<63 microns) and coarse fraction

- Results: 147,000 cubic yards clean sand/gravel (26% mass reduction), 53,000 cubic yards PFAS-concentrated fines
- Clean fraction met unrestricted reuse criteria; used as structural fill in runway reconstruction
- Concentrated fines managed in on-site containment cell
- Cost: \$31.8 million (\$159 per cubic yard processed)

Pathway 3 - Off-Site Disposal:

- 280,000 cubic yards of low-PFAS soils meeting Landfill B acceptance criteria
- Transportation: 340,000 tons × \$32/ton (148-mile haul) = \$10.9 million
- Tipping fees: 340,000 tons × \$142/ton = \$48.3 million
- PFAS surcharge: 340,000 tons × \$35/ton = \$11.9 million
- Profiling and verification sampling: \$1.2 million
- Total disposal cost: \$72.3 million (\$258 per cubic yard)

Construction Modifications (Months 12-14):

- Runway grading plan modified to minimize excavation in high-PFAS zones
- Stormwater design changed from infiltration basins to detention with lined bottoms
- Utility alignments shifted to avoid highest-concentration areas where feasible
- Soil reuse plan developed maximizing use of soil-washed materials

Project Completion and Long-Term Obligations:

Final project metrics:

- Total construction duration: 29 months (11-month delay)
- Total project cost: \$197 million (132% increase over original budget)
- PFAS-specific costs: \$127 million
 - Investigation and planning: \$4.8 million
 - Soil handling and segregation: \$6.2 million
 - On-site containment cell: \$18.3 million
 - Soil washing: \$31.8 million
 - Off-site disposal: \$72.3 million
 - Construction delays and modifications: \$8.9 million
 - Regulatory compliance and reporting: \$2.4 million
 - Contractor claims settlement: \$3.1 million

Long-term obligations:

- Groundwater monitoring: 15 wells, quarterly sampling for 5 years then annual, estimated present value \$3.2 million
- Containment cell inspection and maintenance: annual, estimated present value \$850,000
- Stormwater monitoring: quarterly PFAS analysis, estimated present value \$1.6 million
- Institutional controls: deed restrictions on containment cell area, groundwater use prohibition

Lessons Applied to Future Projects:

Airport implemented comprehensive PFAS management program including:

- Mandatory PFAS screening for all projects involving >1,000 cubic yards earthwork
 - 25% PFAS contingency in earthwork budgets
 - Standing agreements with two backup disposal facilities
 - Pre-qualified soil washing contractor for mobilization within 60 days
 - Annual PFAS training for project managers and construction inspectors
-

Appendix D: Division 31 GEO Solutions and Services

Company Overview

Division 31 GEO, LLC is a specialized geoenvironmental consulting firm headquartered in Indianapolis, Indiana, providing comprehensive PFAS investigation, remediation, and management services to airports, municipalities, industrial facilities, and government agencies nationwide.

Founded in response to the emerging PFAS crisis, Division 31 GEO combines deep expertise in geotechnical engineering, environmental chemistry, hydrogeology, and regulatory compliance to deliver integrated solutions for PFAS-contaminated sites. The firm's name reflects its focus on "Division 31" earthwork in construction specifications—the interface where environmental contamination meets infrastructure development.

Core Service Areas

PFAS Site Investigation and Characterization

- Comprehensive PFAS sampling programs designed for airport environments
- Multi-media characterization (soil, groundwater, stormwater, sediment, air)
- Advanced analytical coordination including EPA Method 1633 and emerging techniques
- Conceptual Site Model development specific to aviation operational history
- 3D visualization of PFAS distribution and migration pathways
- Integration with geotechnical investigations for capital projects

Regulatory Strategy and Compliance

- Navigation of federal, state, and local PFAS regulatory frameworks
- Preparation of regulatory submittals, work plans, and closure documentation
- Negotiation with regulatory agencies on cleanup standards and remedial approaches
- Risk assessment and exposure pathway analysis
- Groundwater use restriction and institutional control implementation
- Expert testimony and litigation support

Remedial Design and Implementation

- Evaluation of soil management alternatives (avoidance, minimization, treatment, disposal)
- Design of engineered containment systems tailored to airport land constraints
- Soil washing feasibility assessment and system design
- Thermal treatment evaluation and vendor selection
- Stabilization/immobilization approach selection and field implementation
- Stormwater treatment system design for PFAS removal

Construction Support and Soil Management

- Pre-construction PFAS planning and contingency development
- Real-time construction support including field screening and waste segregation
- Contractor coordination for PFAS-aware earthwork practices
- Soil stockpile management and stormwater controls
- Verification sampling and waste profiling for disposal
- As-built documentation and post-construction reporting

Long-Term Monitoring and Stewardship

- Groundwater monitoring network design and implementation
- Stormwater and sediment monitoring programs
- Remedial system performance monitoring
- Data management and trend analysis
- Adaptive management recommendations based on monitoring results
- Institutional control compliance verification

Specialized Capabilities for Airports

Division 31 GEO has developed airport-specific expertise addressing the unique challenges PFAS presents in aviation environments:

Operational Continuity Focus

- Investigations and remediation designed to minimize airfield disruptions
- Phased approaches aligned with capital improvement program schedules
- Rapid mobilization capabilities for construction-critical projects
- 24/7 availability for emergency response to unexpected discoveries

Aviation Regulatory Integration

- Coordination with FAA requirements and Airport Improvement Program compliance
- ARFF operational continuity during PFAS investigations and remediation
- Integration with airfield safety and certification requirements
- Experience navigating joint civilian/military airport complexities

Cost Optimization Strategies

- Value engineering to minimize PFAS management costs while meeting regulatory requirements
- Soil reuse strategies maximizing beneficial use of impacted materials
- Disposal pathway optimization including landfill negotiations
- Grant funding identification and application support

Proprietary Tools and Methodologies

Division 31 GEO has developed several proprietary analytical frameworks specifically for airport PFAS assessment:

Airport Loading Ratio (ALR) A quantitative methodology for allocating PFAS mass among multiple source areas based on historical operational data, soil characteristics, and fate-and-transport modeling. ALR enables airports to prioritize investigation and remedial efforts based on actual contribution to total site burden rather than maximum detected concentration.

PFAS Soil Burden Index (ASBI) A scoring system evaluating airport-wide PFAS risk based on intensity of historical AFFF use, soil/hydrogeologic properties, proximity to receptors, and capital improvement needs. ASBI supports strategic planning and budget forecasting at the portfolio level.

Landfill Acceptance Probability Model A database-driven tool predicting likelihood of landfill acceptance based on PFAS concentrations, co-contaminants, geographic location, and facility-specific policies. The model enables realistic disposal planning and contingency development.

Representative Airport Projects

While client confidentiality restricts detailed disclosure, Division 31 GEO has supported PFAS investigations and remediation at commercial, military, and municipal airports.

Project values have ranged from \$75,000 (limited investigations) to \$18 million (comprehensive multi-year investigation and remediation).

Professional Qualifications

Division 31 GEO maintains professional licensure and certifications including:

- Professional Engineers (PE)
- Professional Geologists (PG)
- Certified Hazardous Materials Managers (CHMM)
- 40-Hour HAZWOPER and 8-Hour Supervisor training
- OSHA 30-Hour Construction Safety
- Airfield Driving and Safety Certifications

Staff include experts in:

- Geotechnical engineering
- Environmental engineering

- Hydrogeology and contaminant fate-and-transport modeling
- Environmental chemistry and analytical methods
- Remediation technology assessment and design
- Regulatory compliance and risk assessment
- Construction management and contract administration

How to Engage Division 31 GEO

Airports seeking PFAS assessment, remediation, or strategic planning support can engage Division 31 GEO through:

Initial Consultation (No Cost):

- 60-90 minute discussion of airport PFAS concerns, regulatory context, and project drivers
- Preliminary review of existing data or reports
- Overview of potential approaches and approximate cost ranges
- Determination of fit and next steps

Scoped Proposal Development: Based on consultation, Division 31 GEO develops detailed scope of work addressing:

- Specific investigation or remediation objectives
- Technical approach and methodologies
- Deliverables and timeline
- Cost estimate with transparent assumptions
- Qualifications of proposed project team

Project Execution: Upon authorization, Division 31 GEO executes work under project management structure ensuring:

- Regular progress updates (weekly or as requested)
- Proactive communication of field findings or changes
- Quality assurance/quality control at all project stages
- Budget tracking and cost control
- Responsiveness to airport schedule and operational constraints

Continued Partnership: Many airports engage Division 31 GEO on a continuing basis as their PFAS technical advisor, providing:

- On-call support for construction projects encountering PFAS
- Annual strategy sessions reviewing regulatory developments and portfolio planning
- Training for airport staff on PFAS sampling, handling, and compliance
- Expert testimony or regulatory negotiation support as needed

Contact Information

Division 31 GEO, LLC

Corporate Headquarters: Indianapolis, Indiana

Telephone: (317) 619-0601 Email: contact@division31geo.com Web: www.division31geo.com

Regional Offices:

- Northeast Region (Supporting New England and Mid-Atlantic airports)
- Southeast Region (Supporting airports in the Carolinas, Georgia, Florida)
- Midwest Region (Supporting Great Lakes and Central states)

For project inquiries, please reach out to corporate headquarters for routing to the appropriate team serving your airport's location.

Sources and References

Federal Regulatory Documents

U.S. Environmental Protection Agency (EPA)

- National Primary Drinking Water Regulation for PFAS (Final Rule, April 2024)
- PFAS National Primary Drinking Water Regulation (40 CFR Part 141), effective 2024, compliance required by April 2029
- EPA Method 1633: Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS
- Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites (updated periodically)
- CERCLA Designation of PFOA and PFOS as Hazardous Substances (Final Rule, 2024)
- Interim Guidance on the Destruction and Disposal of PFAS and PFAS-Containing Materials (December 2020)
- Technical Brief: Addressing PFAS at Airports and Other Sites with Aqueous Film-Forming Foam (AFFF)

Federal Aviation Administration (FAA)

- National Plan of Integrated Airport Systems (NPIAS) 2025-2029
- FAA Terminal Area Forecast (TAF), Fiscal Years 2024-2045
- Advisory Circular 150/5210-6D: Aircraft Fire and Rescue Facilities and Extinguishing Agents
- Airport Improvement Program (AIP) Handbook, Order 5100.38D
- Transition from PFAS-containing AFFF guidance and implementation timeline

Department of Defense (DoD)

- DoD PFAS Task Force Reports and Implementation Plans
- Department of Defense Addressing Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) Action Plan (2020 and updates)

- Installation Restoration Program (IRP) guidance for PFAS investigation at military installations

Agency for Toxic Substances and Disease Registry (ATSDR)

- Toxicological Profile for Perfluoroalkyls (Draft for Public Comment, 2021)
- PFAS exposure and health effects guidance documents

State Regulatory Documents

Michigan

- Michigan PFAS Action Response Team (MPART) Reports
- Michigan EGLE Part 201 Generic Cleanup Criteria for PFAS
- Michigan Drinking Water Standards (MCLs) for PFAS compounds
- Michigan PFAS Science Advisory Panel Reports

New Jersey

- New Jersey Drinking Water Quality Institute (DWQI) Health-Based Maximum Contaminant Levels for PFOA, PFOS, and PFNA
- New Jersey Department of Environmental Protection (NJDEP) Site Remediation Program PFAS Guidance
- New Jersey Administrative Code Title 7, Chapter 26 (Safe Drinking Water Act rules)

California

- California State Water Resources Control Board PFAS Investigation Guidance
- California Office of Environmental Health Hazard Assessment (OEHHA) PFAS notification levels and response levels
- CalEPA guidance on PFAS in drinking water and groundwater

Massachusetts

- Massachusetts Department of Environmental Protection (MassDEP) PFAS in Drinking Water
- Massachusetts Contingency Plan (MCP) PFAS-specific guidance
- Massachusetts PFAS6 drinking water standard (20 ppt)

Vermont

- Vermont Department of Environmental Conservation PFAS Investigation and Remediation Guidance
- Vermont Groundwater Protection Rule and Strategy amendments for PFAS
- Vermont Act 154 (2019): Regulation of PFAS in drinking water

Additional States with PFAS Regulatory Programs

- New York Department of Environmental Conservation PFAS guidance documents
- Pennsylvania Department of Environmental Protection PFAS action plan
- Colorado Department of Public Health and Environment PFAS regulations
- Minnesota Pollution Control Agency PFAS guidance
- New Hampshire Department of Environmental Services PFAS rules
- Connecticut Department of Energy and Environmental Protection PFAS program
- Delaware Department of Natural Resources and Environmental Control PFAS standards

Scientific and Technical Literature

PFAS Chemistry and Environmental Fate

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PFAS Toxicology and Health Effects

- Fenton, S.E., et al. (2021). "Per- and Polyfluoroalkyl Substance Toxicity and Human Health Review: Current State of Knowledge and Strategies for Informing Future Research." *Environmental Toxicology and Chemistry*, 40(3), 606-630.

- Sunderland, E.M., et al. (2019). "A review of the pathways of human exposure to poly- and perfluoroalkyl substances (PFASs) and present understanding of health effects." *Journal of Exposure Science & Environmental Epidemiology*, 29, 131-147.

Industry and Trade Association Publications

Airport Cooperative Research Program (ACRP)

- ACRP Research Report Series on PFAS at Airports
- ACRP Synthesis Reports on Airport Environmental Management
- ACRP Legal Research Digest on PFAS Liability Issues

American Association of Airport Executives (AAAE)

- PFAS guidance documents and policy statements
- Airport environmental management best practices

Airports Council International - North America (ACI-NA)

- PFAS working group reports and recommendations
- Policy positions on PFAS regulation and airport liability

Interstate Technology & Regulatory Council (ITRC)

- ITRC PFAS Technical and Regulatory Guidance Document (2020 and updates)
- ITRC PFAS Training Materials and Case Studies
- ITRC Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS) (2021)

Legal and Litigation Resources

Case Law and Settlements

- *In re: Aqueous Film-Forming Foams Products Liability Litigation*, MDL No. 2873 (D.S.C.)
- 3M PFAS Water Contamination Settlement (2023): \$10.3 billion settlement with public water systems
- DuPont/Chemours/Corteva Settlement (2023): \$1.185 billion settlement with public water systems
- Various state attorney general enforcement actions and consent decrees

Government Accountability Office (GAO) Reports

- GAO Reports on DoD PFAS Contamination and Cleanup Costs
- GAO Analysis of EPA PFAS Regulatory Development

Cost and Economic Analysis

Construction Cost Data

- RSMean Environmental Remediation Cost Data (annual editions)
- Remediation cost databases from Engineering News-Record (ENR)
- Industry surveys on PFAS investigation and remediation costs

Landfill Tipping Fee Surveys

- Environmental Research & Education Foundation (EREF) surveys
- State solid waste association fee compilations
- Waste industry financial reports and disclosures

Additional Technical Resources

National Academies of Sciences, Engineering, and Medicine

- Consensus Study Report: Guidance on PFAS Exposure, Testing, and Clinical Follow-Up (2022)
- Research reports on PFAS environmental transport and treatment

Water Research Foundation (WRF)

- Multiple research projects on PFAS occurrence, treatment, and analytical methods
- Utility perspectives on PFAS challenges and solutions

American Water Works Association (AWWA)

- PFAS technical resources and policy statements
- Drinking water treatment guidance for PFAS

Disclaimers and Notes on Sources

Currency of Information: PFAS regulation, science, and treatment technologies evolve rapidly. While this document reflects best available information as of 2025-2026, users should verify current regulatory requirements, analytical methods, and technical approaches with qualified professionals and authoritative sources.

Confidentiality: Many specific case studies and cost data reflect confidential client projects. Information has been anonymized and aggregated to protect client confidentiality while preserving educational value.

Professional Judgment: This document incorporates professional judgment and experience from multiple projects alongside published sources. Where specific numeric values or cost ranges are provided based on project experience rather than published sources, this reflects industry practice and should be verified for specific applications.

Regulatory Variability: State and local regulatory requirements vary significantly and change frequently. Always consult current regulations and regulatory agency staff for site-specific compliance requirements.

No Legal Advice: This document provides technical and regulatory information but does not constitute legal advice. Airports facing PFAS contamination should consult qualified legal counsel regarding liability, compliance, and contractual issues.

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- Academic researchers advancing the science of PFAS environmental fate, toxicology, and treatment
- Aviation industry associations that have elevated PFAS as a sector-wide priority deserving coordinated response

The document also benefits from extensive review of peer-reviewed scientific literature, regulatory guidance documents, industry technical reports, and legal proceedings related to PFAS contamination. While specific citations are not included in the narrative text to maintain readability, the technical content reflects current scientific understanding as of 2025.

Any errors of fact or interpretation remain solely the responsibility of Division 31 GEO, LLC.

Contact for Professional Services

Users requiring professional PFAS investigation, remediation, or management services should contact Division 31 GEO, LLC directly to discuss formal engagement terms, scope of work, and contractual arrangements that include appropriate professional liability coverage and defined responsibilities.

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Professional services engagements are governed by separate written agreements that supersede the terms of this complimentary educational Report.

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A narrative exploration of regulatory frameworks, scientific realities, and the human choices that created a multi-billion dollar environmental challenge

Prepared by: **Division 31 GEO, LLC** Indianapolis, Indiana 2026

This document represents a comprehensive synthesis of technical, regulatory, economic, and operational information relevant to PFAS contamination at airports. It is intended as a reference resource for airport managers, regulators, engineers, and policymakers navigating the complex challenges of PFAS investigation, remediation, and long-term stewardship.

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