

Downwind

*How Failed Great Salt Lake Water Policy and Toxic
Dust Create Generational Debt and
Jeopardize Utah's Future*



Preface

The disappearance of the Great Salt Lake is a health and economic crisis for the entire Wasatch Front as well as a wildlife crisis of hemispheric proportions. This report provides the most comprehensive database assembled on the issue of air pollution caused by the continued desiccation of the Great Salt Lake, and it goes far beyond the media stories that have been generated so far.

This report seeks to help the public understand the economic liability of not saving the Great Salt Lake and outlines the myriad toxic impacts to Utahns from failing to raise lake levels. Utah Physicians for a Healthy Environment and the Utah Rivers Council's Great Salt Lake Waterkeeper have spent 18 months researching and summarizing this material and consulting some 577 published references.

When the Great Salt Lake, the largest remaining wetland ecosystem in the American West, reached its modern-day record low in 2022, alarm for its perilous future registered throughout the world. Global news outlets published stories about the demise of this saltwater ecosystem, which is critical to roughly 330 species of migratory birds traveling across the Western Hemisphere. Some 12 million individual birds depend upon the lake every year for survival, a fact that has generated national concern about the plight of the lake and Utah's failure to conserve it.

This historic decline is primarily a function of upstream water diversions approved over decades without the consideration of their impact on this precious aquatic landscape downstream. During this time, many of Utah's water policies discouraged water conservation and incentivized water waste, and there has been a reluctance to share water with the Great Salt Lake ecosystem among policymakers. Some baby steps have been taken in policy since 2022, but these measures are not nearly enough to stop the decline of the Great Salt Lake ecosystem or prevent the public health crisis posed by the desiccated lakebed.

If our objective is to raise Great Salt Lake to the minimum healthy level by the year 2045, then it is important to understand that all of the current measures combined only deliver 10% of the extra water the lake needs every year during this timeframe. This assumes that no new water diversions are allowed upstream and climate change and dust don't continue to shrink Northern Utah snowpacks — the source of most of the Great Salt Lake's water. Simply put, the conservation and water delivery efforts adopted by Utah so far will not come close to saving the broader Great Salt Lake ecosystem.

Despite this reality, state officials have demonstrated a resolute unwillingness to launch a realistic plan to save the Great Salt Lake. It isn't that their plan isn't good enough or that it won't work because it lacks a proper strategy or the resources for implementation. It's that there is essentially no plan to raise lake levels being offered that has any authority to be implemented. Numerous entities have created plans to raise Great Salt Lake water levels, including Utah Rivers Council. These plans have detailed water budgets to gauge our state's progress over the several decades required to raise water levels, but Utah is not implementing any of these plans.

Many of the news stories published since 2022 quote state legislators pitching new policies they claim will raise water levels with no counterbalancing opinions provided from critics who perceive the problems inherent in the proposed legislation. Utahns are being told that Utah has a concrete plan to save the lake, that a viable solution is just around the corner, and that water levels will soon rise. But after a brief respite in 2023 due to the largest winter snowpack in 40 years, the lake's water levels have resumed the alarming downward trajectory that began before the turn of this century.

The state continues approving upstream water diversions, thereby expanding the water footprint upstream of the Great Salt Lake and siphoning its water. Meanwhile, the state applies significant resources to obscure their lack of a restoration plan. Massive obstacles to preserving the lake's inflows were erected decades ago under pressure from special interests that monetized upstream water diversions, preventing substantive water volumes from entering the lake. Those obstacles are still in place.

There are many people inside and outside Utah state government who are passionately working to see the Great Salt Lake restored to a water level of 4,198 feet above sea level. The limitation is they are not the decision-makers in Utah government. Unwillingness to realistically address the lake's plight has become institutionalized among those decision-makers, and dealing with the tremendous, irreversible, and intergenerational damage it will cause is being off-loaded to future generations.

It appears that Utah's current plan is to dry up the North Arm of the Great Salt Lake. The next step will be the construction of new berms and dikes around the lake's South Arm to shrink the remaining lake into

a smaller and smaller footprint. This costly and inadequate strategy mirrors what was done to the Aral Sea, and similar strategies have failed to save other saline lakes that have disappeared around the globe.

Utah government's unlimited ability to construct berms and dikes around the Great Salt Lake was authorized in a mineral bill passed after the lake's 2022 record low. This bill was heralded as the lake's salvation, yet there was no acknowledgement of the consequences of allowing Utah to build dikes and berms without restrictions, sacrificing some areas of the lake as the remaining water gets pushed into a smaller surface area.

Then, in May of 2025, the Utah Speaker of the House proposed building berms on the Great Salt Lake's exposed lakebed to cover toxic dust hotspots. The details of this proposal are vague, and doubts remain whether this could actually mitigate air quality problems in the long term. Other proposed mitigation efforts actively being considered entail withdrawing groundwater to spray onto the dry lakebed, and media stories have been written about this "solution" to address the looming health crisis. Costly engineered stopgaps like these appear to be the foundation of the state's short-sighted leadership on the Great Salt Lake which could trigger a serious exodus out of Utah among wealthier households and younger populations.

It seems that Utah state government has given up on restoring the Great Salt Lake to the surface area of roughly 1,660 square miles required to prevent toxic dust storms and protect public health. At the time of this publication, the lake's surface area is only 950 square miles and its water level is only 1.5 feet above the 2022 record low. The least expensive option to preserve the lake and therefore a healthy future for the millions of people living in Northern Utah is for the legislative and executive branches to reduce diversions to the lake's rivers. But so far, they are refusing their obligation to do so. This will lock the state into more costly mitigation strategies, necessitating billions upon billions of taxpayer and ratepayer spending that could easily be avoided.

This report does not address the wildlife consequences of failing to restore the lake, and we only estimated the costs of creating a mitigation system to curtail toxic dust. Neither did we estimate the full scope of economic losses that have already begun from Utah's failure to sustain the Great Salt Lake. The foreseeable health consequences from a drying Great Salt Lake are disastrous and are already leading many residents to contemplate leaving Utah.

Our hope in producing this report is that by outlining the scope of the public health crisis looming from a desiccated Great Salt Lake and summarizing the mitigation costs to Utah taxpayers, we can show the Utah public that there is only one viable dust-mitigation solution: restore the Great Salt Lake's surface area to 1,660 square miles. Utah's future depends on it.

Downwind

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The Utah Rivers Council is a 501(c)(3) grassroots nonprofit organization dedicated to the conservation and stewardship of Utah's rivers and sustainable clean water sources for Utah's people and wildlife.



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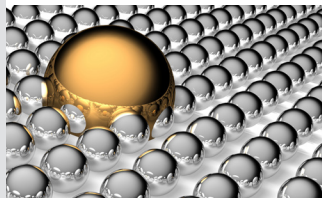
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Cover photo by David Jackson Photography.

Special thanks to Mary McFarland, Information Specialist at the Spencer S. Eccles Health Sciences Library, University of Utah, for her assistance organizing this report's citations.

The background image shows a vast, flat landscape, likely a salt flat, with a building in the middle ground and mountains in the distance. The sky is clear and blue. The text is overlaid on the upper portion of the image.

DUST PHYSICS OF THE GREAT SALT LAKE

SECTION
ONE

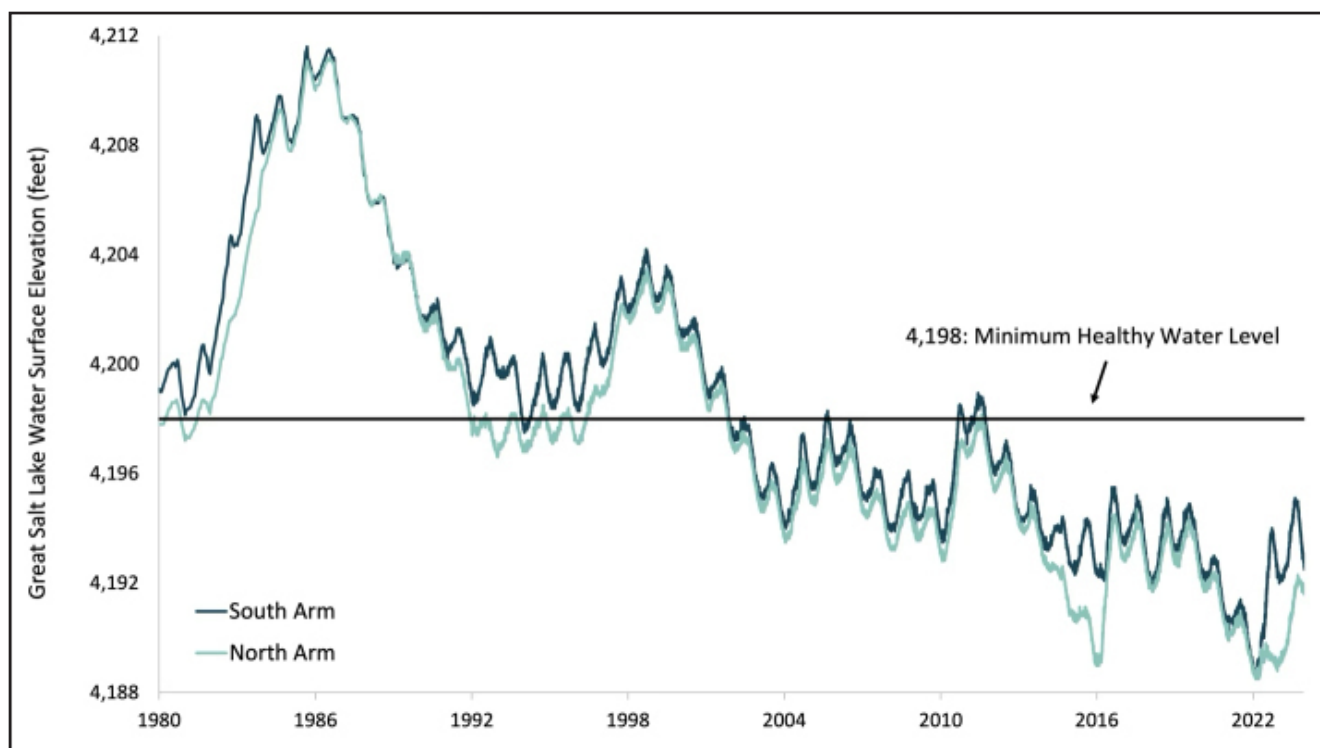
Declining Great Salt Lake Water Levels Create an Air Quality Problem

Dust Physics of the Great Salt Lake

The water levels of the Great Salt Lake have been in a long-term decline since the late 1980s. The driving cause of this decline is increased, unsustainable upstream diversions of the Lake's main tributary rivers – namely the Bear, Weber, and Jordan Rivers.^{1,2,3,4} Since the mid 19th century, diversions have reduced inflows from tributary rivers approximately 39%, leading to an overall decline of 64% in the water volume of the Great Salt Lake.⁵ Figure 1 shows the decline in water levels of the Great Salt Lake – both its North and South Arms – since the late 1980s.

An array of scientific studies and agency reports have studied optimal water levels for the Great Salt Lake and have recommended a 'Goldilocks' lake level range.^{6,7} These studies considered various uses of and services for the Great Salt Lake and the \$1.9 billion economy it supports. The general consensus among these findings is that the minimum sustainable level for the Great Salt Lake that optimizes most of the uses and ecosystem services for the water body is 4,198 feet above sea level, as shown in Figure 1.

Figure 1: Great Salt Lake Water Levels, 1980-2024



Both the North and South Arms of the Great Salt Lake – which are divided by a railroad causeway – have been in decline since the late 1980s and have mostly been below the 4,198-foot minimum healthy level since the year 2000. Data from USGS.^{8,9}

Below that optimum level of 4,198 feet, there is a ripple effect of impacts. Declining Great Salt Lake water levels create a number of deleterious impacts to migratory birds, wetlands, native flora and fauna, industries that rely on the Lake, recreationists, tourists, and others. The Utah Rivers Council's 4,200 Project outlines the many impacts accruing to the Great Salt Lake ecosystem as a function of upstream water diversions, alongside comprehensive policy solutions to raise water levels. More information can be found at 4200project.org. One of the most widely-felt consequences of declining Great Salt Lake water levels is the negative impact on Wasatch Front air quality.

Great Salt Lake Dust is Carried by Wind to Utah's Major Population Centers



Saltair at the Great Salt Lake. High winds carry particulate dust and toxins from the exposed lakebed of the Great Salt Lake, creating unhealthy air conditions along the Wasatch Front. Image from Wikimedia Commons.

The exposed lakebed of the Great Salt Lake contains many fine grains of dust and toxins, including heavy metals, neurotoxins, harmful organic compounds, and a wide variety of industrial pollutants.^{10,11,12,13} When winds blow across the exposed lakebed, they pick up these dust particles, which may have toxic molecules intermeshed, and transport these particles toward Utah's population centers along the Wasatch Front, greatly reducing air quality.

Much of the literature on Great Salt Lake dust emissions focuses on "dust storms," or short periods, usually a few hours to a few days, when sufficiently strong winds blow across the Great Salt Lake's lakebed and pick up significant quantities of dust. From 1930 to 2020, Salt Lake City saw an average of 4.7 storms per year.¹⁴ Since then, declining lake levels have exposed larger tracts of lakebed.^{15,16} These growing areas of dry lakebed may increase impacts on public health downwind, but there is a lack of peer-reviewed science to demonstrate this trend at this time.

Windstorms rapidly load the air with high quantities of particulate pollutants and toxins from the dry lakebed, posing serious public health threats.

These storms are dangerous as they rapidly load the air with high quantities of particulate matter pollutants and toxins that pose a number of serious public health threats. Particulate matter pollutants are typically broken into multiple categories based on the size of the particle. The largest category regulated by the U.S. Environmental Protection Agency is referred to as PM₁₀, also referred to as “coarse-mode” particles, and includes particles that are between 10 and 2.5 microns in size. A micron is 0.000001 meters, or one millionth of a meter. Particles 10 microns in size and smaller are widely thought to be those capable of being inhaled, thus the focus of government regulations. A second category is PM_{2.5} particles, 2.5 microns and smaller. PM_{2.5} is the most common size monitored and is the size most referred to in air pollution research.

PM_{2.5} can be divided further into two subset sizes, a third size of particulate matter called “accumulation-mode” particles, between 0.1 and 2.5 microns, and a fourth class size called “ultrafine particles,” which are particles 0.1 microns or smaller. Ultrafine particles are the most difficult to detect by conventional monitors. While all classes of particulate pollution are harmful, generally the health hazard potential of a particle is inversely proportional to its size for reasons that will be detailed later in this report.¹⁷

Ultrafine particles are usually thought of as the products of high temperature combustion, such as with wood and fossil fuels, and much of the science conducted concluded that mineral dust particles alone are usually larger than 2.5 microns. However, newer science has found significant numbers of ultrafines and accumulation-mode particles in desert dust.¹⁸

As one group of authors stated, “dust particles were initially associated with coarse modes, although subsequent studies clarified that they also exist in the fine mode.”¹⁹

Because ultrafines are ubiquitous and continually added to the global atmosphere from these combustion sources, it is reasonable to expect that ultrafine particles from those same sources will also be found in the Great Salt Lake and its sediments. Ultrafine-size plastic nanoparticles have been documented in Great Salt Lake dust, discussed later in this report.

Several studies have used a variety of methods to demonstrate that dust from the Great Salt Lake’s lakebed is being blown toward the Wasatch Front. A 2018 article used atmospheric back trajectory modeling to determine that a single dust storm that occurred from April 13th to 14th, 2017 originated at the Great Salt Lake, blew through the Salt Lake Valley, and deposited a significant amount of dust onto snow near Alta, Utah.²⁰ Aside from posing a public health risk, this storm also significantly increased the snowpack’s capacity to absorb solar radiation, accelerating melt by an estimated 25%.²¹

A different study found that dust from the Great Salt Lake has a unique strontium isotope ratio that can act as a sort of ‘chemical tracker’ to

Aside from posing public health risks, dust storms can increase snowpack's capacity to absorb solar radiation, accelerating melt by an estimated 25%.

identify Great Salt Lake dust that has been blown into nearby population centers and mountains. Using this unique isotope ratio, researchers were able to determine that the lake contributed between 30% and 34% of Salt Lake City's, Ogden's, and Logan's dust load, about 5% of Provo's dust load, about 11% of the Uinta Mountain's dust load, and about 22% of the Wasatch Mountain Range dust load.²²

Another study also used modeling to examine how declining Great Salt Lake water levels could increase dust emissions in the future. These researchers found that declining Great Salt Lake water levels could increase PM_{2.5} concentrations by 8%, and that, based on current and expected demographic distributions around the Salt Lake Valley, people of color and people without a high school diploma would experience the greatest exposure to these heightened pollution levels.²³

Dust storms may not be the only mechanism by which dust is transported from the Great Salt Lake to the Wasatch Front. Traditionally, physicists have assumed that the process known as saltation drives dust emissions.^{24,25} In saltation, grains of sand are blown horizontally along the ground by wind, causing them to skip and hop. As these sand grains impact the ground at the bottom of each skip, they dislodge more sand grains, creating a cascading effect. Importantly, however, dust is also dislodged by incoming sand grains, and since the dust is so much smaller than the sand grains, it is ejected away from the ground and into the air where it remains suspended. This barrage of sand grains releasing dust into the air is called saltation bombardment, and under sufficiently high wind conditions like those present during dust storms, it can release large quantities of dust into the air.²⁶

Another mechanism exists that can also move dust into the air, called aerodynamic entrainment. In aerodynamic entrainment, no saltation occurs because winds do not reach speeds high enough to move sand grains. Rather, surface dust particles are picked up by lower-speed winds and are carried into the air directly.²⁷

The amount of dust emitted by aerodynamic entrainment is therefore limited by the supply of surface dust particles.²⁸ However, researchers have shown that if surface dust particles are replenished by some source, such as an erodible crust, then aerodynamic entrainment can continuously loft dust into the air.^{29,30,31}

California's Owens Lake Shows a Possible Future for the Great Salt Lake



Dust clouds blowing off the dry lakebed of Owens Lake in California. Owens Lake provides a real-world example of how exposed lakebeds throw PM₁₀ particles into the air during windstorms. Image from Wikimedia Commons.

Scientists have observed aerodynamic entrainment in environments that are seemingly closely analogous to the Great Salt Lake's lakebed. One study in California at Owens Lake demonstrated that PM₁₀ can become airborne when winds speeds are very low, only half that required for saltation.³² In this case, the lofting of PM₁₀ under aerodynamic entrainment is so subtle it could not be detected by the human eye, only by instrumentation. This does not mean the dust emissions were insignificant. The researchers found that PM₁₀ concentrations from aerodynamic entrainment were up to 30% of those that occur during saltation.³³ In other words, their research shows that aerodynamic entrainment could be responsible for up to about a third of the PM₁₀ emissions at Owens Lake. However, it is theorized that particle size distributions at Owens Lake are smaller than at the Great Salt Lake. Similar research has shown that aerodynamic entrainment also occurs in desert playas of the Mojave Desert that stretch across southeast California and parts of the southwest, and Central Asia's Aral Sea, where particulate matter has also been observed being lofted into the air by very weak winds.^{34,35}

Aerodynamic entrainment is significant because it can occur at much lower wind speed thresholds. It doesn't require strong winds and an obvious dust storm to bring large quantities of dust into the air of population centers. Rather, modest winds, which are likely to occur far more often, are sufficient to mobilize dust. While less dust is likely transported by any single aerodynamic entrainment event than by a dust storm, the higher frequency of these aerodynamic entrainment events

Regardless of the mechanism, the Great Salt Lake's lakebed has been proven to be a significant source of Wasatch Front dust.

may mean that under the right conditions, a more regular stream of dust may occur.

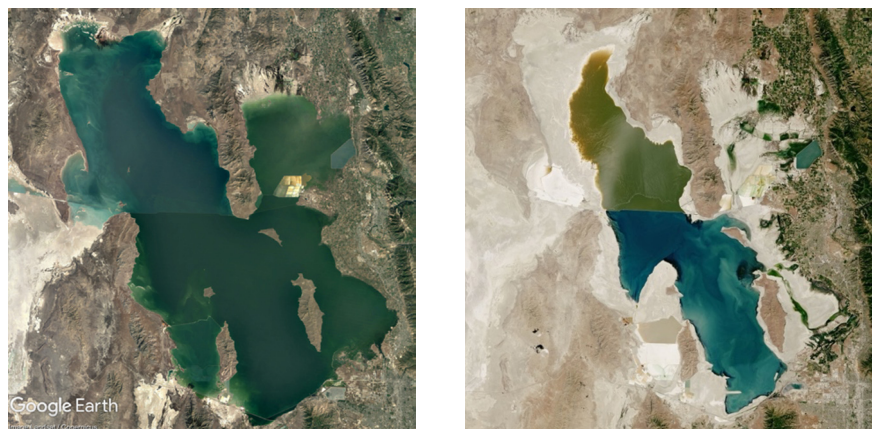
This has potentially significant implications for Wasatch Front air quality. If aerodynamic entrainment is occurring on the Great Salt Lake's lakebed, it could represent a significant and overlooked source of dust emissions. To be clear, we are not aware of any studies that have tested whether aerodynamic entrainment occurs on the Great Salt Lake's lakebed or whether this mechanism is carrying dust from the lakebed to the Wasatch Front. But, given that aerodynamic entrainment has been observed at places analogous to the Great Salt Lake, such as Owens Lake, the Aral Sea, and playas in the Mojave Desert, it seems a plausible possibility and worthy of further investigation. Regardless of the mechanism, the Great Salt Lake's lakebed has been proven to be a significant source of Wasatch Front dust.

Great Salt Lake Water Levels Determine How Much Dust is Exposed

The Great Salt Lake has a large surface area but is relatively shallow, meaning that even small changes in water levels can expose large tracts of land to the air. Large changes in water levels – like the decline that has occurred since the late 1980s – exposes substantially more land.

In 1987 the water levels of the Lake reached a record high elevation of 4,211 feet, covering approximately 1,520,000 acres with water. In 2022, the water levels of the Lake reached a record low elevation of 4,188.5 feet, reducing the Lake's surface area to just 564,000 acres and exposing 964,000 acres of previously inundated land to the air. Put differently, the decline in Great Salt Lake water levels from 1987 to 2022 exposed an area of land slightly larger than the entire state of Rhode Island.³⁷ Figure 2 shows satellite images of the Great Salt Lake in 1987 and 2022, visually demonstrating the extent of land that was exposed.

Figure 2: Satellite Images of the Great Salt Lake, 1987 & 2022



Satellite images of the Great Salt Lake in 1987 near its record high (left) and in 2022 near its record low (right).

Images from Google Earth³⁸ and NASA.³⁹

The Great Salt Lake's lakebed is not uniform. Different areas of the lakebed have different physical characteristics, making some areas more emissive – capable of producing airborne dust. From 2016 to 2018, Dr. Kevin Perry, a professor of Atmospheric Sciences at the University of Utah, surveyed and sampled the majority of the exposed portions of the Great Salt Lake's lakebed to determine the emissive properties of different portions of the lakebed. He divided the lakebed into 122 subunits, visited each one, and recorded a number of observations, including the extent of vegetation, the thickness of surface crust, whether the surface crust was erodible, and what the land cover mix was composed of including: visibly fine particles, cobbles, sand, or other substrates.

Dr. Perry collected 5,323 samples, with each sample representing an area of either approximately 139 acres, 62 acres, or 15 acres.⁴⁰ The difference in size is due to the different size of sampling grid for different portions of the Lake. Dr. Perry purposely designed his survey this way to ensure an even distribution and adequate number of samples across the entire lakebed, which is best practice for surveys of this kind.

While conducting his survey, Dr. Perry observed that parcels containing no vegetation, no surface crusts or thin and erodible surface crusts, and visibly fine particles were emissive. He classified parcels containing these characteristics as dust hotspots.

However, Dr. Perry states that these criteria likely underestimate the true number of dust hotspots on the Great Salt Lake lakebed. This is because he was unable to access some portions of the Great Salt Lake during his survey because of thick mud, dense vegetation, and other problems, making it likely that some hotspots did not get sampled. Additionally, the criteria used to determine what counts as a hotspot (no vegetation, no surface crusts or thin and erodible surface crusts, and visibly fine particles) may exclude areas of land that are actually emissive. For example, a parcel with a small amount of vegetation could still emit dust under the right conditions. Therefore, Dr. Perry's data likely represents a minimum bound of dust hotspots.

Dr. Perry released data of every sampling site in Appendix C of his report.⁴¹ The Utah Rivers Council obtained the data from this appendix and sorted through the data to identify dust hotspots, or samples that had the following characteristics: no vegetation, no surface crusts or thin and erodible surface crusts, and visibly fine particles. From this analysis, the Utah Rivers Council identified sampling sites that met the stated criteria for the emissive category, effectively representing the dust hotspots of the Great Salt Lake's lakebed.

The Utah Rivers Council then determined the elevation of each hotspot location by using the U.S. Geological Survey's Elevation Point Query Service and latitude-longitude coordinates for each hotspot.⁴² This gave us a table of data indicating the size and elevation of each dust hotspot.

For sections that were underwater during his period of field survey, Dr. Perry theorized that for three of the four quadrants of the Lake, hotspots are unlikely to exist below the 4,194-foot elevation level because below 4,194 feet, both Farmington and Bear River Bays are effectively drained and all hotspots are already exposed. In the North Arm of the Great Salt Lake – an area that is much more saline than the rest of the Lake – Dr. Perry believes that a thick layer of accumulated salt crust would prevent the exposure of any new hotspots. However, as water levels recede in the South Arm of the Great Salt Lake, Dr. Perry theorized that new hotspots are likely to appear. Specifically, Dr. Perry stated:

However, unlike Farmington Bay and Bear River Bay, further reductions in the Great Salt Lake elevation below 4194 ft are likely to follow the same linear trend with regards to the number of dust “hotspots” exposed. The reason for this is that Gilbert Bay still has significant surface area of lakebed to expose if the lake level were to continue dropping.⁴³

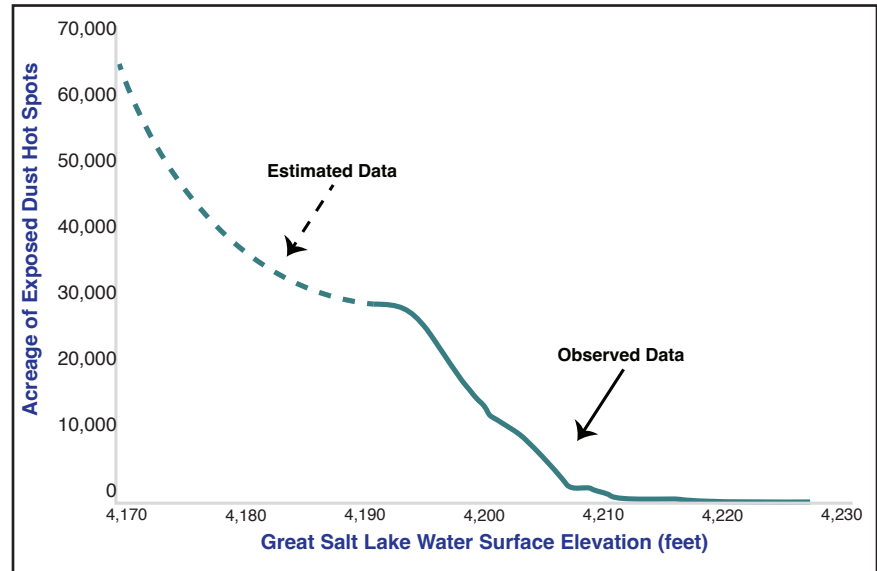
The Utah Rivers Council used this correlation to extrapolate estimated hotspots down to the approximate minimum elevation of the Great Salt Lake of 4,170 feet – an elevation at which the Lake is effectively dried up. In other words, below elevation 4,196 feet, the lowest elevation data point, the Utah Rivers Council assumed that the acreage of hotspots in most of the Lake would remain constant, but hotspots in the South Arm would increase by 11.67% for every additional one-foot decline. Table 1 shows the approximate area of dust hotspots for select Great Salt Lake water surface elevations.

Table 1: Acreage of Exposed Dust Hotspots by GSL Elevation

GSL Water Surface Elevation	Exposed Lakebed (acres)	Exposed Dust Hotspots (acres)
4,194	927,000	30,911
4,188	1,069,000	35,705

Figure 3 shows the acreage of uncovered dust hotspots given various Great Salt Lake water surface elevations. The solid line represents Dr. Perry’s observed data while the dashed line represents an estimate of hotspots below elevation 4,196.

Figure 3: Water Surface Elevation vs. Acreage of Exposed Dust Hotspots



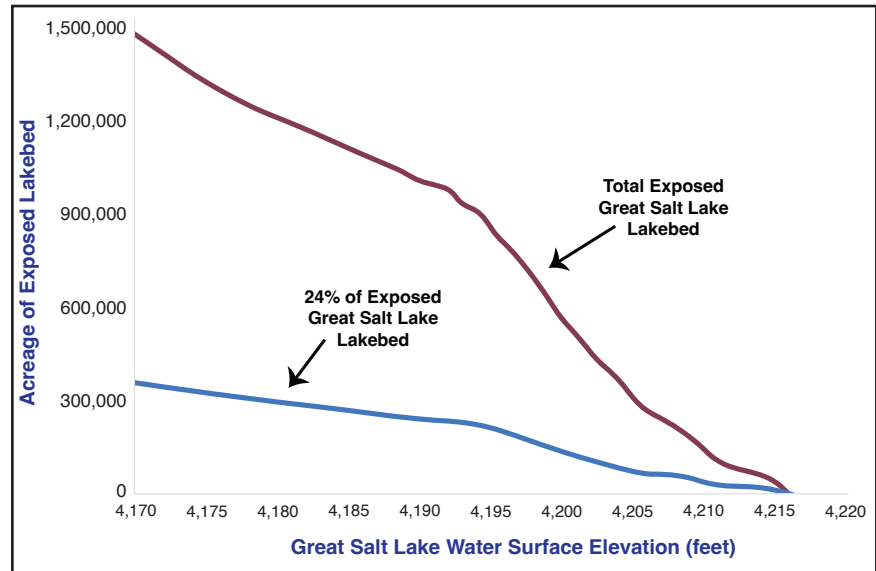
*As Great Salt Lake water levels decrease, more dust hotspots are exposed.
Graph created using data from Perry, Crosman, and Hoch (2019).⁴⁴*

Hotspots exist all around the Great Salt Lake and at different elevations, meaning that as Great Salt Lake water levels rise or fall, different hotspots become covered or uncovered by water. Since hotspots cannot emit any dust when covered by water, the water level of the Great Salt Lake plays a strong role in determining the number of hotspots. As one would expect, the lower the water level of the Great Salt Lake, the larger the acreage of dust-producing land. But this relationship is not perfectly linear. This is due in large part to the physical characteristics of different portions of the Great Salt Lake.

Notably, however, Dr. Perry theorizes that as more lakebed remains exposed for longer periods of time, new hotspots could form. This could increase to the point where hotspots cover as much as 24% of the total exposed lake bed.

The financial costs of a drying Great Salt Lake lakebed are important to consider for Utahns. In order to estimate costs for this scenario, we calculated the total exposed lakebed at different Great Salt Lake water levels using data from Tarboton (2017).⁴⁵ Then, using the 24% lakebed coverage, we estimated the number of acres that would need to be mitigated at the Great Salt Lake. The results are shown in Figure 4.

Figure 4: Water Surface Elevation vs. Acreage of Exposed Dust Hotspots Using 24% Coverage Ratio



As more lakebed remains exposed for longer periods of time, new hotspots could form. We used an estimate from Dr. Kevin Perry to provide a high-end estimate of the number of potential dust-producing acres at the Great Salt Lake. Data from Tarboton (2017).⁴⁶

New Water Diversions Could Expose More Dust Hotspots

If approved, proposed Bear River Development could deplete, or withhold from the Great Salt Lake, somewhere between 120,000 and 200,000 acre-feet of water every year.

As seen in Figure 4, as Great Salt Lake water levels fall, more hotspots are exposed. This makes proposals to further deplete water from the Lake's major tributaries especially problematic. The largest planned water diversion in Utah is the proposed Bear River Development – a project to build several new diversions, three to four new dams, almost 100 miles of pipeline, a new water treatment plant, and other infrastructure – to divert up to 400,000 acre-feet of Bear River water upstream of the Great Salt Lake every year.^{47,48}

It is important to note that not all of the 400,000 acre-feet of water diverted from the project would be withheld from the Great Salt Lake. Some of the diverted water would be used and then returned to one of the Lake's tributary rivers or the lake itself, mostly through the discharge of wastewater from treatment plants. Therefore, to ascertain the impact of Bear River Development on the Great Salt Lake, we need to determine the amount of water that is diverted away from and not returned to the Lake. This is known as a water depletion.

Water depletions vary from community to community in Utah, depending on the water delivery and treatment infrastructure in a given community, the extent of indoor versus outdoor water use, the conservation incentives and mandates in effect, and other factors. The Division of Water Resources reports that communities slated to

More Bear River diversions could lower Lake levels by several feet in a decade, reversing progress made to restore water levels.

receive water from Bear River Development have depletion rates of approximately 30% to 50%.⁴⁹ This means that, if built, Bear River Development could deplete, or withhold from the Great Salt Lake, somewhere between 120,000 and 200,000 acre-feet of water every year.

Withholding 120,000 to 200,000 acre-feet of water from the Great Salt Lake annually would likely produce only a moderate change in Lake levels in any single year. Depending on the Lake level, a reduction of 120,000 to 200,000 acre-feet of water could reduce levels by approximately half a foot. But these reductions in water levels will have a cumulative impact. Over a ten-year period, Bear River Development could withhold 1,200,000 to 2,000,000 acre-feet of water from the Lake. That's enough of an impact to drop Lake levels several feet.

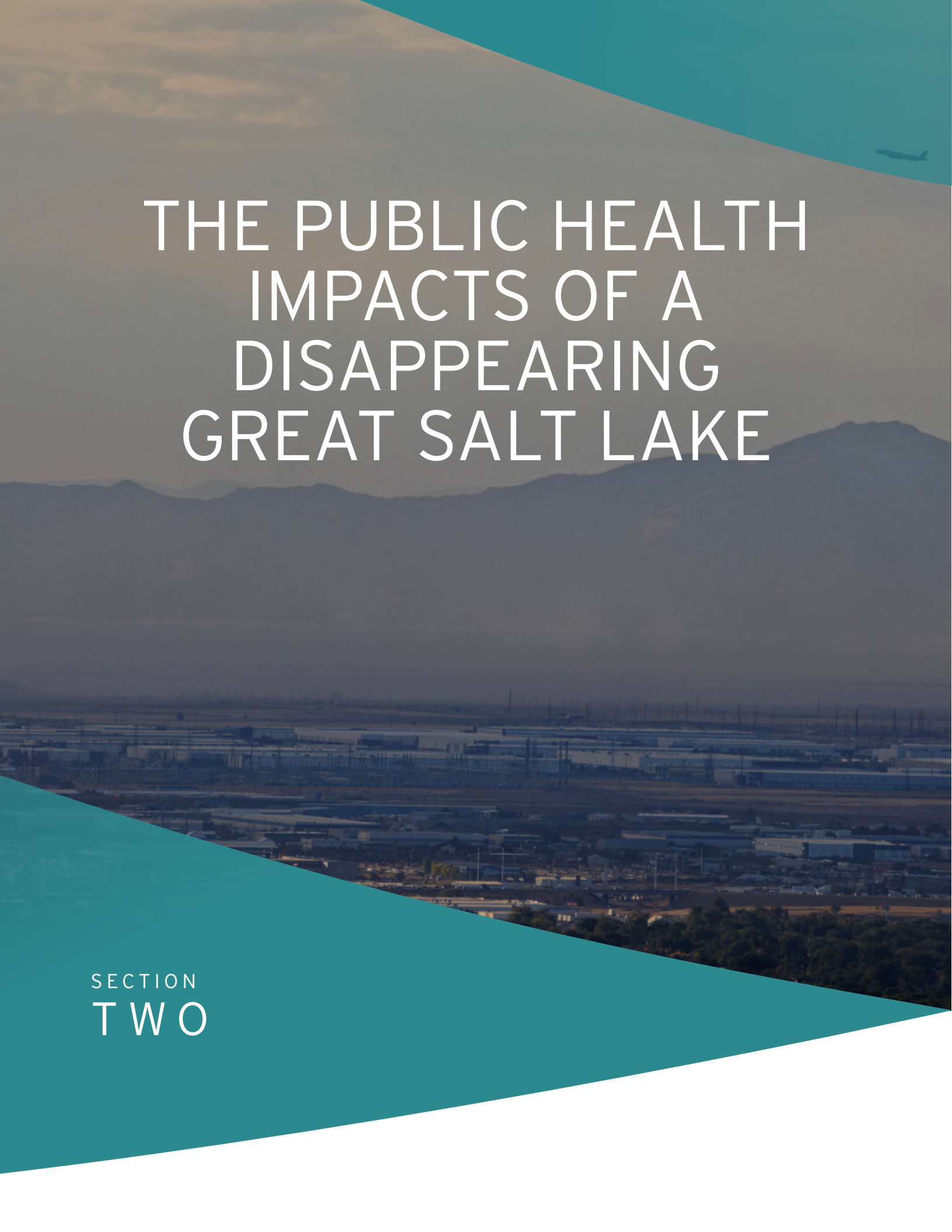
Bear River Development is not the only new water diversion that could occur on the Bear River. According to a study from Utah State University, the Bear River Compact – an agreement between Utah, Idaho, and Wyoming that governs the use of Bear River water – envisions that as much as 1.3 million acre-feet of water could be developed, which would lower the Great Salt Lake by an estimated 5.4 feet.⁵⁰

Planned future water diversions upstream of the Lake not only impede Utahns' collective efforts to reverse the long-term decline of the Great Salt Lake and raise it back to a minimum healthy elevation of 4,198 feet, they also further lower Lake levels and expose many more acres of dust-producing lakebed.

Toxic Dust From the Depleted Great Salt Lake Endangers Us All



Salt Lake City in the late afternoon. As the Great Salt Lake dries due to climate change and upstream diversions, more of the lakebed becomes exposed, posing serious air pollution health risks to residents along the Wasatch Front. Image from Wikimedia Commons.

The background of the entire page is an aerial photograph of an industrial area, likely a port or refinery, with numerous large storage tanks and buildings. In the distance, a range of mountains is visible under a hazy sky. A small airplane is seen in the upper right corner. The image is framed by teal-colored geometric shapes: a large triangle in the top right corner and a larger triangle in the bottom left corner that points towards the center.

THE PUBLIC HEALTH IMPACTS OF A DISAPPEARING GREAT SALT LAKE

SECTION
TWO

Introduction

The evolving saga of Great Salt Lake dust is emblematic of a story repeated many times in the past. Environmental threats and contaminants, chemicals, compounds, pharmaceuticals and various consumer goods are initially claimed to be harmless, released into the market, become popular, profitable, and widespread use ensues. Then evidence of toxicity and harm emerges and eventually becomes so undeniable that continued pretense of their safety becomes pointless. But by then, widespread, massive damage to public health has been done and is often irreversible. Lead, mercury, hexavalent chromium, perchlorate, asbestos, nuclear radiation, tobacco, oxycontin and numerous other pharmaceuticals, pesticides such as DDT and chlorpyrifos, and a range of chemicals that include BPA, PCBs, flame retardants, and PFAS are some of many examples of this all too common scenario.

In virtually all these cases, political pressure or paralysis, industry malfeasance, or claims of insufficient research was the excuse for allowing ongoing exposure with millions of lives lost or damaged over many decades. In all these cases, including some ongoing, the precautionary principle in medicine was not followed. This approach to public policy calls for preventive measures to avoid public health hazards when the evidence of serious harm is plausible and consistent with overall health research, even if that evidence is incomplete.¹

The reasonableness of enacting a preventive measure to a potential threat depends on calculating the benefit versus the harm of the action considered. In all these examples, the benefit of preventive action would have far exceeded the cost. However, when weighing whether to mitigate or prevent an impending catastrophic outcome, the usual rules of cost versus benefit no longer apply.²

There are very few examples of precautionary efforts turning out to be wasted or economically costly because the hazard of a substance suggested by early research was later contradicted by more complete research (early false positives). Costs of overreacting are rare. But consequences of insufficient or delayed responses to what turn out to be false negatives are frequently excessive and irreversible.³

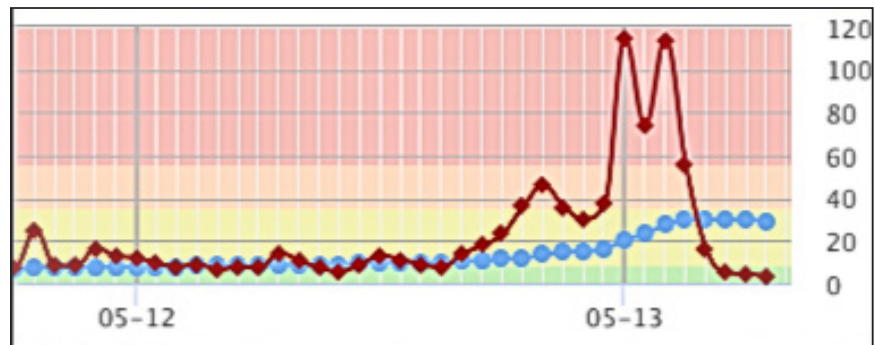
We believe the precautionary principle is not being followed in public policy regarding the shrinking of Great Salt Lake and the issue is indeed whether lawmakers will mitigate a looming catastrophic outcome. We believe that the benefit to public health of preserving the lake and aggressively suppressing its dust far exceeds the harm of the policies necessary to accomplish that. As with these many other examples, great harm to millions of people will ensue if policymakers insist on more evidence before serious action is taken to restore the lake to a viable level. This report details the existing evidence for public health harm that can reasonably be anticipated by allowing the lake to continue to contract, with much of that harm occurring from increasing dust emissions because of the expanding dry lakebed.

Great harm to millions of people will ensue if policy makers insist on more evidence before serious action is taken to restore the lake to a viable level.

Since the Mormon pioneers arrived in the Salt Lake Valley in 1847, the Great Salt Lake ecosystem has been under ever-mounting stress from the nearby development of human settlement. In the 178 years since, millions of people have migrated to Utah, and resultant large-scale mining, agricultural, and other industrial operations have contaminated the lake and extracted, consumed, and diverted its water. Many of the toxic chemical byproducts of modern civilization have been accumulating in the lake and settling into the lakebed. As Great Salt Lake levels decline, increasingly large tracts of dust-producing lakebed become exposed to the air. The toxins can then be carried by dust particles downwind toward Utah's Wasatch Front population center, posing a potentially substantial public health threat.

Large, obvious Great Salt Lake dust storms occur several times a year, but days with the threshold speed for fine particles to launch into the atmosphere are much more frequent. It is almost certain that health consequences of dust from a dried up lake bed also occur in between widely recognized dust storms. The threshold wind speed for suspending the smallest particles of dry soil in a desert landscape can be as low as 10 mph.⁴ And it is the smallest particles that constitute the greatest health hazard as explained later in the report. The wind speed over the Great Salt Lake is highest in April with a mean average hourly wind speed of 6.8. But it is important to remember that is only a mean average so that the threshold of 10 mph will often be exceeded.⁵ The wind is usually from the west for 2.7 months, from April 2 to June 22, with a peak percentage of 33% on May 2. For the remainder of the year the wind usually blows from the south.⁵

Figure 5: Dramatic spikes in PM2.5 are common from Great Salt Lake dust storms



A Division of Air Quality monitor in Salt Lake City at Hawthorne station on the night of May 12- May 13, 2025 shows a huge spike up to 120 ug/m3 from a dust storm. Because the spike occurred at night, it wasn't easily visible to the public. Graph courtesy of the Utah Division of Air Quality.

The problem is not just obvious dust storms. Wind as slow as 10 mph can send surface particles into the atmosphere.

Once atmospheric, prevailing westerly winds carry the dust towards residents of the Wasatch Front, who account for the majority of Utah's total population. This report documents a cascade of public health consequences from this dust, whether exposure occurs as readily visible "dust storms" provoked by strong winds, or more common, less visible, less dramatic degradation of air quality from lesser winds. Some of what is discussed in this report is from research specific to the Great Salt Lake and the Utah population, and much more is what can be reasonably inferred by extrapolating from research from around the globe. Though the Wasatch Front is where most of the human impact from Great Salt Lake dust is felt, numerous studies have proven that desert dust can be carried thousands of miles and that dust storms anywhere can have a health impact on a global scale.⁶ Given that there is no safe level of air pollution exposure,⁷ Great Salt Lake dust carried hundreds or even thousands of miles away will have a small impact on the public health of a large number of people beyond the Wasatch Front.

Mineral dust particles suspended in the atmosphere can widely vary in size from less than 0.1 microns, commonly called ultrafines, to 100 microns.⁸ Mineral dust accounts for two-thirds of the total particulate pollution in the global atmosphere.⁹

Substances considered "natural" are often mistaken as benign. Wood smoke, heavy metals, asbestos, many radioactive isotopes, and micro-organisms are "natural," but can be deadly. Likewise, dust may be "natural," but dust pollution is toxic and can be as toxic as that from more readily identifiable sources of pollution such as fossil fuels. As an inhalable contaminant, dust particles can provoke adverse health outcomes in two major ways. First, regardless of the elemental make-up of the particle, the arrival of foreign material in the lungs triggers a direct and cumulative response of the immune system¹⁰ followed by a cascade of inflammatory chemicals.

Second, dust particles, as with any other pollution particles, can act as carriers for adsorbed material like plastic nanoparticles, heavy metals, industrial chemical compounds and others that can enhance the inflammatory cascade. As one study author put it, "Dust is a complex matrix of mineral particles with chemical coatings, gases, water with dissolved chemical species in equilibrium with the particulate coatings, and many forms of organic matter."

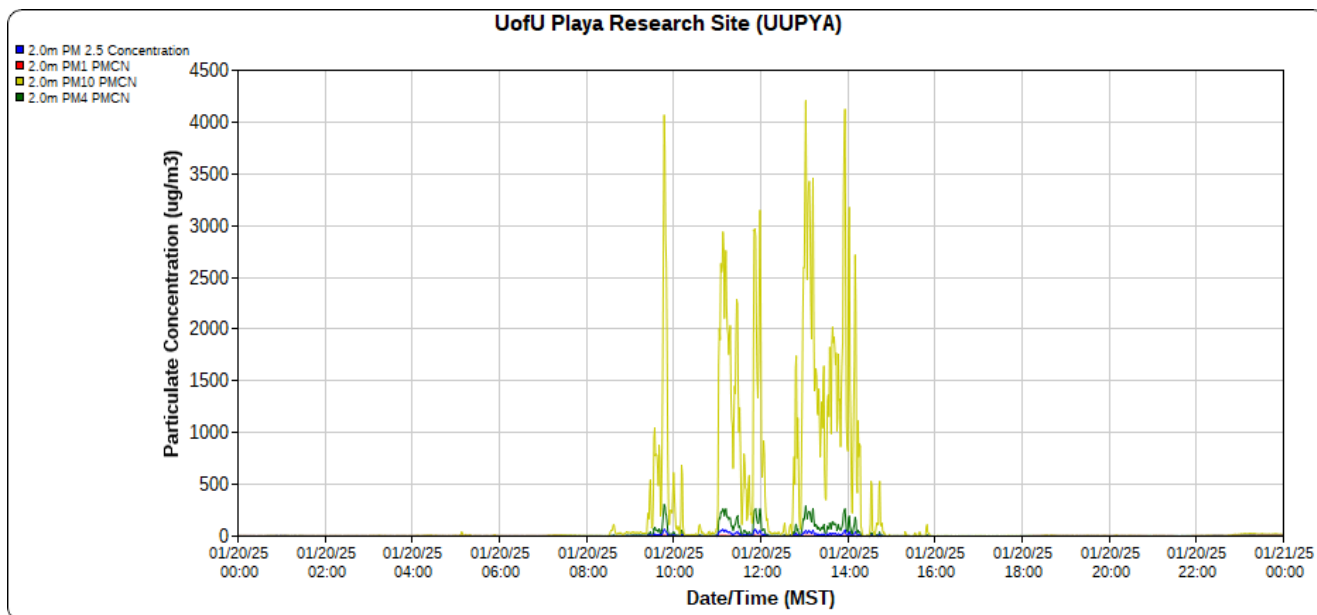
The next series of photographs and charts document a significant dust storm on January 20, 2025, originating from Great Salt Lake despite minimal winds and typical winter temperatures and precipitation.

Figure 6: Approaching dust cloud visible from the west, behind an eastern Salt Lake Valley neighborhood



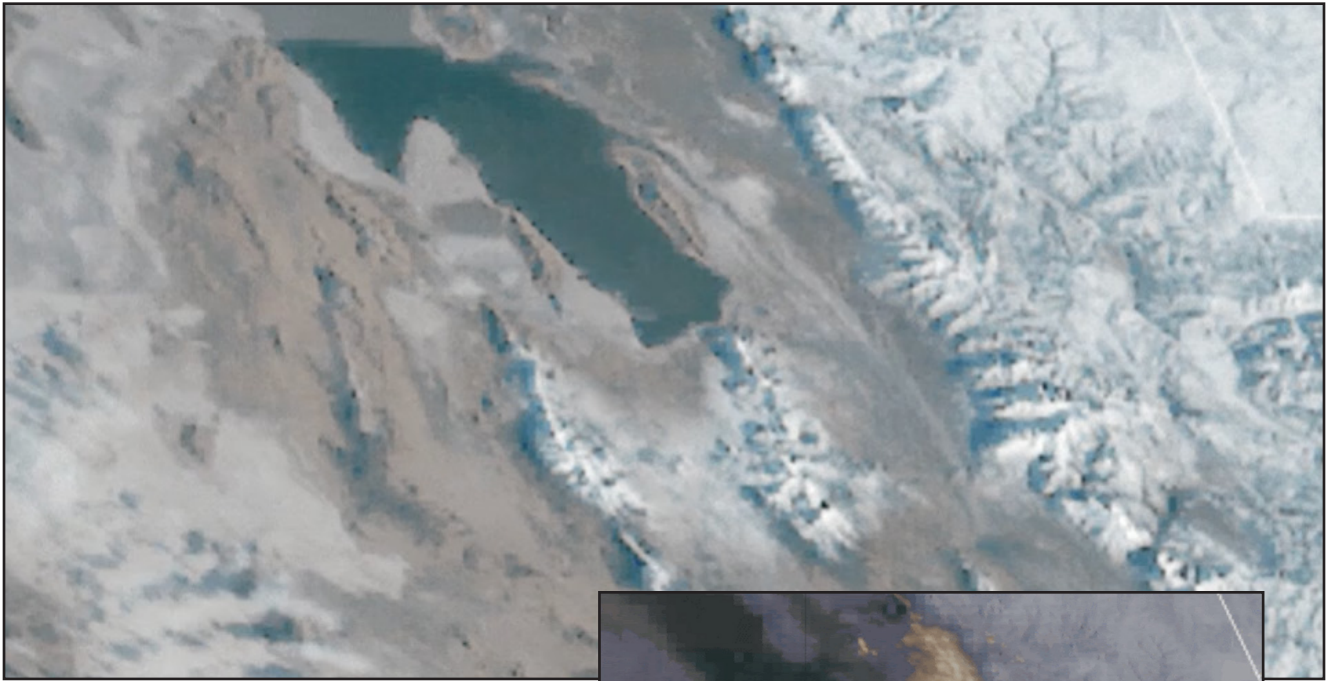
View to the West from an eastside Salt Lake Valley neighborhood of the January dust storm coming from Great Salt Lake. It is especially alarming that this occurred in the middle of winter.

Figure 7: Sharp spike in PM_{2.5} during the storm



A recording from the PM_{2.5} monitoring station operated by the U. of Utah Department of Atmospheric Sciences on the Farmington Bay playa about 7 km south of the causeway entrance, shows the corresponding sharp spike in PM_{2.5}. Graph courtesy of MesoWest (Horel et al. 2002).

Figure 8: Great Salt Lake storm visible from satellite



The same dust storm was visible from a satellite. The yellow arrow points to a band of dust from Great Salt Lake drifting over the Wasatch Front, extending south to Utah Lake. Image courtesy of CSU/CIRA & NOAA

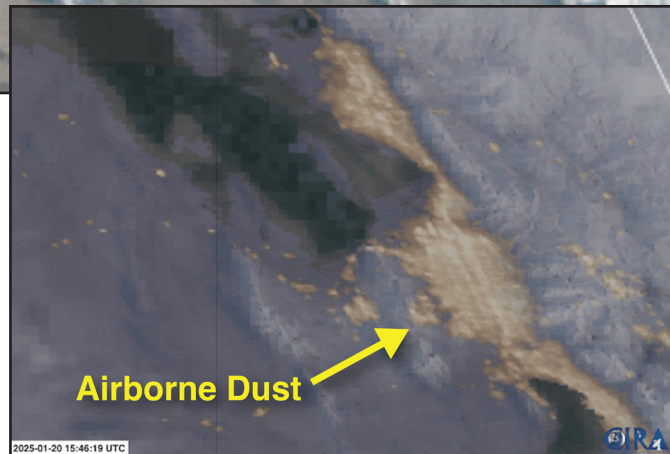
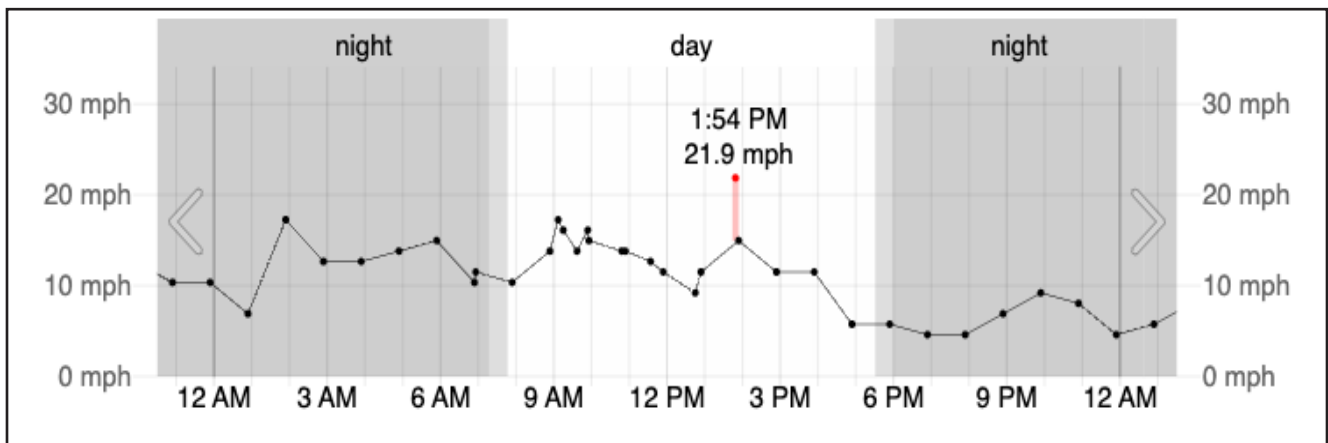


Figure 9: Very low levels of wind can cause dust storms



Recording of wind speeds over Salt Lake City during the time of the dust storm. Note that the wind speeds that day were only between 10 and 15 mph. Graph courtesy of James Diebel, on WeatherSpark.

“My wife and I were given tickets to see the band Bleachers at the Great Saltair. As we drove out to the venue, we talked about how chemicals and heavy metals associated with the copper mine have polluted Great Salt Lake. After the band had been playing for about an hour, a storm started brewing in the distance behind the stage. The wind picked up and the band played on as best they could. But eventually, the dust blowing over the crowd became so thick and choking that people ran from the concert to their cars and the band was pulled from the stage before they could finish their set. During the strongest wind, I had to turn my back to the wind and get on the ground to protect my face. I think it was then that the disappearance of the Great Salt Lake and the impact that it can have on my family’s health and our quality of life became very, very real.”

— Nick Merrill

There are many published medical studies documenting the effect of dust events which show the impact of short-term air pollution on human health. However, isolating the health hazard specifically from dust from the dry Great Salt Lake bed is difficult because there are no good control groups that are not also exposed to other pollution types and sources and no longitudinal health studies over a long-term period devoted to addressing this concern. Reviewing the available epidemiologic literature on dust exposure however, allows us to draw some important conclusions.

Studies from Africa, Taiwan, and elsewhere show desert dust exposure is associated with morbidity and mortality.^{11,12} As with other types of particulate pollution, the smaller the dust particle the more damage is possible once inhaled, ingested or absorbed through the skin or nasal mucosa, the inside lining of the nose.

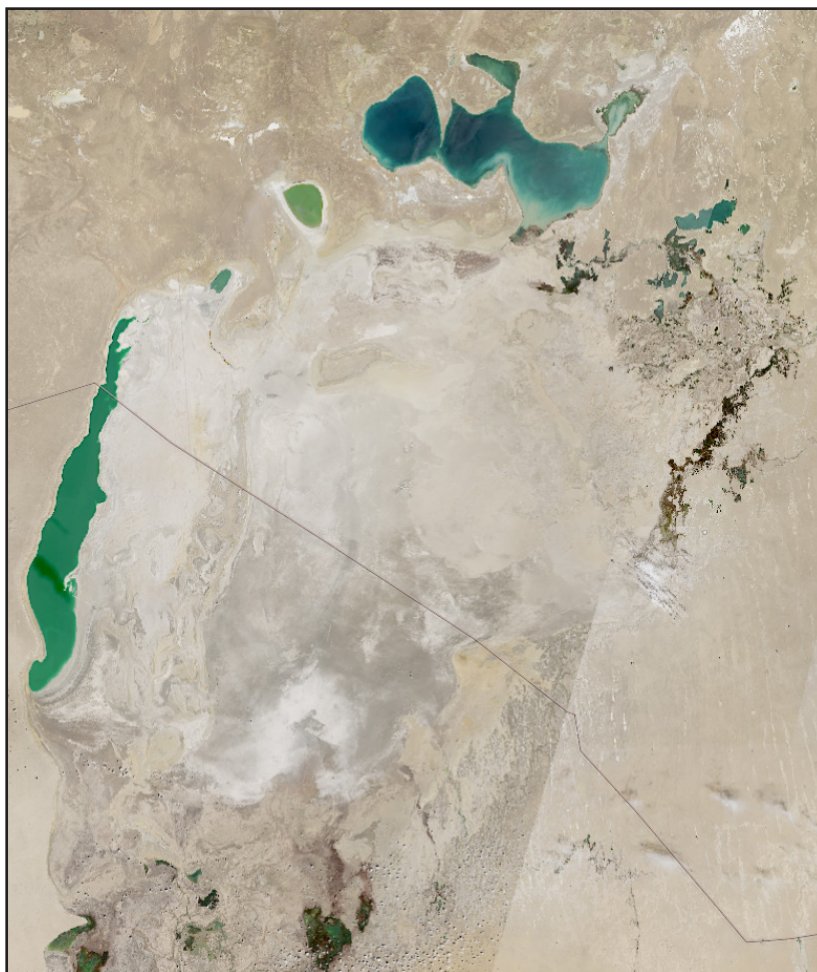
In a review of 204 studies from throughout the world, between 75% and 88% of the studies found adverse health effects from dust in specific regions.¹³ Most studies were limited to examining short-term effects occurring during or immediately after the event. “Most studies (84.8%) reported significant associations between desert dust and adverse health effects, mainly for respiratory and cardiovascular mortality and morbidity causes.”¹³ In another review of 22 epidemiologic studies of populations surrounding dried up lakes, 17 of the 22 studies found adverse health effects.¹⁴

Depending on meteorological conditions and particle size, desert dust can remain suspended in the atmosphere for days or even weeks and the impact on public health can extend to thousands of miles from the source.^{15,16}

Many lakes in the world are drying up, primarily because of upstream diversion of tributary rivers and the impacts of the climate crisis. Prominent among them are Lake Urmia in Iran, Lake Chad in Africa, Aral Sea in central Asia, Owens Lake and the Salton Sea in California. These provide parallels to examine when considering the potential public health impacts of Great Salt Lake dust.

The ecosystem collapse at the Aral Sea is perhaps the most analogous situation to the shrinking Great Salt Lake. The Aral Sea used to be the fourth largest inland lake on earth, but it is about 10% of its 1960 size, exposing about 26,000 sq. miles (16,540,000 acres) of dry lakebed, about ten times the size of Great Salt Lake. On average, every day about 200,000 tons of dust are suspended by the wind into the atmosphere according to United Nations’ estimates.¹⁷ The entire Central Asia region has become 7% dustier as a result.¹⁷

Figure 10: What's left of the Aral Sea (May 2024) should be a warning to Utah



The Aral Sea in modern day Uzbekistan provides a disturbing look at the dangers that dried up saline lakes pose to public health. Mortality rates, birth defects, kidney and numerous other diseases have all increased in the Aral Sea area, and life expectancy has decreased by 13 years.

ESA, Remnants of the Aral Sea as seen on 5 May 2024, captured by a Copernicus Sentinel-2 L2A satellite, CC BY-SA 3.0 IGO

About 3.5 million people live in the Aral Sea region, formally declared a disaster area in 1981. Infant mortality rates have increased since the 1970s. As of 2008, the infant mortality rate in Uzbekistan was about seven times higher than in the United States and ten times higher than in the United Kingdom,^{18,19,20} while elsewhere around the world, rates have been decreasing.²¹ Birth defects in the region are five times what they are in European countries.²² Over one-fourth of newborns are low birth weight.²³ Rates of kidney disease are unusually high.²⁴

Average life expectancy in the populated areas surrounding the Aral Sea disaster area has declined from 64 to 51 years. Rates of anemia in all segments of the population, and especially in newborns, respiratory infections like drug-resistant tuberculosis, liver diseases, allergies, and cancer are far higher than in the rest of the former Union of Soviet Socialist Republics and present-day Russia. Infertility rates have

A study of dust from the Salton Sea suggests more than 1,290 respiratory-caused deaths occur on the Wasatch Front per year from Great Salt Lake lakebed dust that has been drying up since 1986.

increased significantly.^{25,26,27,28} One study found higher rates of almost all kinds of cancer, including esophageal, gastric, lung, liver, and breast cancers. Mortality rates from these cancers were about 1.5 times higher than in control areas.²⁹

The toxic consequences of the shrinking of the sea are closely related to decades of aggressive use of pesticides such as DDT, dioxins, and Lindane,^{30,31,32} and the accumulation of heavy metals³³ and PCBs. There are indications that physicians have advised mothers against breast-feeding because their breast milk is too toxic.³⁴

By 1926, California's Owens Lake had been completely desiccated after completion of an aqueduct that sent its water to Los Angeles. The dried lakebed became the largest source of PM₁₀ pollution in the United States.³⁵ Most of the evidence of specific health problems affecting the small population that lives downwind of the lake is anecdotal reports from residents which are consistent with epidemiologic studies of large populations. Most of their complaints are respiratory, including exacerbation of asthma, wheezing, shortness of breath, chest tightness and coughing, increased emergency room visits, increased asthma medication usage, and increased hospital admissions for asthma.

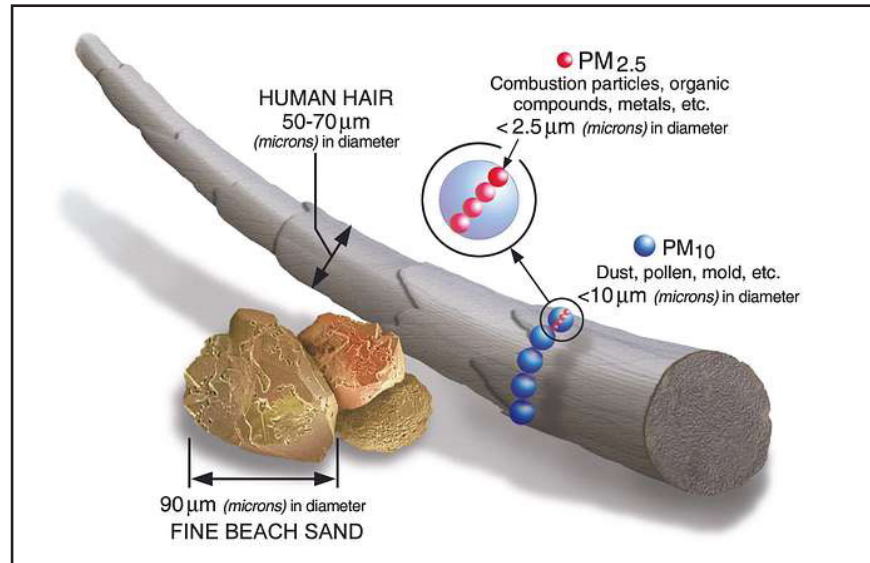
A study of the drying up of the Salton Sea found that each one-foot drop in the lake's elevation was associated with a 3,500 acre increase in exposed lakebed, a 2.6% (0.276 µg/m³) increase in PM_{2.5} in surrounding counties, and an increase of 4.2 respiratory deaths per 100,000 people between 1998 and 2014.³⁶ Given the population of the two adjacent counties, that amounts to about 100 extra respiratory deaths. Lung function and capacity are impaired with repeated exposure and children are the most vulnerable to respiratory insult because they are in critical developmental stages of lung growth.³⁷ Bear in mind that does not include mortality from other dust pollution-related diseases such as heart attacks, strokes, and cancer.

By comparison, the Great Salt Lake is now about 19 ft. lower than its average natural level since 1850.³⁸ In 2025 about 1130 sq. miles or 723,200 acres of lake bed have been newly exposed.³⁹ This is an area nearly 207 times larger than the expansion of dry lakebed at the Salton Sea per ft drop in lake level. The Utah population near Great Salt Lake is comparable to the two counties that surround the Salton Sea (at about 2.7 million people, although the population within 15 miles of the Salton Sea itself is about 130,000.³⁷ If we extrapolated directly from the Salton Sea study to Utah and the Great Salt Lake, based solely on the amount of exposed lakebed, we would end up with a respiratory-related mortality from the dust from the increased dry lakebed of about 1294 deaths per year.

Recall from the previous chapter that particulate matter (PM) is classified by the size of the particle, measured in microns, where PM₁₀, PM_{2.5} and ultrafine PM at 0.1 microns and smaller are the most common categories. Figure 11 shows the size of different classes of particulate matter relative to a human hair.

The Public Health Effects of Particulate Matter Pollution

Figure 11: Small particles cause big health hazards

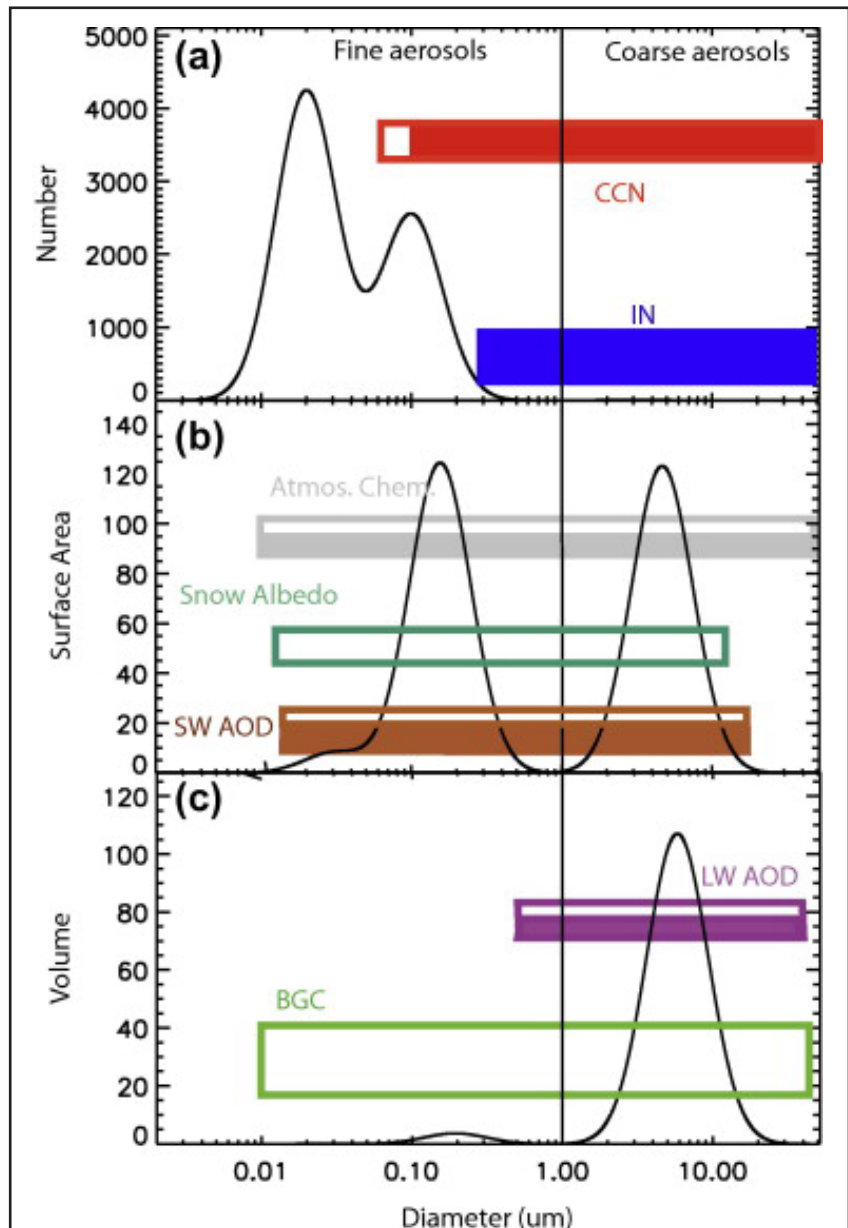


This image shows the size of particulate matter (PM) compared to familiar objects. A single human hair is about 70 microns wide, while a grain of sand is roughly 90 microns. In contrast, dangerous PM 2.5 particles are just 2.5 microns or smaller, and ultrafine particles are less than 0.1 microns—so small they're invisible to the naked eye. These tiny particles can penetrate deep into the lungs, enter the bloodstream, and even reach the brain and all other vital organs.

Particulate matter comes from an array of natural and anthropogenic sources, including automotive tailpipes, road and brake dust, industry and household sources, coal-fired power plants, surface water runoff, wildfires, construction and other sources. These different types of particulate matter all have broad and similar physiologic consequences, and disease potential. In other words, whether a microscopic particulate is made of dust or emitted from a tailpipe, the mere presence of foreign particles in the respiratory tract is enough to provoke oxidative stress and inflammation which can spread to other organ systems causing a long list of diseases.^{40,41,42}

Mineral dust particles suspended in the atmosphere can widely vary in size from less than 0.1 microns to 100 microns.⁸ Federal regulatory standards have focused on PM2.5 for approximately the last 25 years. PM2.5 and PM10 are designated “criteria” pollutants by the United States Environmental Protection Agency (EPA). But the size subset of particulate matter designated as ultrafines that are 0.1 microns in size and smaller are increasingly recognized as the most potent health villains among PM for multiple reasons. Although ultrafines are most often associated with high temperature combustion (wildfires, fuel combustion, incineration, etc.), they are also found in mineral dust.

Figure 12: Tiny dust particles, big health risks



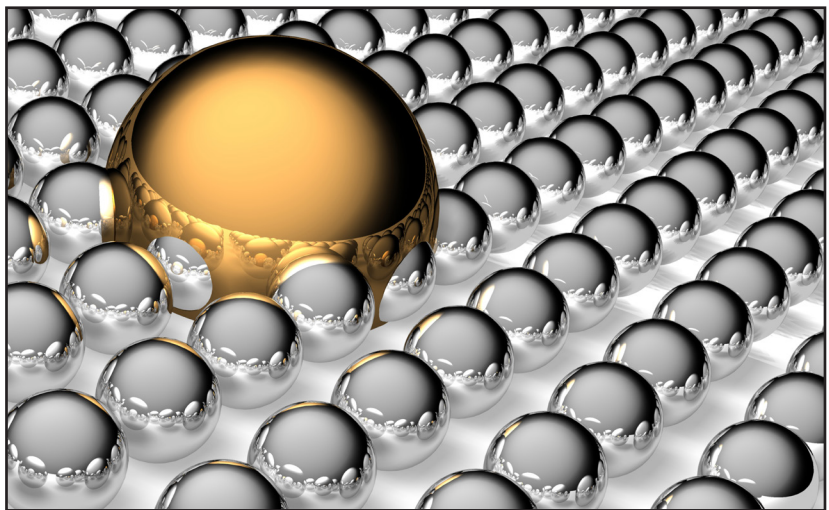
This graph illustrates the size distribution of dust particles collected from typical desert dust. Most of the particles are extremely small—between 0.01 and 1 micron (PM_{0.1} to PM₁)—yet the bulk of total dust volume comes from particles between 2 and 10 microns (PM₂ to PM₁₀). The smallest particles, PM_{2.5} and ultrafines, stay airborne longer, travel farther, and easily infiltrate homes, schools, and workplaces. These tiny particles pose the greatest threat to human health, penetrating deep into the lungs, easily picked up by the bloodstream, and distributed throughout the body. Natalie Mahowald, Samuel Albani, Jasper F. Kok, Sebastian Engelstaeder, Rachel Scanza, Daniel S. Ward, Mark G. Flanner, *The size distribution of desert dust aerosols and its impact on the Earth system*, *Aeolian Research*, Volume 15, 2014, Pages 53-71, ISSN 1875-9637, <https://doi.org/10.1016/j.aeolia.2013.09.002>.

In the case of dust, smaller particles become atmospheric at lesser wind speeds. Given their small size, PM_{2.5}, including ultrafines, is the category of PM that is most likely to penetrate homes and buildings, contributing significantly to indoor air pollution.⁴³ The geographic area of distribution is larger for smaller particles because they often stay in the atmosphere longer.^{39,44}

PM_{2.5} is barely visible even in high concentrations and they contribute negligible mass to dust that is captured on monitor filters. But they are the greatest contributor to particle number, the most relevant metric of toxic potential.^{45,46,47,48,49,50} Other characteristics being equal, toxic potential increases as the size of the particles decreases. Relative surface area generally increases as particle size decreases, which means there is greater opportunity for adsorption of additional toxins like organic compounds, chemicals, and heavy metals.^{47,48} The greater surface area also allows more contact and therefore more hazardous interaction with organ tissues.

Figure 13 demonstrates this principle with a simplified graphic. In the image, the many small silver balls that represent small PM particles such as ultrafines have roughly the same mass as the single large brass ball. That single ball represents larger PM particles such as PM₁₀ or PM_{2.5} pollutants. However, the surface area of the many small silver balls is much larger than the surface area of the single brass ball. Since surface area is an important contributor to toxic potential, the many small silver balls present a much greater toxic threat than the single large brass ball.

Figure 13: Smaller Dust Particles = Greater Surface Area, Greater Toxicity



This illustration compares the surface area of many small particles (silver balls) to one large particle (brass ball) of similar mass. While the total mass is roughly equal, the combined surface area of the smaller particles is much larger. In real-world dust exposure, this means smaller particles have significantly more surface area to carry harmful toxins, metals, or chemicals—one feature making them more dangerous when inhaled.

When captured on official EPA monitor filters, a cloud of a billion 10 nanometer-sized particles will register the same mass as a single PM₁₀ particle but they will have a combined surface area a million times larger.⁴⁸ This means that the monitor will likely mistakenly report that the cloud of a billion 10 nanometer-sized particles has only the relatively low toxic potential of a single PM₁₀ particle when in reality, the cloud of a billion 10 nanometersized particles poses a substantially larger toxic threat.

For both political and bureaucratic reasons, the EPA's nationwide monitoring network for PM pollution and the National Ambient Air Quality Standards (NAAQS) set by the EPA invariably lags behind the science such that both are inadequate to address current medical research on the public health hazard of air pollution in general, especially PM pollution. In Utah, regarding Great Salt Lake dust, this inadequacy is magnified because there is an insufficient number of monitors placed downwind of the most active lakebed dust hotspots to assess the exposure to the populated areas of the Wasatch Front. And in the state Legislature's 2025 session, the budget allotted only \$150,000 for more dust monitoring, which may not be enough for even one additional monitor. The Great Salt Lake strike team points out that Utah has underfunded dust monitors compared with other areas in California with desiccating lakes and much smaller populations.⁵¹

Government-approved air quality monitors are inadequate measures of toxicity. They lag far behind current science. They consistently underestimate the extent of hazardous particulate matter, including dust. Even routine research methods to assess toxicity fall far short of measuring the full extent of the health hazards.

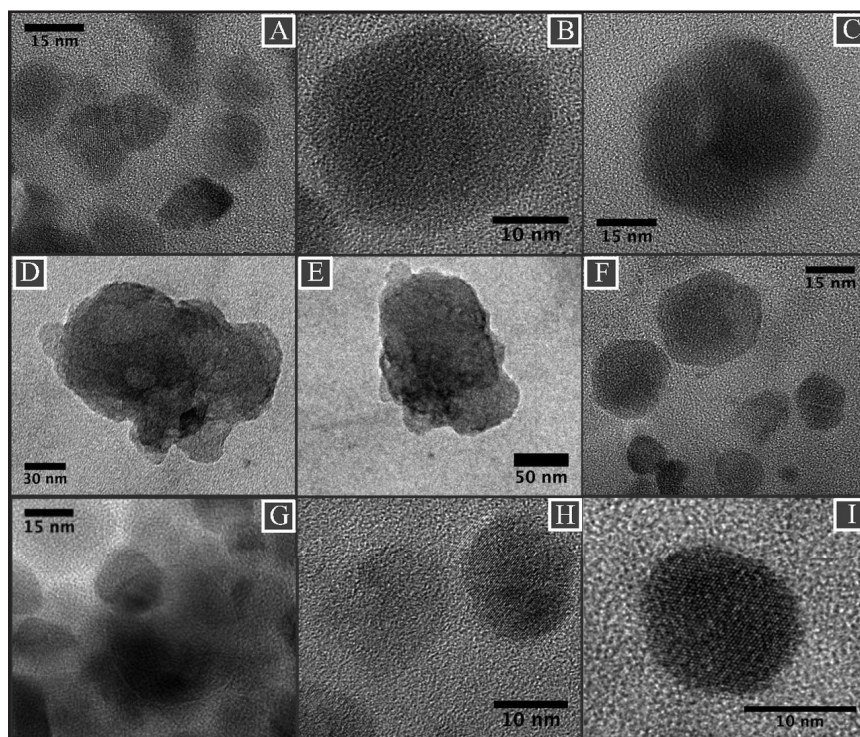
Because of the difficulty in measuring ultrafines, a government monitor can give a false impression of clean air. That is thanks to a low PM_{2.5} reading despite hazardous concentrations of ultrafines.^{46,52,53} While the dust particles most easily seen are in the larger range, i.e. PM₁₀, the greatest health risk is from the smaller particles not easily seen: PM_{2.5} and ultrafines.^{53,54,55} This means there can be a poor correlation between the visibility of a dust storm, the corresponding PM₁₀ and PM_{2.5} readings from the monitors, and the actual health hazard. Generally, particle number is a more important measure of toxicity than particle mass. The majority of particles measured by PM_{2.5} and PM₁₀ monitors are ultrafines. That ultrafines generally stay suspended in the atmosphere longer than larger particles increases the opportunity for human contact.^{56,52} Ultrafines are more easily inhaled into the tiny lung air exchange sacs called alveoli, and are more difficult to exhale. About 50% of ultrafine particles are indefinitely retained in lung tissue.⁵⁵

Ultrafines are the particles most likely to cause disease beyond the lungs, with the capability of harming all organ systems. They are more easily picked up by the blood stream and once delivered throughout the body they more easily penetrate the tissue of critical organs, and can penetrate individual cells including crucial organelles like the mitochondria and the nucleus of the cell where the greatest damage can be done.⁵⁷ For example, ultrafines' small size allows them to attach themselves to the olfactory nerves in the nasal mucosa which can then act as a conveyor belt and allow them to enter the brain stem, as has been proven by autopsy studies.⁵⁸

Ultrafines may also enter the brain by crossing the blood-brain barrier. Their small size allows them to easily pass through the placenta to the fetal circulation and enter the fetus and compromise organ development during the most critical developmental stages of human life.

Figure 14: Tiny airborne pollution particles can penetrate the brain

It is almost certain that virtually everyone living on the Wasatch Front has contamination of all their critical organs with microscopic pollution particles, some of which originated from the Great Salt Lake lakebed.



Electron microscope images showing high-combustion particulate matter (PM) nanoparticles embedded in human brain tissue. Similar ultrafine particles, like those found in Great Salt Lake dust and other pollution sources, are small enough to bypass the body's natural defenses, traveling from the lungs into the bloodstream and even crossing the blood-brain barrier. B.A. Maher, I.A.M. Ahmed, V. Karloukovski, D.A. MacLaren, P.G. Foulds, D. Allsop, D.M.A. Mann, R. Torres-Jardón, & L. Calderon-Garciduenas, Magnetite pollution nanoparticles in the human brain, Proc. Natl. Acad. Sci. U.S.A. 113 (39) 10797-10801, <https://doi.org/10.1073/pnas.1605941113> (2016).

The smallest of the ultrafines, 0.004 microns and smaller, can penetrate intact skin and be absorbed into the systemic circulation.⁵⁹ Slightly larger particles, 0.02 to 0.045 microns, can penetrate damaged skin. This subset of PM is likely to carry adsorbed chemicals like PAHs (addressed later in this report), making the skin an important route of air pollution exposure.

Given the scientific literature's identification of this subset of PM as pervasive and commonly found throughout the human body, including essentially all organ systems, it is almost certain that most Wasatch Front adults, children, pregnant women, and babies in utero, already have ultrafine particles from virtually all pollution sources, embedded in all their critical organs.

Health Effects of Short-Term Exposure to Particulate Matter Pollution

Episodic dust released from the expanding dry lakebed of Great Salt Lake falls into the regulatory category of “short-term” particulate air pollution. This is because winds typically pick up and transport dust from Great Salt Lake to population centers in sporadic bursts. While at first one may think that short-term exposure to particulate matter pollution doesn’t cause many negative health effects, a wealth of research has established the health hazard of short-term pollution.

Much of the medical literature on air pollution focuses on particulate pollution, microscopic particles of solids or liquids that are of an inhalable size. These particles can be emitted directly into the atmosphere and are referred to as primary particles or formed secondarily in the atmosphere by chemical reactions from precursors that include nitrogen oxides, volatile and semi-volatile organic compounds, and sulfur dioxide.⁶⁰

When atmospheric concentrations of these particles are captured and measured, most studies do not distinguish whether these particles originated from fossil fuels or from dust. Furthermore, the health consequences of inhaling these particles are similar regardless of the origin. For example, both dust and fossil fuel pollution cause much of the same pathophysiology. This was illustrated by a study published in November 2024 of over 8,500 adolescents from different geographical areas across the United States, including some from Utah. The study found that exposure to PM_{2.5} from “crustal materials” such as desert dust) was as toxic to the subjects’ brain function (learning and memory, general cognition, and executive function) as industrial or fossil fuel sourced PM_{2.5}, if not more so.⁶¹ Given that ultrafine PM is the most toxic subset of PM_{2.5}, that suggests that desert dust also contains ultrafines.

Regardless of the source, whether from desert dust or industrial smokestacks, particles in the atmosphere small enough to gain internal access to the human body through inhalation, ingestion, absorption through the skin, nasal mucosa, or ocular tissues have significant toxic potential, even when the exposure is short term. The body of research cited below, while not specific to dust, is still broadly applicable to defining and understanding the health hazard of dust pollution.

Globally, an average of one million deaths per year are attributable to short-term particulate matter events, including dust storms.⁶² A more familiar example of short-term air pollution events is the occasion of periodic winter inversions in Northern Utah valleys when particulate matter levels climb to unhealthy levels in local airsheds from industry, automobile and residential emissions.

The EPA has long recognized the health consequences of short-term pollution spikes, which is why it established National Ambient Air

Quality Standards for both annual averages and 24-hour exposures. It is worth noting that the World Health Organization, less influenced by political pressure, has recommended a 24-hour PM_{2.5} standard much stricter than the EPA's recent revision of the NAAQS. It has called for a standard of 15 µg/m³ for no more than 3-4 days per year.⁶³

Short-term pollution events have acute, subacute, and chronic health impacts for several reasons. Inhaled or ingested particles, small enough to be picked up by the blood stream, can still be contaminating any and all critical organs months later. Some may never be expelled from the body.⁶⁴

The heart and lungs are the first organs in contact with inhaled pollution and therefore the most immediately affected. Oxidative stress is the result, followed by a chronic inflammatory response that infiltrates the circulatory system and eventually all organs proportional to their blood supply.⁶⁴ The inflammatory chemical cascade triggered by the invasion of organ tissue by PM resolves only slowly after exposure has ended.⁶⁵

Much of Utah's overall air pollution problem is due to short-term episodes, including dust events, and the consequences can be profound. A recent study found that Utah air pollution causes between 2,480 and 8,000 premature deaths every year, shortens median life expectancy up to 3.6 years, and triggers economic losses of \$750 million to \$3.3 billion annually, up to 1.7% of the state's gross domestic product.⁶⁶

Short-term air pollution increases the risk of premature death throughout the age spectrum, from neonates to the elderly. Analyzing short-term PM_{2.5} via satellite, researchers found daily concentrations < 30 µg/m³ (below the EPA's 24-hour standard) were associated with increased daily mortality of 2.14% for every increase of 10 µg/m³ PM_{2.5} for two days. This association was found even in zip codes that meet the EPA's current annual standard. This study highlights that PM_{2.5} affects even rural populations with low air pollution levels.⁶⁷

A 10 µg/m³ increase in daily PM_{2.5} concentrations was associated with a 6% increase in the risk of infant mortality from all causes, including pneumonia and congenital heart disease, and a 10% increase in the risk for post-neonatal mortality.⁶⁸ Even mortality rates in the intensive care unit are related to short-term PM_{2.5} exposures. Per 10 µg/m³ increase in PM_{2.5}, mortality within 30 days increased 18%.⁶⁹

Short-term air pollution's non-mortality impact on public health includes a long list of morbidities. Air pollution increases blood pressure within one hour of exposure,⁶⁵ increasing the rigidity, constriction, and clotting tendency within the body's entire network of small arteries.⁷⁰ Once inhaled, nanoparticles preferentially accumulate at pre-existing sites of vascular inflammation and narrowing; in other words, at the worst possible locations.⁵⁷ Acute increases in particulate pollution also increase the friability of atherosclerotic plaques and their risk of rupture.⁷¹

These are all pathophysiologic processes that contribute to the clinical outcomes of increased risk of strokes, heart attacks, heart failure, and other adverse cardiovascular outcomes within as little as an hour after pollution exposure.^{72,73} Short-term air pollution can disrupt the heart's normal electrophysiology, increasing the risk of life-threatening rhythms and cardiac arrest.^{74,75}

Short-term air pollution increases the risk and severity of multiple types of infections, such as pneumonia, influenza,⁷⁶ and COVID-19.⁷⁷ In one Utah study of patients admitted through emergency rooms (ER) for pneumonia, researchers found that increases in PM_{2.5} concentrations of 10 µg/m³ within the 6 days prior to presentation of pneumonia increased the risk of pneumonia 35%, and pneumonia-related mortality 50% for levels above 12 µg/m³.⁷⁸ Short-term air pollution increases the risk of hospitalization for other types of infection such as appendicitis⁷⁹ and of dying of sepsis.⁸⁰

Studying over 95 million Medicare inpatient claims for 13 years, short-term PM_{2.5} exposure was associated with increased risk of hospitalization for multiple diseases not frequently studied, such as septicemia, fluid and electrolyte disorders, urinary tract and skin and subcutaneous infections, acute and unspecified renal failure, and intestinal obstruction, phlebitis, thrombophlebitis, and thromboembolism. For each 1µg/m³ increase in PM_{2.5}, lag 0-1 days, the absolute increase in risk of hospital admissions for all these disease groups ranged from 0.02 to 0.68 per 10 million people at risk per day, and the relative percentage increase in risk of these hospital admissions ranged from 0.05% to 0.40%.⁸¹ Furthermore, each unit increase in lag 0-1 PM_{2.5} was associated with an annual increase of 5,692 hospital admissions, 32,314 days in hospital, and 634 deaths at discharge. It was also associated with enormous costs; \$100 million annual inpatient and post-acute care costs, and \$6.6 billion in the value of statistical lives lost due to the deaths at discharge.⁸¹

Short-term PM_{2.5} increases are associated with decreased fecundability, which is the potential or capability to produce offspring. An increase in PM_{2.5} of 10 µg/m³ prior to attempted conception is associated with a 22% decrease in fecundability.⁸²

Impaired cognition is a well-established consequence of both acute and chronic PM_{2.5} exposure. In a study of Salt Lake City school children, short-term spikes that only reached as high as 23 µg/m³, well below the peaks of many dust storm events, had a greater impact on academic performance than chronic PM_{2.5} levels.⁸³

Short-term PM_{2.5} levels are associated with increases in emergency room visits for psychiatric disorders during the three days following. A 10 µg/m³ increase in PM_{2.5} was associated with a 7% increased risk of a disorder requiring hospitalization.⁸⁴ In a French study, for periods of 6 days with PM_{2.5} above 20 µg/m³, hospital admissions for psychotic disorders were significantly increased.⁸⁵ Suicide risk is increased for spikes of PM₁₀ in the days just prior to the attempt.⁸⁶

Particulate matter aggravates inflammatory autoimmune disorders like systemic lupus erythematosus (SLE).⁸⁷ In a group of 237 patients with SLE, a 10 µg/m³ increase in PM_{2.5} averaged over 48 hours prior to a clinic visit, there was a 34% higher risk of serum-specific autoantibodies and a 28% increased number of renal tubular cellular casts, i.e., markers of SLE disease activity.⁸⁸ Short-term particulate pollution is associated with increased risk of exacerbations of and hospitalizations for SLE.⁸⁹

Short-Term Exposure to Particulate Matter Pollution, Effects on Children and Pregnant Women

Unfortunately, adults are not the only people at risk from short-term exposure to particulate matter pollution. Children are also susceptible and given their critical stage of development the health impacts can be severe.

In a study of children in Atlanta, Georgia, PM_{2.5} was correlated to ER visits for pneumonia and upper respiratory infections in children younger than five years old. A three-day moving average PM_{2.5} increase of 8.8 µg/m³ prior to the hospital visit increased the risk of an ER visit of about 2%.⁹⁰ A study of 146,000 Utah children, most of who were younger than two years old, found that the risk of an acute lower respiratory infection increased within one week of an elevation in PM_{2.5}.⁹¹ In a case-crossover study including 20,017 medical visits for infant bronchiolitis and 42,336 for otitis media, infant bronchiolitis risk was elevated for PM_{2.5} exposure on same day by 7% and 4 days prior to clinical encounter by 4%, per 10 µg/m³ increase in PM_{2.5}. Risks for preterm infants were substantially increased.⁹²

Figure 15: Rates of lower respiratory infections in children jump almost immediately with short term spikes in PM2.5



A study of 146,000 Utah children, most of whom were younger than two years old, found that the risk of an acute lower respiratory infection increased within one week of an elevation in PM2.5. Photo courtesy of Brian Moench, M.D.

PM can impair fetal development and increases the risk of just about every pregnancy complication and poor outcome, from minor to catastrophic, from premature birth to stillbirths, birth defects, and cerebral palsy.⁹³ Short-term PM2.5 specifically is associated with premature birth. For example, a study found a 6% increased risk factor for premature birth for every increase of 10 $\mu\text{g}/\text{m}^3$ on the day prior to birth.⁹⁴ A meta-analysis of 84 studies of acute and long-term PM2.5 exposure during pregnancy found that for short-term exposure, preterm birth risk of 0.3% was associated with a 10 $\mu\text{g}/\text{m}^3$ increase in PM2.5 on lag day 2 and 3.⁹⁵ Worldwide, air pollution is responsible for nearly half of all stillbirths.⁹⁶ Short-term particulate pollution spikes just in the week before delivery are associated with increased risk of stillbirth.⁹⁷

Premature rupture of uterine membranes (POM) is another pregnancy complication associated with PM2.5 exposure. The risk of preterm POM was increased 53% for each increase in PM2.5 of 10 $\mu\text{g}/\text{m}^3$ for the whole pregnancy, and with further positive trends for the last week and day of pregnancy.⁹⁸ A 20 $\mu\text{g}/\text{m}^3$ spike in PM2.5 three days prior was associated with an 18% increase in the risk of pregnancy loss.⁹⁹

In preschool-age children, short-term spikes in PM2.5 were associated with symptom onset of juvenile arthritis. Per 10 $\mu\text{g}/\text{m}^3$ increase in 3-day lag moving average, the risk increased 76%.¹⁰⁰

The Public Health Effects of Exposure to Toxins in Great Salt Lake Dust

As mentioned at the beginning of this section, dust is also harmful due to the different “tag along” toxins it can carry to population centers. A new study from China, tracking dust events and hospitalizations over seven years, found that the greatest health impacts from dust corresponded to the concentrations of environmentally persistent free radicals (EPFRs) in dust and its oxidative potential (OP), both of which are better measures of the potential of the dust to cause biological harm, derived from multiple characteristics of the particles rather than just the mass of the PM captured on monitor filters.¹⁰¹

Both expressions are pathways to quantification of the existence of ROS (reactive oxygen species) or “free radicals” in biological systems. A free radical is an atom or molecule with an unpaired electron in its outermost shell that destabilizes nearby molecules by stealing or donating electrons, triggering biological harm, cell damage or death, and ultimately human disease. EPFRs describes a unique subset of carbon-based free radicals that are either attached to or embedded in matrixes like soil or dust which contribute to their environmental persistence. The toxicity of EPFRs can be potent enough to cause erosion of building materials and metal structures.¹⁰²

However, EPFRs describe only some of the toxins in dust and only half of the equation of biological harm. Oxidative stress (OS) describes the end result when free radicals exceed the capability of the body’s antioxidants to neutralize them (the other half of the equation). OS leads to inflammation and damage to important biologic compounds such as lipids, proteins, and DNA, and is the common denominator in many if not most chronic human diseases.¹⁰³ Metals’ contribution to the production of EPFRs is a primary vehicle for their disease potential via the triggering or direct production of ROS and OS.

University of Utah scientists compared the toxic potential of Great Salt Lake dust to coal fly ash, known to be highly toxic to the lung, and found that both in cell cultures and in lab animals exposed only for short time periods, Great Salt Lake was more toxic to cells and produced a greater inflammatory response than coal fly ash PM.¹⁰⁴

But even measuring EPFRs and OP underestimates the disease potential of PM. A study published in April 2025 demonstrated that the vast majority of these highly reactive compounds decompose within hours such that standard methods of measuring these ROS compounds captured on filters, which often won’t allow measurements for days, weeks, or sometimes months later, vastly underestimate, by factor of up to 100, their atmospheric concentrations and their disease potential. These short-lived but highly toxic compounds are continuously formed in the atmosphere and trigger different and more intense inflammatory reactions than the longer-lived free radicals measured with standard, delayed methods.¹⁰⁵

Some scientists have sampled Great Salt Lake dust to test for certain toxins such as heavy metals, but there are a great number of toxins that have

never been tested for. The table below clarifies which toxins have been measured in Great Salt Lake dust and which toxins are likely to be in Great Salt Lake dust but have never been tested for. In cases where researchers have not yet tested for toxins, funding should be allocated to perform the necessary tests to assess the occurrence and extent of toxin presence.

Toxin	Has Testing Been Done to Confirm Presence in GSL?
Arsenic	Confirmed Presence in GSL
Mercury	Confirmed Presence in GSL
Other Heavy Metals	Confirmed Presence in GSL
Pesticides	Likely Presence: Testing Needed
Forever Chemicals (PFAS)	Confirmed Presence in GSL
Polycyclic Aromatic Hydrocarbons (PAHs)	Likely Presence: Testing Needed
Micro/nano Plastic Particles	Confirmed Presence in GSL
Radionuclides	Confirmed Presence in GSL
Pathogens	Confirmed Presence in GSL

The following sections describe each class of toxin and summarize the relevant medical literature examining its human health impacts.

Heavy Metals in Great Salt Lake Dust

Among the numerous toxins in Great Salt Lake dust, heavy metals have received the most public attention so far. But they are only one category of many toxic components.

Decades of industrial operations near the lake such as mining that includes discharges into the lake, have resulted in a flow of numerous heavy metals into the lake, the soil around the lake, and groundwater nearby. The operations of the Rio Tinto copper mine are particularly notable.

Utah perennially ranks in the top five states for the greatest amount toxic releases in the environment as tracked by the EPA.¹⁰⁶ That inventory registered over 180 million pounds of toxins released in Utah in 2022, a typical year. Nationally, mining operations account for the largest volumes of those toxic releases, and in Utah, the Kennecott/Rio Tinto copper mine operations account for 80% of those releases.

Metal ore has been mined, processed, and smelted as part of the Bingham mine operation for about 100 years, resulting in contaminated sludge, soils, surface water, and ground water in the area including the Great Salt Lake.¹⁰⁷

Copper mines typically release ores rich iron pyrite which readily oxidizes forming acid mine drainage, a soup of sulfuric acid and dissolved metals, including mercury, arsenic, aluminum, copper, lead, and selenium. Kennecott publicly downplays Utahns exposure to those annual 180 million pounds of toxins, claiming those releases are “safely stored in specifically sited, engineered, constructed and permitted facilities.”¹⁰⁸

But whenever Wasatch Front home owners wipe dust from their patio furniture or from inside their homes, or see their furnace filters needing to be changed, some of that dust is the arrival of those 180 million pounds of toxic releases that will be inhaled within their own personal environment and living spaces.

Heavy metal contamination of the Great Salt Lake ecosystem by the Bingham mine has been underway for many decades in multiple ways. The three most important are:

1. Emissions from the smelter/refinery. The Utah Department of Environmental Quality records that the smelter emits 6.16 tons of lead up its smoke stack annually. Lead is the only heavy metal that is a criteria pollutant, so it is the only one routinely monitored, but no doubt other heavy metals are in the smoke stack emissions as well.
2. A contaminated groundwater plume in the southwest part of Salt Lake County, which has been called the “world’s worst groundwater contamination plume,”¹⁰⁹ eventually makes its way to the lake and its wetlands. As the lake and wetlands recede, heavy metals are left in the residual dry lake bed.

3. Wind-blown dust from the 10 (soon to be 12) square miles of tailings impoundment, waste rock piles, and the excavating operations within the pit, that land on the lake and the lakebed, especially when the wind is from the South. The tailings impoundment is expanding by 200,000 tons per day.

Figure 16: Dust from Rio Tinto's tailings impoundment blows over to the lake bed and can be resuspended secondarily from the dry lakebed



This image shows the tailings impoundment from Rio Tinto's mining operations near Great Salt Lake. Winds routinely carry dust from this impoundment onto the exposed Great Salt Lake lakebed. Tailings dust contains heavy metals and other harmful contaminants which can mix with lakebed dust and secondarily become airborne again.

Photo taken by Steven I. Dutch sourced from Emel, Jacque & Huber, Matthew. (2011). The Richest Hole on Earth? Nature, Labor and the Politics of Metabolism at the Bingham Canyon Copper Mine. 10.1007/978-90-481-9920-4_21.

Figure 17: Ominous dust storm over the receding lake



Dust blowing from south to north (l/r) from Kennecot tailings pile. Numerous adsorbed toxins have been documented in Great Salt Lake's lakebed and its dust. Photo was taken in October of 2024, provided courtesy of David Jackson Photography.

The past, present, and future operations of the Bingham canyon copper mine will contribute in perpetuity to heavy metal contamination of the Great Salt Lake, the residual drying lakebed, and ultimately the dust, especially in the southern arm.

Many heavy metals are now recognized as endocrine disruptors, meaning they are toxic at extremely small doses.

The term “heavy metal” is used to describe metalloids or metallic elements which have adverse health effects on humans (and other living organisms) such as neurotoxicity, teratogenicity, and carcinogenicity. Heavy metals are generally non-biodegradable which means they cannot be converted into less dangerous compounds over time, do not decompose, and remain and spread throughout the environment in perpetuity. In addition, they can be enriched thousands of times through biological amplification of the food chain and can enter the human body through multiple routes including inhalation, ingestion, and skin absorption. The most toxic heavy metals are mercury, lead, cadmium, and arsenic, have no useful biologic function and are poisonous to humans at very low doses.¹¹⁰

Heavy metals are now recognized as endocrine disruptors, another reason why they are toxic at extremely small doses via their ability to disrupt or mimic human hormones. The heavy metals most thoroughly researched and documented as endocrine disruptors are lead, cadmium, arsenic, mercury, copper, zinc, nickel, and manganese.¹¹¹

Heavy metals form covalent bonds, attaching them to organic groups and forming lipophilic (fat-loving) compounds. Obtaining lipophilic properties helps them penetrate the skin and enhance exposure from metals-contaminated dust. Furthermore, the lipophilic property allows them to penetrate individual cellular membranes and enter the cell where they can do significant damage to intracellular organelles, including chromosomes.^{112,113}

The industrial revolution launched a massive increase in human exposure to heavy metals because of wide-spread environmental contamination from the manufacturing and burning of fossil fuels. Mercury, lead, chromium, cadmium, and arsenic are the most prominent and well-studied. Acute and chronic poisonings may occur following exposure through any source of air pollution including dust. Bioaccumulation of these heavy metals within the human body leads to various toxic effects on multiple body tissues and organs. Heavy metals disrupt essential cellular processes including growth, proliferation, differentiation, damage-repairing processes, and apoptosis (a mechanism of cell death often necessary for maintaining organ health). These metals share common biologic pathways to induce toxicity including production of reactive oxygen species (ROS) which is one of the reasons that focusing on concentrations of individual metals underestimates the overall toxic profile of metals contaminated dust.

Simultaneous exposure to multiple contaminants, all of which are in concentrations theoretically below toxic levels, does not mean the combined exposure is non-toxic. The toxins may interact additively, or

Simultaneous exposure to multiple contaminants, all of which are in concentrations theoretically below toxic levels, does not mean the combined exposure is non-toxic. The toxins may interact additively, or even synergistically.

even synergistically.¹¹¹ For example, chromium, cadmium, and arsenic cause instability of genes, and simultaneous exposure to two or more metals may have cumulative genetic effects^{114,115,116,117} even if all are below “reference levels.” Studies of the components of the Great Salt Lake ecosystem show a long list of heavy metals, including the most well-known, lead, arsenic, and mercury, which is harder to measure.¹¹⁸

Heavy metals are particularly toxic to the developing fetal brain because the brain is the primary fat reservoir of the fetus, and the preferred site of accumulation of heavy metals that cross the placenta.¹¹⁹ Because the adverse impacts of heavy metal exposure at the earliest, critical stages of human development are largely irreversible, consequences can be lifelong.

Of the elements measured in Great Salt Lake dust and Great Salt Lake ecosystem, the heavy metals with the highest concentrations compared to average composition of the earth’s crust, or where we have the most information on their toxicity, are strontium, magnesium, boron, arsenic, cadmium, silver, uranium, antimony, lithium, and mercury.^{104,118} Concentrations of common earth crustal elements such as barium, iron, magnesium, and manganese are greater in dust than in the soil from which they originate because the smaller particles that preferentially become atmospheric have greater surface area-to-mass ratios and therefore more availability for chemical and metals adhesion.^{120,121,122} In addition to the natural metal coatings on smaller particles, anthropogenic sources may cause those metal ratios to enrich further.¹²³ And that means metals in dust are more prominent in urban and industrial areas than in rural areas, especially those areas near mining operations, as is the case on the south shore of Great Salt Lake.¹²⁴ The Great Salt Lake is alkaline¹²⁵ and in alkaline circumstances, several of the most toxic of these heavy metals are more mobile and more available for human exposure.^{126,127,128}

Some studies have compared metals concentrations in Great Salt Lake dust to Regional Screening Levels (RSL) and Hazard Quotients (HQs). RSLs were originally developed for the primary purpose of triggering cleanup of contaminated industrial sites under the Superfund program.¹²⁹ While RSLs and HQs are health-based, they are hardly synonymous with comprehensive health hazard. RSLs only look at cancer risk and HQs are intended to quantify non-cancer health risks. These attempts to create mathematical equations that accurately describe health impacts from toxins have been widely criticized since their development. These calculations are based on the assumption that a threshold exists at which no health effect would occur. Although there is often some correlation between exposure dose and health outcome, for many toxins the dose/response curve is not linear and there is no threshold dose below which safety can be assumed. For example, it is now widely accepted that there is no safe level of exposure to lead and that dose/response curve is likely not linear.¹³⁰

Neither RSLs nor HQs assesses cumulative risk from simultaneous exposure to multiple potential toxins. Furthermore, that assumption includes this caveat:

*a threshold for a population of individuals may or may not exist because of other endogenous or exogenous factors that may increase the sensitivity of some individuals in the population. Thus, the addition of a toxicant may result in an increased risk for the population, but not necessarily for all individuals in the population.*¹³¹

Because the adverse impacts of heavy metal exposure at the earliest, critical stages of human development are largely irreversible, consequences can be lifelong.

Another of the many problems with traditional HQs is that their endpoints have only considered whatever organ system is found to be the most sensitive to a toxin, and the HQs for other organ systems were essentially ignored. A recent study attempted to better quantify the total risk of simultaneous exposure to multiple chemical toxins. Researchers found when multiple, simultaneous exposures were considered and the HQs for all organ systems, not just the most sensitive, were added together, the overall risk profile was found to be much higher, as much as an order of magnitude higher.¹³²

For example, EPA risk assessments only look at the toxicity of formaldehyde on the respiratory system because it is the most sensitive. It is an arbitrary and scientifically indefensible regulatory approach. But under the cumulative assessment approach, looking at multiple simultaneous toxic exposures, the study calculated that formaldehyde contributed to health hazards in 10 other key organ systems.

“The dose makes the poison” concept has been the core tenet of toxicology for hundreds of years and is the basis of federal regulations like RSLs and HQs that govern air and water pollution, and environmental toxins like heavy metals and chemicals, and air pollution components. The concept assumes there is a concentration threshold below which a potential toxin is harmless, and beyond that there is a linear relationship between concentration and adverse outcome. Both of those assumptions are now known to not be consistently valid.¹³³

As with pharmaceuticals there is great variability in how people process and are harmed by environmental toxins even with the same exposure. That variability stems from individual variability in chemical concentration that arrives at a target organ or organ system (pharmacokinetics in the case of pharmaceuticals, toxicokinetics in the case of environmental toxins) and how that target organ responds to that chemical concentration (pharmacodynamics and toxicodynamics). These individual differences in toxicokinetics and toxicodynamics are dependent on wide variations among individuals according to their age, gender, hormonal levels, multiple exposure pathways, developmental stage (from embryo to adult), uptake, distribution, solubility, metabolism, and excretion. That is especially true when multiple simultaneous or even sequential toxic exposures are involved or when the exposures occur at critical developmental stages such as the prenatal period given that most toxins readily cross the placenta. Some people will

get lung cancer and others won't despite the two groups being subjected to the same concentration of a toxic exposure (or combined exposures). Children have a higher metabolic rate than adults, breathe faster, and have a higher heart rate. They will be exposed to proportionally more air pollution than adults for the same atmospheric concentrations, made worse by the fact that their organs are still developing.^{134,135,136}

The significant overlap in the toxic effects of heavy metals means that even when concentrations of individual metals are below reference thresholds, the aggregate exposure to multiple metals may nonetheless be toxic. That multiple simultaneous or even sequential exposures to different environmental toxins at levels supposedly considered safe or acceptable, such as those below the EPA's RSLs, can have additive or even synergistic effects is well-established. A growing number of studies conclude that simultaneous exposure to low doses of heavy metals can lead to harmful effects such as multiple organ damage and neurobehavioral alterations.^{137,138}

Most heavy metals can harm the kidneys and nervous systems with prolonged low-dose exposure.^{139,140} The risk of kidney disease in agricultural workers in Sri Lanka is related to heavy metal and pesticide (glyphosate) exposure.¹⁴⁰ The risk of metabolic syndrome is related to multiple different chemical toxins but augmented significantly when smoking is added.¹⁴¹ The risk of lung cancer is dramatically increased when smoking is added to asbestos or radon exposure.¹⁴² Exposure to noise pollution and toluene significantly increases the risk of hearing loss more than exposure to either one.¹⁴³

Lead, cadmium, mercury, and arsenic individually damage the kidneys and the brain, so it is intuitive that those outcomes would be increased in multiple exposure settings such as inhaling Great Salt Lake dust. Dietary exposure to the combination of lead, cadmium, arsenic, and mercury amplifies the risk of neurotoxicity and kidney disease.¹⁴⁴

Maternal exposure to ambient heavy metals that include lead, nickel, and cobalt increases the risk of childhood cancers.¹⁴⁵ In the study that established this association, the exposure of pregnant women was estimated using the EPA's Toxic Release Inventory (TRI). Utah perpetually ranks in the top five states for volume of environmental toxins in the TRI. This is due primarily to the Rio Tinto mine on the south shore of Great Salt Lake and thus makes this study particularly relevant to the issue of toxicity of Great Salt Lake dust.

Heavy metals have adverse reproductive effects. Women with higher levels of metals in their urine were more likely to have diminished ovarian reserve. Arsenic and cadmium possess endocrine-disrupting characteristics, meaning they act as either agonists or antagonists of one or more of critical human hormones such as testosterone, estrogen, progesterone, insulin, thyroid, cortisol and others, at extremely low concentrations.¹⁴⁶ Endocrine disruptors' defining characteristics are broad-based toxicity at very low-dose exposures.

The next section focuses on a few of the specific heavy metals that were found in Great Salt Lake dust, because of their abundance or prominent toxicity, as well as a quick overview of some of the others.

Arsenic

High arsenic concentrations are endemic to much of the Western US due to geothermal and tectonic processes. Arsenic-rich, volcanic, and meta-sedimentary mountains steadily erode, washing the sediment to the valleys below them.¹⁴⁷

Arsenic is one of the most toxic and most prevalent heavy metals in Great Salt Lake dust. Arsenic exposure affects virtually all organ systems including the cardiovascular, dermatologic, nervous, hepatobiliary, renal, gastrointestinal, and respiratory systems.¹⁴⁸ Research has also revealed significantly higher standardized mortality rates for cancers of the bladder, kidney, skin, and liver in many areas of arsenic pollution.^{149,150,151,152,153,154,155,156} Arsenic is both a developmental and teratogenic toxin.^{157,158}

Arsenic is a potent neurotoxin affecting the brain and peripheral nervous system. All forms of arsenic accumulate in the brain. They can cross the placenta and the blood-brain barrier and interfere with intrauterine brain development, including killing fetal brain cells.¹⁵⁹

Epidemiologic and animal studies confirm that arsenic damages neurodevelopment including intellectual and motor function,¹⁶⁰ and at commonly encountered exposure levels. In studies of children throughout the world, chronic exposure to arsenic is associated with a profile of neurologic damage similar to lead.^{161,162}

Arsenic is genotoxic to both human and lab animal cell cultures, meaning it is deleterious to the DNA of chromosomes.^{163,164}

Mercury

Mercury is the most neurotoxic substance known, likely orders of magnitude more toxic on a per weight basis than lead. A major proportion of what is absorbed accumulates in the kidneys, neurological tissue, and the liver. All forms of mercury are toxic, and their effects include gastrointestinal toxicity, neurotoxicity, and nephrotoxicity.¹⁶⁵

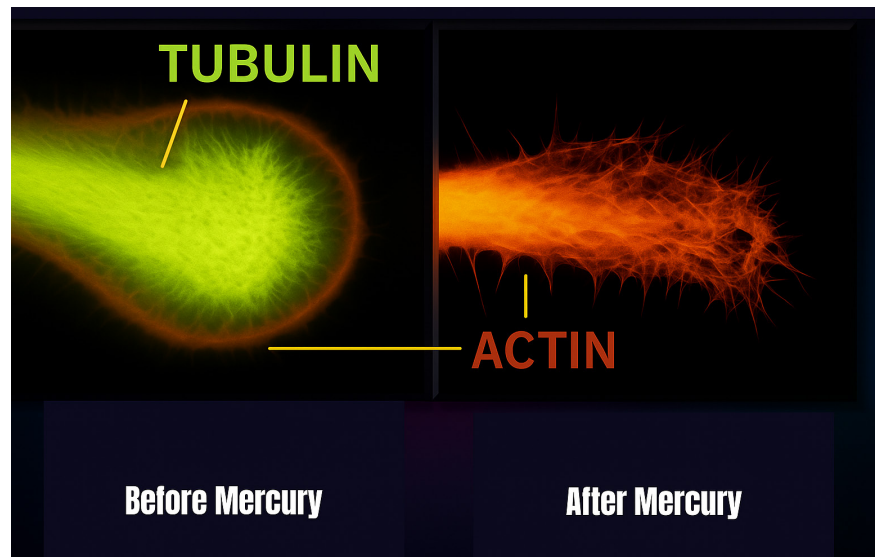
A distinguished group of 23 mercury scientists, in support of the EPA's Mercury and Air Toxics Standards, stated in a letter to President Barack Obama in 2011 that:

Mercury is such a potent toxin because it bonds very strongly to functionally important sites of proteins including enzymes, antibodies and nerve growth-cones that keep [brain] cells alive, intelligent, and safe. Target enzymes, organs, or metabolic pathways

vulnerable to mercury poisoning may change from cell to cell, person to person, and in the same individual over time.

Mercury inhibits the action of neurotransmitters, such as acetylcholine, serotonin, dopamine, glutamate, and norepinephrine,¹⁶⁶ and can literally make the axons of neurons shrivel up.¹⁶⁷

Figure 18: Mercury, the only heavy metal that destroys developing nerve cells in minutes



Left: Electron microscope image of a healthy nerve growth cone—the structure that guides growing nerve cells—taken from a lab petri dish. Right: The same nerve just 30 minutes after researchers added a tiny amount of mercury. The nerve's internal structures (microtubules) rapidly disintegrated, halting its ability to grow or function. Image recreated from a University of Calgary video on how mercury causes brain neuron degeneration.

Soil is a primary reservoir of mercury in its global cycle. There is reason to believe that both methylmercury and elemental mercury are present in dust from Great Salt Lake despite the difficulty in measuring it. Household and street dust are typically primary sources of mercury exposure in urban children.^{168,169,170}

Elemental mercury, found most often as a vapor, enters the body via the lungs, nasal and oral mucosa. About 80% is absorbed by the blood stream and can easily cross the blood-brain barrier reaching the brain directly.¹⁷¹ It can also cross the placental barrier reaching the fetus. It passes easily through cell membranes. Once inside a cell, mercury vapor is oxidized to an ionic form of Hg^{++} which can damage intracellular organelles. Hg^{++} cannot diffuse back across the blood-brain barrier so it accumulates in the brain.¹⁷² Hg^{++} is also increased after methylmercury ingestion so there is a common toxic endpoint for those two forms of mercury.¹⁷³ Importantly, when elemental mercury vapor is absorbed by the nasal mucosa it can be transported directly to the brain via the olfactory nerves.

Methylmercury also easily crosses the blood and placental barriers because of its lipid solubility. Both methyl and elemental mercury (mercury vapor) are secreted in human breast milk.¹⁷⁴ Once absorbed they have a very low excretion rate.

In 2003, the US Geological Survey reported methylmercury levels in Great Salt Lake were some of the highest ever recorded anywhere in the US. Shortly after, high mercury concentrations in muscle tissue from three species of ducks at Great Salt Lake resulted in the world's first waterfowl consumption advisory due to mercury.¹⁷⁵ Historic and continuing elevation of mercury in the Great Salt Lake ecosystem appears to fluctuate with the open or closed status of the causeway, allowing or preventing flow between the North and South Arms of the lake.¹⁷⁶ Nonetheless, the high mercury levels are unique and their connection to high mercury levels throughout the rest of the Great Salt Lake food chain and ecosystem is still somewhat of a mystery, despite having been studied on multiple occasions by state agencies and other researchers.

Methylmercury is the most toxic form of mercury and is created by aquatic organisms' transformation of elemental mercury. Methylmercury makes up 50% of the mercury in the Great Salt Lake system. The normal percentage is about 1%.¹⁷⁷ But contrary to common perception, although methylmercury is the most toxic form, all forms of mercury are highly neurotoxic,¹⁷⁸ and the developing brains of fetuses, infants, and children are the most vulnerable targets.

These heavy metals in the Great Salt Lake ecosystem will be mobilized into the food chain as plants transfer them to their leaves and stems.¹⁷⁹ Food crops raised commercially or by individuals can absorb heavy metals from contaminated soil, air, and water. As a result, heavy metals from continuous Great Salt Lake dust events will undoubtedly contribute to contamination of food grown on the Wasatch Front, with children being affected the most.¹⁸⁰

Other Metals

Lead can affect virtually all human organ systems. It causes anemia, alters the permeability of blood vessels, and impairs the immune system.^{181,182} Chronic low-level lead exposure is associated with impaired kidney function, higher blood pressure, and cardiovascular disease.^{183,184,185} Lead is a developmental and reproductive toxin to both males and females.^{186,187}

The brain is the most sensitive organ to lead exposure. It is well-known that there is no safe level of lead exposure because of its potent neurotoxicity. Lead-contaminated dust inhaled by a pregnant woman is easily transferred to the developing fetus.¹⁸⁸ Prenatal exposure is associated with reduced birth weight and preterm delivery¹⁸⁹ and with neuro-developmental abnormalities in offspring.¹⁹⁰ Lead is considered a probable carcinogen by The International Agency for Research on Cancer (IARC).¹⁸¹

Chronic inhalation of particulates with adsorbed cadmium can lead to emphysematous changes in the lung.¹⁹¹ Cadmium and chromium VI are considered human carcinogens by several regulatory agencies, such as the IARC, and the US National Toxicology Program.^{192,193,194} Chromium VI is cytotoxic and can induce DNA damage.¹⁹⁵

Copper is one of the metals that has been identified as 2.6 times as concentrated in Great Salt Lake dust compared to average soil. Copper has not been as well studied as many of the other heavy metals, but a new study of the toxicity of PM generated from vehicle brakes found that those brakes with the most copper were the most toxic, to the point of being more toxic to lung alveoli (air sacs) than particles from diesel exhaust.¹⁹⁶

University of Utah researchers examined the oxidative potential of PM₁₀ particulates in dust from Great Salt Lake playas. Oxidative potential (OP) is a proxy for disease potential. They found higher OP in dust from Great Salt Lake playas compared to dust samples from other areas of the western region, and it was associated with the concentration of heavy metals, including copper, manganese, iron, and aluminum.¹⁹⁷

Pesticides

Numerous pesticides (herbicides and insecticides) are being sprayed throughout the Great Salt Lake ecosystem and likely are present in Great Salt Lake dust to some degree. Insecticides are being sprayed by mosquito abatement districts and multiple entities are spraying herbicides to combat invasive phragmites along Great Salt Lake's shoreline. These practices have been institutionalized with little consideration for the multiple, legitimate concerns with empirical evidence about their effect on wildlife and humans. Evidence of their persistence in the Great Salt Lake environment and likely presence in the dust is germane to this report.

Pesticides are biologic poisons. Given that humans share most of the same genetic, metabolic, and physiologic processes with the rest of the biological world, it is highly unlikely that we would be spared the toxicity of these poisons. Indeed, much of the literature summarized below demonstrates that pesticides are in fact detrimental to human health.

Most of the commonly used insecticides target the nervous system of insects, and many are derived from chemical warfare nerve agents.^{198,199} A nerve cell in a developing human fetus shares common physiology and biochemistry with mosquito nerve cells. Neuronal connections between brain cells of most species share common processes.²⁰⁰

There is no reason to believe that chemicals toxic to mosquito nerves would be non-toxic to human nerves. And there is a substantial body of medical and toxicologic research that shows humans are indeed being clinically harmed by pesticides, increasing the risk of cancer, neurologic diseases and impaired brain development, reproductive disorders and more.

Some of the ongoing heavy metal contamination of Great Salt Lake bed soil with higher concentrations than average earth crust may be due to legacy and current pesticide use. Arsenic was widely used as an ingredient in pesticides throughout the first half of the 20th century and was not banned by the EPA until 1988. Mercury was used in pesticides until the late 1970s in the US.²⁰¹ There are still 189 registered pesticides that contain boron.¹⁹³

Pesticides as Endocrine Disruptors

Human hormones (estrogen, testosterone, progesterone, insulin, thyroid, cortisol, growth hormone, etc.) may be the most potent biologic compounds known.²⁰² About 30 years ago, scientists began seeing evidence that many industrial chemicals mimicked or antagonized human hormones at extremely low levels, wreaking havoc with the functioning of the endocrine system—the thyroid, pancreas, adrenals, pituitary, testes and ovaries. The term endocrine disrupter was applied to these hazardous chemicals.

In the 1990s, research emerged showing many pesticides are endocrine disruptors; they mimicked or antagonized critical human hormones at extremely low concentrations, adding an entirely new dimension of harm to human health.²⁰³

As a result, Congress passed legislation in 1996 requiring the EPA to test all pesticides for endocrine-disrupting activity. Twenty-eight years later that still has not happened.²⁰⁴ This should be seen as a stinging indictment of the agency and Congress, and it adds to the many other reasons why “EPA-approved” does not equate with safety.

Endocrine disruptors have been identified as causing a wide spectrum of harm, especially at the earliest, most critical stages of human development: in utero, infancy, and childhood. Clinical consequences include developmental disorders, reproductive toxicity, multiple cancers, immunosuppression, and damage to the brain and nervous system.²⁰⁵

The Office of Chemical Safety and Pollution Prevention recommended in 2015 that 17 of the most heavily used pesticides be tested for endocrine disruption. But that hasn’t happened either. The Office of Inspector General issued a scathing report in July 2021, whose title encompasses the content, “EPA’s Endocrine Disruptor Screening Program Has Made Limited Progress in Assessing Pesticides.”²⁰⁶ That report stated, “some EPA staff indicated that they were instructed to function as if the [Endocrine Disruptor Screening Portal] was eliminated from the EPA’s budget.” Given the apparent unwillingness or inability of the EPA to investigate this critical issue in any meaningful time frame, despite its legal mandate, it’s crucial to act based on what evidence is available. And that evidence is very disturbing.

Evidence continues to mount that most pesticides are endocrine disruptors, and therefore behave as carcinogens, neurotoxins,

teratogens, and reproductive toxins at very low, environmentally-common concentrations. In 2009, the Endocrine Society, the world's largest body of endocrine disease specialists, released this statement regarding endocrine disruptors:

*Even infinitesimally low levels of exposure, indeed, any level of exposure at all, may cause endocrine or reproductive abnormalities, particularly if exposure occurs during a critical developmental window. Surprisingly, low doses may even exert more potent effects than higher doses.*²⁰⁷

Herbicides

Glyphosate, which is found in commercial formulas like Roundup, is the most widely-used herbicide in the Great Salt Lake ecosystem. Numerous studies on animals suggest that glyphosate and its commercial formulas play a role as endocrine disruptors. For example, Roundup added to drinking water for rats, diluted to 50ng/L glyphosate equivalence (half of the level permitted in drinking water in the EU and 14,000 times lower than that permitted in drinking water in the USA), caused severe organ damage and a trend of increased incidence of mammary tumors in female animals.²⁰⁸

Glyphosate and glyphosate-based herbicides have the potential to precipitate a wide variety of maladies including birth defects, hormone and reproductive disorders^{209,210,211} cancer,^{212,213,214} fatty liver disease,²¹⁵ and impaired brain development through inhibition of the thyroid gland and through other multiple pathways,²¹⁶ all at very low doses of exposure.

The nervous system is particularly vulnerable to glyphosate.²¹⁷ Glyphosate enters the brain and is associated with an increase in the chemical hallmarks of brain inflammation in both brain tissue and blood.²¹⁸ Exposure to pesticides, including glyphosate, is associated with neurodegenerative diseases like autism²¹⁹ and Parkinsonism,^{218,220,221,222,223,224} most of which is environmentally caused, and has become the fastest growing non-genetic neurologic disease. A study published in December 2024 found that glyphosate exposure in lab animals, comparable to what humans commonly experience, caused brain inflammation, accelerated the development of Alzheimer's Disease pathology, and decreased survival rates. Moreover, the breakdown products of glyphosate were detectable in the brain even after a six-month recovery period from exposure.²¹⁸

All environmental toxins, including glyphosate, are more hazardous in children than adults because of the differences in their physiology and developmental life stage. Exposure during critical developmental windows, in utero and infancy, can have a greater and more persistent impact on organ function and disease vulnerability. Glyphosate can damage human placental embryonic and umbilical cells, and cross the placenta directly reaching the fetus.²²⁵

Pesticides are routinely and repeatedly sprayed throughout the shores and wetlands of Great Salt Lake. Their toxicity to humans is indisputable, not necessarily dose dependent, and almost certainly present in Great Salt Lake dust.

Glyphosate is so ubiquitous in our environment that it is present in the air we breathe, water we drink, and rain that falls from the sky. An extensive analysis by the US Geological Survey from 38 states' sampling of streams, groundwater, ditches and drains, rivers, soil water, lakes, ponds, wetlands, precipitation, soil and sediment, and wastewater treatment plants found glyphosate in 91% of soil samples, 39.4% of overall samples, and its metabolite AMPA (aminomethylphosphonic acid) in 55% of samples. It's probable the contamination is worse today since this study concluded 15 years ago.²²⁶ This, coupled with the fact that glyphosate herbicides are used in close proximity to the Great Salt Lake, provides strong evidence for the inference that glyphosate can be found in the Great Salt Lake and its dust.

The human, wildlife, and ecological impacts can be enhanced from repeated glyphosate-based herbicide applications because repeated application has been shown to slow its degradation in soil.^{227,228} Manufacturers' carefully-crafted reputation that glyphosate breaks down quickly in soil is contrary to numerous studies. Depending on conditions, glyphosate can persist in the environment for a long time. In Hawaii, in soils with pH less than 6, glyphosate half-life was found to be as high as 22 years.²²⁹ Glyphosate's toxic, major metabolite has a soil half-life of between 119 and 958 days.²³⁰ Glyphosate was found in pond sediments 400 days after direct application.²³¹ Almost certainly these herbicides and their metabolites contaminate Great Salt Lake dust.

Many of the now out-of-date studies that glyphosate manufacturer Monsanto claimed exonerated Roundup (an herbicide that uses glyphosate) from causing any health effects, and that formed the basis of the EPA's approval, made the mistake of only testing the active ingredient, glyphosate. But Roundup contains other chemicals as adjuvants and surfactants that facilitate binding to vegetation. These chemicals were billed by the manufacturers as benign, and regulators largely bought into the premise. A 2014 study found that the toxicity of eight out of nine pesticide formulas was greater than the toxicity of their active ingredient alone, which indicates these chemicals are not benign.²³² Roundup was the most toxic of the pesticides studied, and the commercial formulas of the pesticides were as much as 1,000 times more toxic than the "active ingredient" by itself.

In 2023, Bayer reformulated consumer Roundup for residential use in an attempt to stem the tide of lawsuits. The company replaced glyphosate with a combination of four active ingredients: diquat dibromide, fluazifop-P-butyl, triclopyr, and imazapic. The non-profit Friends of the Earth analyzed EPA studies and found, on average, this new combination to be 45 times more toxic to human health following long-term, chronic exposure.²³³

Diquat dibromide is the most toxic of the four, 200 times more toxic than glyphosate. It is classified as a "highly hazardous pesticide" and banned in the European Union. These replacement chemicals are also more hazardous to bees, birds, fish, aquatic organisms, and earth worms. They are also more persistent in the general environment, meaning if

they are used by any entity in the Great Salt Lake ecosystem, they are more likely to be present in lakebed dust.²³³ The new chemicals are listed on product labels, but the EPA so far has not required any warning to users of the increased risk.

Insecticides

Mosquito abatement districts apply primarily two groups of insecticides over tens of thousands of acres along the southern and eastern shores of Great Salt Lake: organophosphates and pyrethroids, which are usually applied with the synergist piperonyl butoxide (PBO). Both types of pesticides have a robust body of research indicating significant consequences to human health at doses relevant to environmental exposures.

In the early 1990s growing awareness of the toxicity of pesticides led to a National Academy of Sciences Report, *Pesticides in the Diets of Infants and Children*.²³⁴ The report emphasized that children's pesticide burdens differ from adults quantitatively and qualitatively and questioned the validity of risk tolerances used by the EPA to declare "safety." The report estimated that 50% of lifetime pesticide exposure occurs during the first 5 years of life. By the age of 6 the brain reaches 90% of its eventual adult volume and that corresponds to about 90% of its overall, permanent organizational and architectural structure,²³⁵ the most critical window for brain development.

The National Academy of Sciences report raised concerns about children being uniquely susceptible to organophosphates. The new concerns highlighted the vast physiologic differences between children and adults that go far beyond differences in size. Children at the prenatal and early infant stages of development are much more chemically sensitive for multiple reasons, one of which is that they have a decreased ability to metabolize chemical toxins.^{236,237,238} For example, children do not have the necessary enzymes to detoxify insecticides like organophosphates and pyrethroids.²³⁹ In eight-day-old rats, pyrethroids are nearly five times more acutely toxic than in adults because they lack permethrin-specific esterases.²⁴⁰ In humans the blood-brain barrier doesn't mature for at least six months after birth.²⁴¹ That allows more of any toxic chemical to reach brain tissue, and at the worst possible time for brain development.

Research showing the toxicity of pyrethroids to human health is direct and extensive. Insecticides in general, and pyrethroids in particular, are associated with a wide range of neurologic and brain diseases, especially impaired early-stage brain development, and loss of intellect and behavioral disorders in children. The damage to the nervous system from pyrethroids is comparable to that from the banned legacy pesticide DDT.²⁴² Consistent with this research, several epidemiologic studies have found an increased risk of autism with pyrethroid exposure.^{243,244,245} A study of contaminants in human breast milk from multiple countries found every milk sample from each country was contaminated with pyrethroid insecticides,²⁴⁶ and at levels high enough to cause neurologic

and endocrine effects.²⁴⁷ Other studies show contamination even in households where no pesticide is used.²⁴⁸

Most pyrethroid compounds are endocrine disruptors and as such can interfere with human reproduction and act as carcinogens.^{249,250} Pyrethroid metabolites have greater endocrine-disrupting activity than their parent compounds.²⁴⁹ In other words, after application, up to a point, the toxicity of the chemicals increases as they “age” in the environment. Other studies show that the synergist PBO, when mixed with pyrethroids, perpetuates its ecological impact.²⁵¹

Over 30 years ago, the Office of Technology Assessment of the US Congress released an extensive report entitled “Neurotoxicity: Identifying and Controlling Poisons of the Nervous System.” One of the two primary targets of the report was chemical pesticides. They stated, “Of particular concern are the delayed effects of some of the organophosphate pesticides [OP].”²⁵² In 2018 a meta-review of data and literature on OPs analyzed and cross-referenced numerous reviews and epidemiological studies with a UN database that includes 71 countries, and other research material.²⁵³ The lead author of the panel of experts involved in the study, Irva Hertz-Picciotto, Director of the University of California, Davis Environmental Health Sciences Center, said:

*We have compelling evidence from dozens of human studies that exposures of pregnant women to very low levels of organophosphate pesticides put children and fetuses at risk for developmental problems that may last a lifetime. By law, the EPA cannot ignore such clear findings: It's time for a ban not just on chlorpyrifos, but all organophosphate pesticides.*²⁵⁴

Researchers at New York University concluded that 81% of the cognitive loss in children from environmental neurotoxins came from exposures to polybrominated diphenyl ethers, i.e. flame retardants, and organophosphate pesticides, far eclipsing that caused by heavy metals like lead and mercury.²⁵⁵

Naled is an organophosphate pesticide that leaves a breakdown product, dichlorvos, which is also an insecticide with similar acute and chronic effects as the parent compound. This serves to prolong the toxicity of naled. In fact, dichlorvos is classified by the EPA as a possible human carcinogen, while naled itself is not. Dichlorvos exposure during pregnancy or childhood has been linked to an elevated incidence of brain tumors and leukemia.²⁵⁶ Analogous to the Great Salt Lake, in the summer, in sea water, dichlorvos persists for six months,^{257,258} which makes the supposed short half-life of naled itself almost irrelevant.

Highly relevant to Great Salt Lake dust toxicity, naled is far more toxic by inhalation exposure than by ingestion, maybe as much as 20 times more toxic.²⁵⁹ Another study found that small droplets of naled, the size produced by the ultra-low volume sprayers that Salt Lake City Mosquito Abatement District uses, were about four times more acutely toxic than larger droplets.²⁶⁰

There are numerous studies in animals showing that naled at low-dose exposures causes a wide variety of adverse health outcomes, including diseases of the nervous, circulatory, reproductive, and immune systems. Like pyrethroids, organophosphate pesticides as a group are endocrine disruptors. A meta-analysis by researchers at University College London found chronic, low-level exposure to organophosphate pesticides causes permanent damage to cognition, including information processing and working memory.²²¹ Urinary levels of organophosphate pesticide metabolites were measured in pregnant women, and those of the children they gave birth to, who were tested at age 7. The children from those mothers who were in the highest 20% of exposure showed an average IQ deficit of a stunning 7 points.²⁶¹ Like pyrethroids, organophosphate pesticides have also been routinely found in breast milk.²⁶²

Naled has been banned by the European Union, which found that naled represented an “unacceptable risk” to human health and the environment and removed it from all European markets in November of 2012.^{263,264,265,266,267} Dichlorvos was banned in the EU in 1998 and also banned in many other countries including Sri Lanka, Cambodia, and Bangladesh, none of which is recognized as having strong environmental standards.

A new study from the University of Nebraska showed that exposure to multiple pesticides increased the risk of childhood cancers. Specifically, a 10% increase in the combined exposure to multiple pesticides increased the risk of leukemia and brain cancers an average of 30%. Nebraska, a state dominated by agriculture, has a comparatively high rate of pediatric cancers. Glyphosate, commonly used against invasive phragmites throughout the Great Salt Lake ecosystem, was one of the chemicals most highly associated with these cancers.²⁶⁸

The intentional role of piperonyl butoxide is to act as a synergist to pyrethroids, and it can magnify their toxicity by a factor of ten. There are several studies to suggest that PBO is, itself, also a neurotoxin,^{269,270} which contradicts the official statement by the EPA that it is not. One of the most alarming studies on neurotoxicity from pesticides, published in the flagship journal of the American Academy of Pediatrics, showed that children in the highest PBO-exposed group, compared to the lowest exposed group, showed delayed neurodevelopment at 36 months and loss of intelligence of about 4 IQ points, comparable to that from lead toxicity.²⁷¹ PBO also enhances another toxin in the Great Salt Lake ecosystem, methylmercury.²⁷²

Forever Chemicals (PFAS)

Highly toxic PFAS, i.e. “forever chemicals” are found in Great Salt Lake dust. Likely sources include pesticides and the discharge from 28 sewage treatment plants to the lake and its tributaries.

Forever chemicals are likely one of the greatest health threats of Great Salt Lake dust. These chemicals have been grossly underregulated for decades. In many of the examples of environmental toxins mentioned in the introduction, industry malfeasance contributed to the prolonged production of dangerous chemicals. With forever chemicals, that malfeasance was a deliberate withholding of company-produced research and information from the public and government regulators on the hazard of their products by the original manufacturers, Dupont and 3M, in order to continue their revenue stream.

PFAS compounds are per- and polyfluoroalkyl substances that are otherwise known as “forever chemicals” because they last so long in our environment. PFAS came into use after the invention of Teflon in 1938 to make fluoropolymer coatings and products that resist heat, oil, stains, grease, and water. They have become a ubiquitous ingredient of thousands of consumer and industrial products.

While there is a rush in the worldwide scientific committee to better understand the extent of the environmental contamination and health threat from PFAS compounds, enough is already known to trigger great alarm. So far there is very limited research that documents PFAS compounds in Great Salt Lake dust, but because of their intense toxicity, it is important to provide detail about the potential health hazard.

Dr. Yiming Su, Assistant Professor of Environmental and Civil Engineering at Utah State University (USU) has measured both PFAS compounds and microplastic and nanoplastic particles (MNPs) in Great Salt Lake dust from the Farmington Bay area. PFAS concentrations were comparable to what has been measured in dust near fire stations, which are sites common for high PFAS because of PFAS foam used in firefighting drills. MNPs were ten times what has been measured in dust from Tokushima, Japan. He comments:

While these data are from just one location of the dried lakeshore, it clearly demonstrated the possible existence of PFAS and MNPs in dust. Due to the historical industrial discharge, rivers inflow, man-made discharges (especially discharge from wastewater treatment plants) around the whole lake, it is anticipated that different locations of the dried lakeshore will have different levels of contaminations.²⁷³

Human exposure to PFAS chemicals comes from many sources including thousands of consumer and household goods. Of the two significant sources of PFAS compounds to the Great Salt Lake ecosystem, one is the multiple sewage treatment plants that discharge into the lake or its tributaries and the other is a likely abundance of pesticides (herbicides and insecticides).

Likely Sources of PFAS in Great Salt Lake Dust

Sewage Treatment Plants on the Eastern Shore of the Great Salt Lake

There are at least 28 sewage treatment plants that discharge into the lake or its tributaries.²⁷⁴ Sewage treatment plants are designed for organic and nutrient removal from municipal sewage water and not for removal of micropollutants like pesticides, PFAS compounds, pharmaceuticals, nanoparticles of heavy metals, and the myriad chemicals in industrial and municipal sewage.²⁷⁵ Indeed much of this will end up in the effluents of the plants,^{276,277} which are discharged into Great Salt Lake. There are anywhere from 80,000 to 140,000 industrial chemicals that make it into municipal sewage, sewage treatment plants, and the discharge wastewater. One study found that on average, about 40% of the burden of “chemicals of concern” (CEC) in the influent to these plants was found in the effluent. The high concentrations of CECs in plant effluent resulted in, on average, 50% higher concentrations of CECs in water downstream of plants compared with upstream. Moreover, during the wastewater processing and treatment of sludge, many toxins can form intermediate products, often more toxic than the original compounds.²⁷⁸

Not only are PFAS compounds in Utah’s sewage treatment plant discharge, but conventional water and wastewater treatment facilities are not capable of removing them.²⁷⁹ In fact numerous studies confirm that PFAS concentrations are actually higher in the discharge than in the intake.^{280,281,282,283,284,285,286,287}

Pharmaceuticals and their metabolites are part of the effluent waste stream from municipal sewage treatment plants. Under a broad definition of a PFAS compound, as of 2021, 363 pharmaceuticals can be classified as PFAS compounds.²⁸⁸ Some of the most widely used pharmaceuticals contain PFAS type moieties, including Lipitor, Prozac, numerous antidepressants, antipsychotics, antibiotics, and Paxlovid, a first line of treatment for COVID-19.

PFAS in Pesticides

Prominent among the sources of PFAS compounds in the Great Salt Lake ecosystem are pesticides that contain PFAS chemical structures from as many as three different sources. First, PFAS structures can be part of the active ingredient. Second, the end product can be contaminated by leaching from fluorinated storage containers. Third, PFAS compounds can be intentionally added as “inert” ingredients to enhance the “effectiveness, stability, shelf life, and application uniformity” of the pesticide.^{289,290} Some pesticides could have all three sources of PFAS.

Although the Biden Administration’s EPA took the first major step toward protecting the public from PFAS chemicals, its actions have been far from comprehensive. In 2022, the EPA did remove 12 inert PFAS ingredients from their approved list in “non-agriculturally-used

pesticides” and cannot be used without prior EPA review.²⁹¹ That hardly scratches the surface of the problem because the majority of pesticide use is for agriculture and the inert ingredients are only one of three paths for PFAS contamination, as noted previously. Other actions call into question the EPA’s commitment to reducing PFAS in pesticides.

In the fall of 2022, a study found high levels of PFAS compounds in widely-used pesticides.²⁹² PFOS (perfluorooctane sulfonate), of the same class of chemicals as PFAS, was found at levels ranging from 3,920,000 to 19,200,000 ppt before dilutants were added. Recall that the EPA proposed a drinking water guideline for PFOS of 0.004 ppt. About six months later, the EPA announced findings of a non-peer reviewed research memo analyzing the same batch of pesticides, publicly stating that, “None of the 29 PFAS compounds, including PFOS, were detected in any of the samples above the method detection limits...” But information obtained via the Freedom of Information Act revealed the EPA did in fact find PFAS in those pesticide batches, and in those independently obtained by the EPA.²⁹³

The samples sent to the EPA for analysis had been deliberately spiked with PFAS (a common quality control practice). The spike’s existence was revealed to the EPA after its tests.²⁹³ That the EPA claimed it could not detect PFAS in those samples means in a best-case scenario their detection technology is flawed. In the worst case, their reporting was a fraud. In either case, the EPA’s credibility on the issue is severely damaged; this suggests the public’s exposure is much greater than previously known. The EPA has not yet responded to the inconsistency.

Scientists around the world are finding PFAS compounds in both active and inert ingredients in pesticides. In a 2022 study, nearly 70% of all pesticides introduced for commercial sale between 2015 and 2020 were found to be contaminated with PFAS/PFOS compounds.²⁹⁴ the state of Maine, in collaboration with the Environmental Working Group, using a broader definition of PFAS chemicals than the EPA, but more consistent with other countries, conducted an extensive chemical analysis of pesticides and found 1,400 of them that contained a PFAS moiety, defined as at least one carbon atom bound to three fluorine atoms.²⁹⁰

Another study published in July 2024 found 14% of all US pesticide active ingredients are PFAS, including nearly one-third of active ingredients approved by the EPA in the past 10 years. PFOA (perfluorooctanoic acid) and PFOS, currently considered the most toxic PFAS chemicals, have been found in other pesticide products, likely from the leaching of fluorinated containers and other unknown sources. Pesticides can accumulate PFAS from multiple other sources, leading to mixtures of different PFAS chemicals in containers. The active ingredients in pesticides were found to be the greatest contributor to PFAS in the commercial pesticides, and 66 PFAS active ingredients are EPA-approved.²⁹⁵ The lead author of that study, Nathan Donley, said:

*This is truly frightening news, because pesticides are some of the most widely dispersed pollutants in the world. Lacing pesticides with forever chemicals is likely burdening the next generation with more chronic diseases and impossible cleanup responsibilities. The EPA needs to get a grasp on this fast-emerging threat right away.*²⁹⁵

PEER Science Policy Director Kyla Bennett, a PhD scientist and former EPA attorney, said, “If the intent was to spread PFAS contamination across the globe there would be few more effective methods than lacing pesticides with PFAS.”²⁹⁶

Multiple private and government entities spray various herbicides and insecticides within the Great Salt Lake ecosystem. It’s likely some or many of the chemicals used contain PFAS compounds from one or all three of these sources. While the first line of blame for the PFAS pesticide crisis may lie with the EPA, the second line is other federal, state, and local agencies that have ignored this emerging crisis. The victims are all Utahns that live close to or downwind of dust from the Great Salt Lake ecosystem, and anywhere else pesticide spray application is happening on a mass scale.

PFAS are “probably the greatest chemical threat the human race is facing in the 21st century” according to Patrick Byrne, a pollution researcher at Liverpool John Moores University.

Growing Worldwide Alarm About Forever Chemicals

Although the research of PFAS chemicals is still in its early stages, the intense toxicity of these compounds and their ubiquitous environmental presence, including in the Great Salt Lake ecosystem and consequently Great Salt Lake dust, demand policy makers attention. This report devotes a large section to PFAS because of that.

Reflecting growing worldwide alarm in the scientific community, Patrick Byrne, a pollution researcher at Liverpool John Moores University, said PFAS are “probably the greatest chemical threat the human race is facing in the 21st century.”²⁹⁴ They contaminate surface and groundwater throughout the globe.²⁹⁷

Forever chemicals are universally present in rainwater and contaminate even remote, uninhabited corners of the earth. Because there is no safe refuge from these chemicals, and the problem is increasing and largely irreversible, forever chemicals represent a planetary boundary threat. That is, an environmental problem in the same category as the climate crisis, ocean acidification, loss of stratospheric ozone, and depletion of global fresh water sources because the threats are global, universal, and profound, and in most cases, getting worse.²⁹⁸

Substantial research has revealed a long list of confirmed and likely adverse health effects in humans, laboratory animals, and wildlife as a result of exposure to PFAS.^{299,300} This fact is made even more potent given that only a tiny fraction of the thousands of commercially-produced

PFAS-type compounds have been well studied. Most have not been studied at all.³⁰¹

Countries around the world are just beginning to acknowledge the crisis of forever chemicals. Great damage has already been done, and without aggressive, urgent action, it will continue and worsen. While the Utah state government is not totally ignoring the problem, its current level of engagement overlooks many of the related issues and causes of exposure.

A steady drumbeat of alarming research on PFAS has triggered increasing attention from the media, the scientific community, and government regulatory agencies in recent years. Health authorities globally have been forced to revise upward their assessment of PFAS toxicity multiple times in just the last ten years. For example, in 2018 the European Union considered a daily intake of 1,500 nanograms of PFOA per kg (ng/kg) of body weight safe. By 2024 they had dropped that number to 0.7 ng/kg of body weight, a decrease of 2,143 times.

Similarly, in 2016, the US EPA 's drinking water safety guideline was 70 parts per trillion (ppt) combined for PFOA and PFOS, the two main categories of the chemicals. By 2022, their guidelines had dropped to 0.02 ppt for PFOS and 0.004 ppt for PFOA, 3,500 times and 17,500 times lower respectively.³⁰² These are unimaginably small numbers. To give that a visual reference, 1 ppt is the equivalent of four grains of sugar in an Olympic- size swimming pool.³⁰³

Figure 19: No safe level of PFAS chemicals

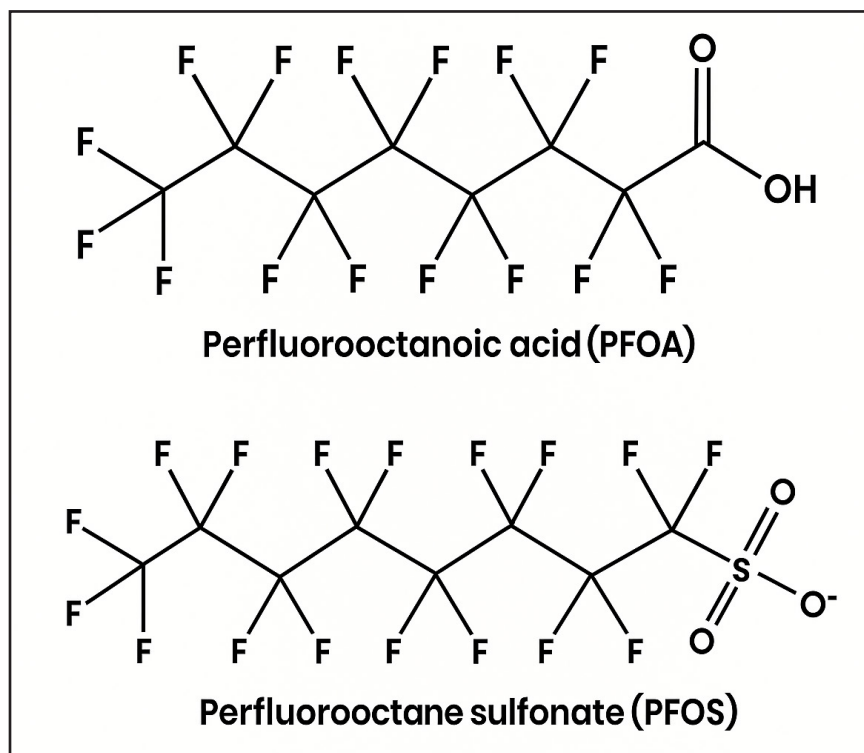


There is essentially no safe level of exposure for PFAS chemicals. In 2022, EPA set drinking water guidelines for the two main PFAS compounds at 0.02 parts per trillion and 0.004 parts per trillion. That's the equivalent of one drop of water in a lake the size of six Rose Bowls in the first case and one drop of water in a lake the size of 30 Rose Bowls in the second case.

Many public health advocates, environmental groups, researchers, and EPA whistleblowing employees, have criticized the EPA for acting as a long-time handmaiden to the chemical industry. When the EPA

announced those guidelines, shock waves should have rolled through every state government. Eleven states developed their own drinking water standards, and 29 states have filed suit against PFAS manufacturers.

Figure 20: Chemical Structure of PFOA and PFOS



PFAS are a family of chemicals known as “forever chemicals” because they are impervious to break down in the environment and the human body. These chemicals are probably the most toxic industrial chemicals ever produced and they are ubiquitous throughout the global environment. There are multiple sources for the presence of these chemicals in the Great Salt Lake ecosystem and they have been documented in Great Salt Lake dust. Image recreated from Post, Gloria & Gleason, Jessie & Cooper, Keith. (2017). Key scientific issues in developing drinking water guidelines for perfluoroalkyl acids: Contaminants of emerging concern. PLOS Biology. 15. e2002855. 10.1371/journal.pbio.2002855.

In 2024 EPA set legally enforceable drinking water standards at 4 ppt, between 200 times and 1,000 times more contaminated than what the agency considers safe, only because that is the current limit of detection technology.³⁰⁴ But that means drinking water from throughout the country could meet regulatory standards but still be very hazardous, even according to the EPA that set those standards.

Almost all residents of the US and most other nations, from newborns on, have blood levels of PFAS compounds that can reach the low parts per billion range. That is more than 1000 times higher than the legally enforceable drinking water standard just set by the EPA in 2024.³⁰⁵ Nursing mothers universally have PFAS compounds in their breast milk.³⁰⁶

Recently the CDC made an unprecedented recommendation that physicians consider testing their patients' blood for forever chemicals.³⁰⁷ That they have never made such a recommendation for any other toxic substances speaks volumes. There is no treatment for PFAS contamination, so their purpose was to see if some communities have unrecognized PFAS sources, and if some patients have personal exposures that can be eliminated.

Despite the EPA's recent dramatic lowering of exposure standards, bear in mind that the EPA's toxicology risk assessments used to establish chemical exposure health standards have been resoundingly criticized by Utah Physicians for a Healthy Environment (UPHE) and other health organizations and researchers.

EPA permits about 15,000 variations³⁰⁸ of PFAS chemicals to be produced by 12 companies. For decades they have been found in over 3,000 consumer products. Only a tiny fraction of these chemicals has had toxicological studies performed, limiting our understanding of the details and the extent of the problem. But those studies have yielded alarming information.

Dupont, the original PFAS manufacturer, concluded there was no safe level of exposure to forever chemicals, which they hid from the EPA. Thirty-five different studies have linked forever chemicals to 55 different diseases.³⁰⁹

There are four main categories of adverse health outcomes from PFAS compounds, each of which is elucidated below:

1. Immunotoxicity.
2. Reproductive and developmental toxicity.
3. Carcinogenicity.
4. Endocrine and metabolic disorders.

Immunotoxicity from PFAS

The immune system is one of the most sensitive targets of PFAS compounds, meaning that effects are seen at lower doses than for other adverse health endpoints. Individual health is dependent on, and proportional to, a healthy immune system. It is the immune system's role to detect threats to the host, launch a response, and once the threat has abated, repair any tissue damage and return to a resting state.³¹⁰ Composed of multiple cell types, the immune system is integrated within virtually all organ systems. As such, it is vulnerable to toxins through nearly any exposure route. Even more concerning is that when the immune system is impaired during development, effects are likely more severe and more long-lasting than from exposures occurring during adulthood after organ development is complete.³¹¹

Clinical effects include diminished response to vaccinations and increased risk of multiple types of infections,^{312–315} both of which not only

threaten the health of individuals but put the entire population at risk. Impaired immunity increases cancer risk.

Both the US EPA and the European Food Safety Authority (EFSA) consider immunotoxicity as the most potent adverse effect to humans from exposure to some PFAS compounds.^{316,317} However, immunotoxicity studies are routinely waived by the EPA during pesticide registration reviews. Between 2012 and 2018, the EPA granted 223 of 229 waiver requests (97%) for immunotoxicity testing of pesticide active ingredients.³¹⁸

Since 2012, manufacturers have been increasingly using fluorinated active ingredients that otherwise meet the definition of PFAS, the very time period that US EPA granted nearly all of these waiver requests for immunotoxicity study requirements. The end result is that fluorinated or PFAS active ingredients may be more likely to be immunotoxic than other types of active ingredients and yet not accounted for given the EPA's waivers.

Other inadequacies of the EPA's regulatory reviews work to obscure or underestimate the toxicity of these chemicals. The EPA's research guidelines are an anachronism; they were not designed for chemical life expectancies similar to those of PFAS compounds. Studies of exposure to parent compounds' active ingredients and their degradants usually do not last longer than 120 days.^{319,320} This is far too short a time frame to assess compounds that are as persistent as PFAS. Furthermore, compared to the original compounds, breakdown products of PFAS pesticides can be more persistent and more toxic than the parent pesticide ingredients, and found in higher concentrations in human blood.^{321–325} The EPA often will require toxicity analyses of PFAS pesticide breakdown products only if they provoke acute toxicity to aquatic organisms.³²⁶ But acute toxicity is not the primary hazard from exposure to PFAS; it is long-term exposure.

Pregnancy Complications and Impaired Fetal Development from PFAS

PFAS exposure, even at very low levels, is associated with reproductive and fetal developmental toxicity, including poor fetal development, birth defects, pregnancy complications, and infertility.^{327–334} For reasons that have yet to be identified, PFAS blood levels in pregnant women increase throughout pregnancy.³³⁵

Carcinogenicity from PFAS

Numerous cancers are associated with environmentally common PFAS exposure levels, including thyroid, testicular, ovarian, uterine, kidney, and breast cancer, melanoma, and childhood leukemia.^{336–341}

Endocrine and Metabolic Disorders from PFAS

PFAS are associated with delayed onset of female puberty, (which in turn can lead to kidney and thyroid disease, and breast cancer³⁴²), increased risk of Type II diabetes,^{209,343,344} gestational diabetes,³⁴⁵ higher gestational blood pressure,³⁴⁶ liver damage, including non-alcoholic fatty liver disease,³⁴⁷ lipid dysfunction, increased serum cholesterol,³⁴⁸ and obesity.³⁴⁹ Ironically, statin drugs used to decrease serum cholesterol can be considered PFAS compounds.

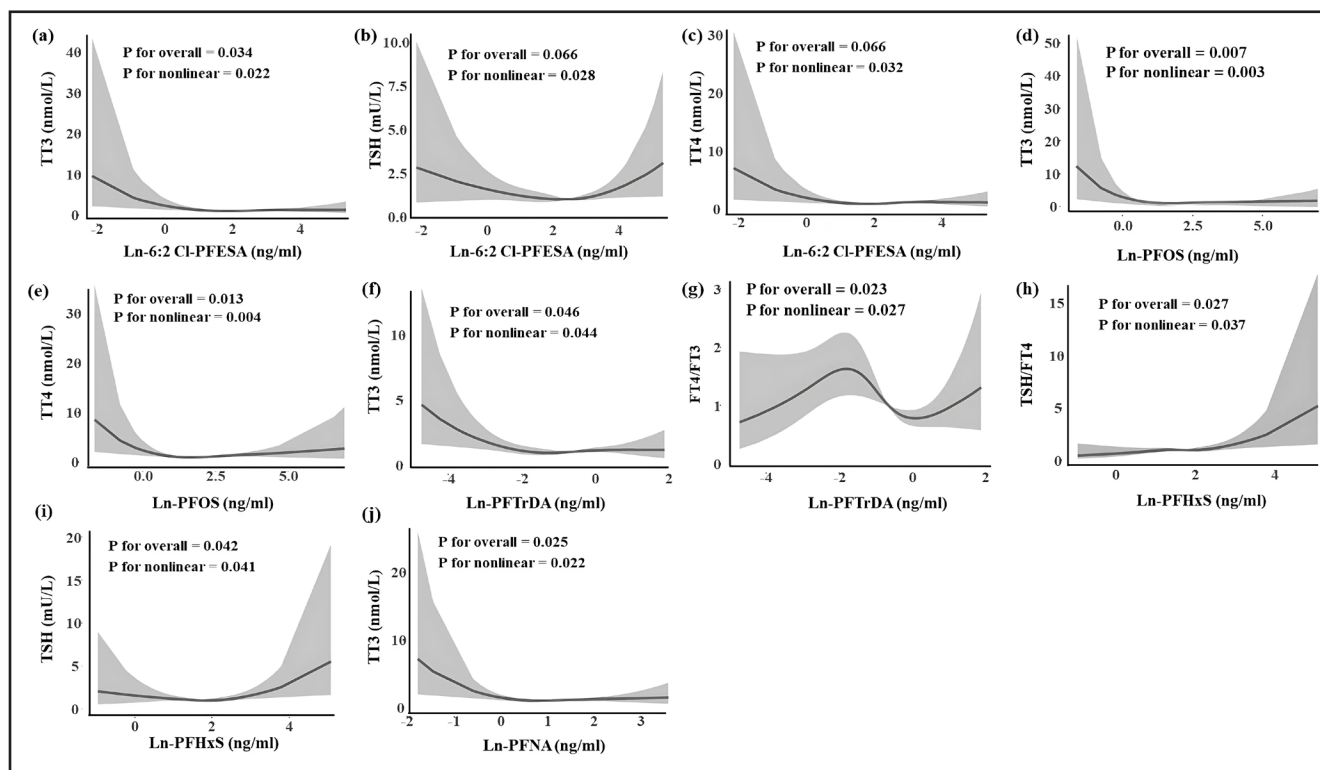
Miscellaneous Impacts of PFAS

In utero, infant, and early childhood PFAS exposures are associated with increased rates of allergic reactions, atopic dermatitis, childhood infections, increased blood pressure, and decreased bone mineral density in adolescents.^{206,350} Because the fetus is totally dependent on maternal thyroid for most of the first two trimesters, mixtures of PFAS compounds in maternal blood have been shown to consistently disrupt thyroid compounds, even synergistically, through multiple biological mechanisms, in both mother and fetus. This can have a profound clinical significance with adverse impact on fetal vital organ development, especially brain development.^{351,352}

PFAS increases the risk of heart attacks by promoting coronary artery stenosis, calcification, and atherosclerotic plaque formation by inducing an inflammatory response and platelet accumulation, compromising critical blood flow to the heart. Additionally, it increases the risk of poor prognosis after a heart attack.^{353–357}

A distinctive feature of many of the PFAS dose-response curves is that they are not linear. Some are hyperbolic, like many other environmental toxins such as air pollution and some heavy metals,^{208–210} with the steepest part of the curve at very low doses meaning everyone is at risk. Others show a dose threshold above which intensified biologic harm is triggered.

Figure 21: Tiny amounts, significant health impacts



Increasing thyroid hormone levels are plotted on the vertical axis, increasing blood levels of several PFAS compounds on the horizontal axis. None of the graphs show a linear relationship. Most of the graphs show an "L" curve demonstrating significant drops in thyroid hormones with minimal PFAS concentrations. Wu M, et al. Prenatal per- and polyfluoroalkyl substances (PFAS) exposure and maternal thyroid homeostasis: Nonlinear, compound-specific, and mixture effects. *Environmental Chemistry and Ecotoxicology*, Volume 7, 2025, Pages 1280-1288, Volume 7, 2025, Pages 1280-1288, ISSN 2590-1826, <https://doi.org/10.1016/j.enceco.2025.06.008>.

The TFA Subclass of PFAS: a Planetary Boundary Threat

TFA (trifluoroacetic acid) is a subclass of PFAS chemicals, otherwise known as "ultra-short-chain" PFAAs because they are smaller and have fewer carbon atoms. TFA was first recognized in 2003 as a breakdown product of many forever chemicals, especially many pesticides, refrigerant gases, and pharmaceuticals.³⁵⁸

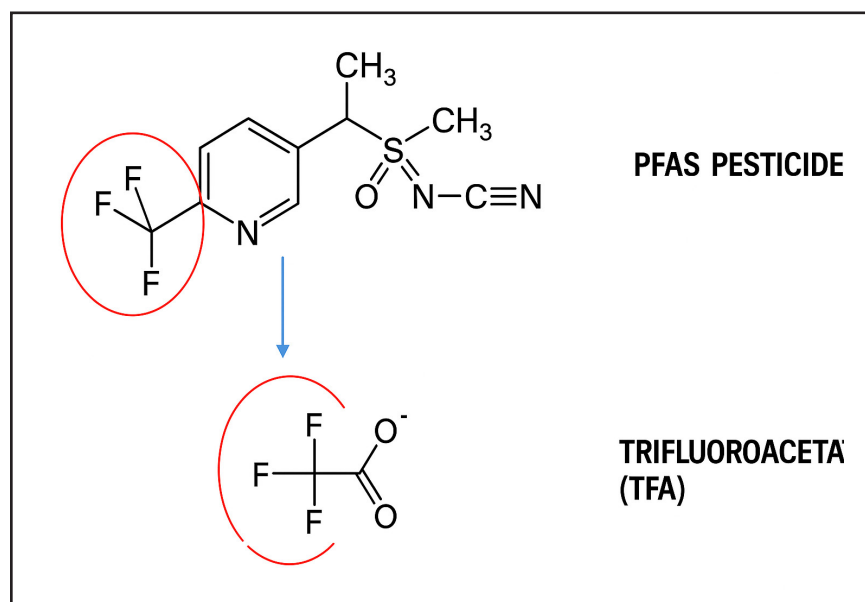
While we are not aware of studies specifically addressing TFA in the Great Salt Lake ecosystem, relevance to the overall toxic profile of Great Salt Lake dust to the PFAS/TFA crisis can be inferred by recent research on TFA, one of the primary degradation products of PFAS chemicals. A few years ago, TFA was thought to be less toxic because it was a smaller molecule, possibly less persistent than the classic PFAS chemicals that were eight-carbon chain molecules. But in recent years, the narrative that short-chain PFAS (like TFA) are benign, a narrative championed by the PFAS manufacturing industry, has been increasingly challenged by current scientific evidence. And a growing number of scientists regard

TFA as deserving of as much regulatory constraint as long-chain PFAS compounds.

Recent research suggests that TFA may represent the single greatest human health threat from these chemicals for several reasons:

1. The concentrations in the environment are orders of magnitude greater than all other PFAS chemicals.^{358–364}

Figure 22: Tiny but toxic



Maternal exposure to PFAS compounds can have significant adverse impacts on fetal organ development.

TFA and other ultra-short-chain PFAS are the most pervasive subclass of PFAS. Assumptions that they may be less toxic than classic PFAS compounds because they presumably break down sooner will likely turn out to be incorrect. Their very small size means they can migrate around the environment and within the human body easily, penetrating deep into sensitive organs, including crossing the placenta, into sensitive organs. Figure 22 from Pan-Europe's 2024 TFA in Water Report.

TFA and other ultra-short-chain PFAS compounds are the most prevalent of all PFAS in human blood.³⁶⁵ They are easily disseminated in all water phases including surface water, ground water, clouds, snow, and rain drops.³⁵⁸ The TFA levels found in surface and groundwater represent the largest known area-wide water contamination by any man-made chemical. One survey showed that TFA was present in all water samples in Europe, with concentrations ranging from 370 ng/l to 3,300 ng/l. The average TFA concentration across all samples was 1,180 ng/l.³⁶⁶

In other words, measurements of TFA in ground and surface water in Europe is between 60,000 and nearly 300,000 times higher than what the US EPA considers safe in drinking water for the main PFAS compounds.

A German scientist researching TFA said, “If you’re drinking water, you’re drinking a lot of TFA, wherever you are in the world ... China had a 17-fold increase of TFA in surface waters in a decade, the US had a sixfold increase in 23 years.” TFA in rainwater in Germany has increased 400-500% in two decades.^{367,368} While we have not found any published measurements of TFA in Utah, there is no reason to conclude that Utah would be exempt from this global trend.

TFA is the “perfect” groundwater contaminant. The filter and buffering function of soil is not effective for removing TFA. There is no degradation pathway in water. Given its high solubility, major concerns with TFA contamination center around environmental aqueous phases such as rivers, lakes, and surface waters.³⁶⁶

A recent investigation found nearly 23,000 sites in Europe are verifiably contaminated with PFAS and another 21,500 sites are suspected.³⁶⁹ European scientists said, “The extent of this contamination is shocking. It is a result of political failure at many levels.”³⁶⁶

A Norwegian TFA scientist said:

*It’s accumulating in our tap water, the food we’re eating, plants, trees, the sea, and all in the past few decades...Future generations will have increasing concentrations in their blood until some kind of global action is taken. Accumulation [in the environment] is essentially irreversible and I’m afraid the impact on humans and the environment won’t be recognized by scientists until it is too late.*³⁶⁸

Short-chain PFAS are even enriched in the leaves and edible parts of plants.³⁷⁰

2. Due to TFA’s prolonged environmental persistence, high mobility, and solubility, these high concentrations and human exposure are steadily increasing. The extreme environmental persistence is itself an incalculable hazard, lasting decades in a best-case scenario and centuries in a worst case.³⁷¹ Once exposed, because of environmental persistence, the hazard is, for all intents and purposes, irreversible.³⁷² Due to poor adsorption potential, short-chain PFAAs do not bind to particles and stay primarily dissolved in the water phase.³⁷⁰ Short-chain PFAS are also found in significant quantities in dust.³⁷³
3. Typical drinking water treatments are not effective in removing TFA. The only technology capable of removing TFA from water is high-pressure reverse osmosis, which is difficult, energy intensive, and wastes large amounts of water.
4. While the health hazard research on TFA is not as mature as on classic PFAS compounds, it is still very disturbing.

A summary of health concerns for short-chain PFAS compounds such as TFA includes:

In most studies human blood levels of classic PFAS compounds are declining but are being offset by increasing levels of short-chain PFAS.

Humans are likely harmed more than laboratory animals because of decreased elimination through the kidneys.³⁷⁴ Ultrashort-chain PFAS are highly bound to proteins³⁷⁰ such as albumin and are disproportionately distributed to highly perfused organs; the liver, lungs, kidney, spleen, testes, brain, and placenta. An autopsy study found PFAS compounds in the tissue of every organ of every patient.³⁷³ The high levels of the short-chain PFAS should worry all public health officials and contradict industry claims that there is no significant bioaccumulation by these compounds. The acute toxicity on freshwater invertebrates is greater in some short- and ultra-short-chain PFAS than that of longer chain PFAS.³⁷⁵

Some of the short-chain PFAS are endocrine disruptors. Clinical outcomes for which there is reasonable evidence that they are associated with short-chain PFAS exposure include lipid dysfunction, infertility, alterations of thyroid hormones, asthma, liver toxicity, and children's behavioral disorders.^{376–384} Shorter length PFAS are more easily transferred from the pregnant woman through the umbilical cord to the fetus, and therefore are of even greater concern as reproductive and developmental toxins.^{385,386} For example, they can disrupt gonadotropins as well as free androgen levels in fetuses.³⁸⁷

Short-chain and ultra-short-chain PFAS are increasing in human breast milk, with concentrations doubling every four years on a global scale.³⁰⁶ It is particularly worrisome that blood levels in nursing infants, obviously at critical stages of organ development, are several times higher than adults using the same drinking water source.³²⁸

In 2024 the German chemical regulating agency informed the European Chemicals Agency that it wanted TFA classified as “reprotoxic” because of the evidence that it harms reproduction and fetal development.³⁸⁸ Under the European REACH regulatory framework, for at least six years, researchers have labeled short-chain PFAS compounds, “substances of very high concern (SVHC)” which require urgent regulation.³⁷⁰

The most important precursors of TFA include pesticides, biocides, and pharmaceuticals, all of which, from different sources, end up in Great Salt Lake. Pesticide users are generally unaware of whether their chemicals are PFAS pesticides because the information is not available on product labels or in safety data information.

Scientists are now describing TFA contamination as a planetary boundary threat, meaning that, as with the climate crisis, ocean acidification, and depletion of stratospheric ozone, TFA contamination represents a threat to the entire planet's ability to provide a safe

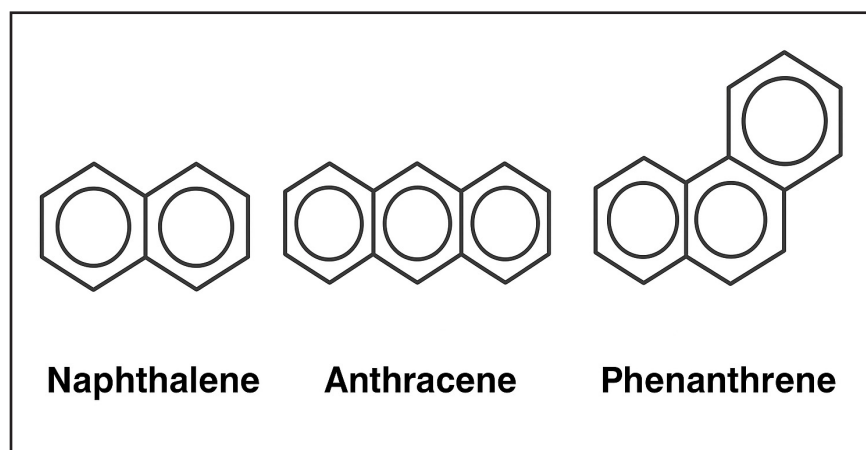
environment for human civilization and the biological systems needed to sustain it.³⁵⁸

European PFAS manufacturers are already halting production due to heavy fines tied to ultra-short-chain PFAS discharge. Drinking water guidelines for ultra-short-chain PFAS are emerging in Europe,^{389,390} but unfortunately, no similar regulatory action has been taken in the US. The TFA and PFAS crisis is pertinent to the threats to the Great Salt Lake ecosystem, the shrinking of Great Salt Lake, and the inevitable increase in dust storms. Outdoor dust, including from the dry lakebed of Great Salt Lake, is an important contributor to indoor dust in Utah homes, where the greatest human dust exposure likely occurs. PFAS and TFA are undoubtedly found in that indoor dust.³⁹¹

Polycyclic Aromatic Hydrocarbons (PAHs)

Some of the most toxic chemicals pervasive in the modern environment are polycyclic aromatic hydrocarbons (PAHs). These are compounds with two or more fused benzene rings in various configurations.

Figure 23: Chemical Structure of Polycyclic Aromatic Hydrocarbons (PAHs)



PAHs are highly toxic pollutants created by the combustion of organic material. These pollutants cause numerous negative health effects and are almost certainly present in the Great Salt Lake. This image was recreated from “Structure and Nomenclature of Aromatic Compounds”, section 13.8 from the book Introduction to Chemistry: General, Organic, and Biological (v. 1.0)

There are about 100 different types, and the most common sources are combustion processes of organic material, via fossil fuels, biomass, wildfires, and waste incineration.³⁹² The physico-chemical properties of PAHs afford them high mobility in the environment, allowing them to move across air, soil, and water bodies.³⁹³

PAHs are ubiquitous in air pollution around the globe and are usually bound to particulate matter. That means they are also undoubtedly

present in waters near urban areas, including the expanding dry lakebed of Great Salt Lake. The Agency for Toxic Substances and Disease Registry states that “...most [PAHs] stick to solid particles and settle to the bottoms of rivers or lakes...In soils, PAHs are most likely to stick tightly to particles. Some PAHs evaporate from surface soils to air.”³⁹² PAHs have been repeatedly measured in soil and all types of dust, indoor and out, especially in or near urban areas.³⁹⁴

Somewhat unique to PAHs is that they are absorbed through the skin or by ingesting after attaching to dust particles. These are the major exposure pathways and as such represent a risk four to five orders of magnitude higher than the risk of inhalation.^{395,396}

Prominent among the well-studied health effects of PAHs are that their actions are carcinogens and mutagens and reproductive toxins.^{397,398} Because no one is exposed to just one PAH, it is not possible to identify from epidemiologic studies the human health consequences of exposure to individual chemicals. PAHs are minimally toxic with acute exposures, but multiple types of cancer, especially breast, lung, and childhood cancers, are the most prominent adverse health outcomes from chronic exposure, based on laboratory animal studies and human epidemiologic studies.^{392,399}

Epidemiological studies show PAHs are associated with several types of lung and cardiovascular diseases. Limited epidemiological evidence also suggests adverse effects on cognitive or behavioral function in children.³⁹⁹

In many cases the derivatives and metabolites of PAHs are far more potent carcinogens than the original compounds.³⁹²

Microplastic and Nanoplastic Particles (MNPs)

Plastic pollution is one of the most serious and vexing environmental hazards in the 21st century. Microplastic and nanoplastic particles (MNPs) contaminate the broad environment because they were intentional additives to numerous consumer products, i.e. primary particles, or the result of breakdown of larger plastics fragments, i.e. secondary particles.

MNPs are ubiquitous, global environmental contaminants of our air, water, and soil. Recall the USU professor Dr. Su, whose research involved measuring high concentrations of MNPs from dust in Farmington Bay. Globally, the volume of plastic produced doubles every 10-15 years, and with it the human exposure to plastic nanoparticles. Undoubtedly there is an additional microplastics burden in the dust given the extensive sewage treatment plant discharges into the lake. Mechanical breakdown of microplastics from water shear induced by treatment facilities that includes pumping, mixing, and bubbling is likely the cause of MNP

High concentrations of plastic nanoparticles are found in Great Salt Lake dust.

discharge into the effluent from these plants.⁴⁰⁰

Previously mentioned research has also found traces of polyethylene, polyethylene terephthalate, and polypropylene, among other common plastic chemicals, in Great Salt Lake dust, evidence of the existence of MNPs.⁴⁰¹

Although research on the overall health effects of human exposure to plastic nanoparticles is still in the early stages, there is a body of work robust enough to draw significant conclusions. This document is not intended to be a comprehensive review of those health effects but a summary of what is known.

Plastic particles can cause mechanical friction and physical injury when infiltrating bodily tissue via inhalation or ingestion. They can represent a chemical hazard because they often have embedded in them a variety of chemicals such as PFAS, BPA, and phthalates that give them specific properties including strength, flexibility, durability, stiffness, or a scent. These chemicals have their own toxic potential, and many of them are endocrine disruptors with the whole range of associated morbidities alluded to in the previous sections on heavy metals and pesticides. A study published in December 2024 found over 400 chemicals commonly found in plastics are potential carcinogens, especially for breast cancer.⁴⁰¹

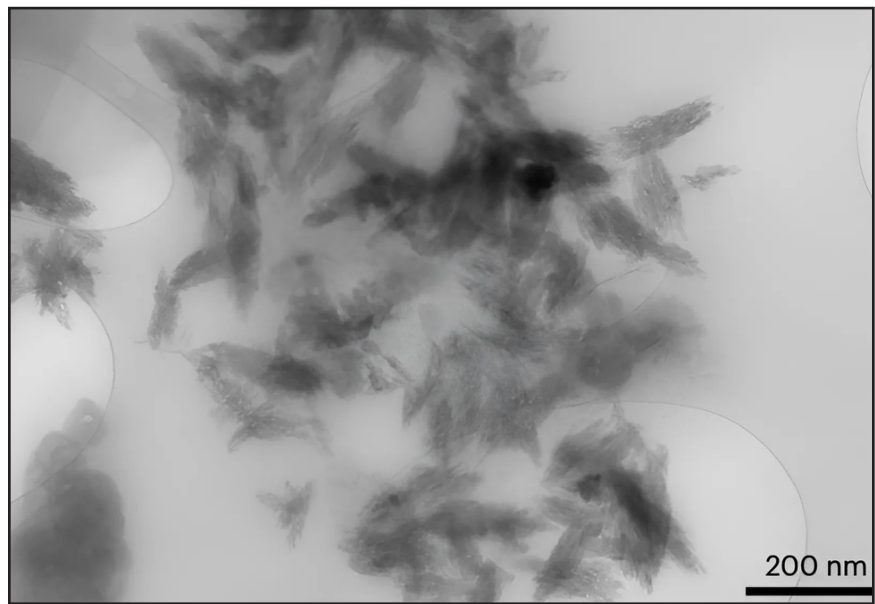
Further, because of hydrophobicity and large surface area compared to their volume, MNPs can behave as sponges for heavy metals and a variety of toxic chemicals they can pick up from the atmosphere, like PAHs.

Through inhalation, ingestion, and dermal absorption, plastic nanoparticles infiltrate every phase of the human food chain and the bodies of virtually every human, including all critical organs, just like particulate air pollution does.⁴⁰² They have been found ubiquitously in the human liver, placenta, blood, testicles, large arteries, and the brain, including the all-important frontal cortex.

And just like other pollution particles, some MNPs can be cleared and excreted through the lymph system or the intestines, but by no means all particles. The severity of organ damage is likely related to the dose of exposure,⁴⁰³ and chronic inflammation is the principal toxic response to MNPs in all tissues studied.^{404–406} All major organ systems - the lungs, heart and cardiovascular system, liver, kidneys, immune and endocrine systems- are likely damaged to varying degrees.⁴⁰⁷

Our exposure to MNPs is increasing. Researchers examined tissue samples from the brain, liver, and kidneys obtained in 2024, and compared them to retrospective examination of tissues collected in 2016. Concentrations of MNPs had increased about 50% over those eight years and the concentrations in the brain were up to 30 times greater than in other organs. These concentrations amount to about the weight of a plastic spoon, or roughly seven grams.⁴⁰⁸

Figure 24: Plastic in our brains



Tiny shards of plastic, less than 200 nanometers long and less than 40 nanometers wide, are found in human brain tissue. Courtesy of Dr Eliane El Hayek.

A review of over 30 papers studying the health consequences of MNPs concluded that they are suspected of causing harm to reproductive, digestive tract, and respiratory health. More specifically, they have been found in the placenta and amniotic fluid, and are suspected of increasing the risk of colon and lung cancer.⁴⁰⁹ A study published in the flag ship journal of the American Heart Association found higher concentrations of microplastics in ocean waters near coastal communities, controlling for other variables, is associated with higher rates of heart attacks, strokes, and type II diabetes.⁴¹⁰

A wealth of research has established a strong connection between intestinal health and brain health. Inflammatory chemicals in the intestine affect brain function and development. Neurologic deterioration in marine animals from feeding them microplastics is well-documented.^{411–413} Feeding laboratory animals plastic nanoparticles in doses comparable to human exposures causes chemical inflammation in the brain, inversely proportional to the size of the particles ingested.⁴¹⁴ Deterioration of memory and reduced cognition paralleled the inflammation. Notably, the effects could be reversed when ingestion of the particles ceased, suggesting that reducing human exposure can diminish the clinical consequences of MNP exposure.

The brain and nervous system in humans is highly susceptible to environmental toxins, especially during embryonic stages of development.⁴¹⁵ Anionic or negatively-charged polystyrene nanoplastics are found in the blood of most people tested.⁴¹⁶ They induce endothelial leaking and compromise of the blood-brain barrier in mammals.⁴¹⁷ They accumulate in the brain and penetrate neurons.^{418–421} They have been

linked to Parkinson's Disease,⁴²² Alzheimer's,⁴²³ and are a risk factor for amyotrophic lateral sclerosis, or ALS.⁴²⁴

Dissection of carotid artery plaques excised during carotid endarterectomies revealed the presence of MNPs of polyethylene or polyvinyl chloride in the plaques of nearly 60% of patients. Electron microscopy revealed visible, jagged-edged foreign plastic particles imbedded in the plaques. Those patients whose plaques were contaminated with plastic particles had 4.5 times the risk of a heart attack, stroke, or death over a 34-month period after surgery.⁴²⁵

New research has found that the combined exposure to PFAS compounds and MNPs has a synergistic toxic effect on survival, reproduction, and growth of *Daphnia* (tiny aquatic insects). The implications are that the combination also is likely synergistic in toxicity on humans, especially fetal development.⁴²⁶

Radionuclides

It is beyond the scope of this report to review all the medical literature on the health hazards of radionuclides. But relevant to the potential toxicity of Great Salt Lake dust is that the Great Basin is still contaminated with a variety of radionuclides from the Nevada open air nuclear testing era of the 1950s and 60s, from the underground testing that continued until 1992,⁴¹⁸ and to a lesser extent, worldwide nuclear testing during those same decades. Cesium 137 and Strontium 90 are still widely present in Utah soil.⁴²⁷⁻⁴²⁹ In addition, dust samples from residences in surrounding states have found plutonium unrelated to global background fallout, resuspended from dust from the test site.⁴³⁰ The study cited earlier that identified specific heavy metals in Great Salt Lake dust found the radionuclides Strontium, Ytterbium, Yttrium, and Cesium, some of whose isotopes are radioactive.

As well, there is likelihood of legacy uranium contamination of the Jordan River delta that empties into Farmington Bay of the Great Salt Lake. The Vitro Chemical Company processed uranium and vanadium at a mill located at 3300 South and near Interstate 15 from 1951 to 1968. Both the Jordan River and Mill Creek flow close to that site that was incompletely cleaned up in the 1980s. There remains residual radioactive contamination at the site.⁴³¹

Strontium and cesium decay by emitting beta particles. Uranium and plutonium decay by emitting alpha particles. Beta particles, and even more so alpha particles, are dangerous in their potential to cause tissue DNA damage and carcinogenicity when they are inhaled, ingested, absorbed through the nasal mucosa or by the cornea. Much greater penetration occurs through these membranes compared to skin,⁴³² something particularly relevant to their presence in Great Salt Lake dust.

A study awaiting peer review centers on radioactive isotopes, including uranium, cesium, and ytterbium, and other toxic metals that were found

Pathogens in Desert Dust

in the furnace filters of homes in Salt Lake, Weber, and Davis Counties.⁴³³ The most likely source of the radioactive isotopes is Great Basin dust, if not specifically from the drying Great Salt Lake.

One grain of sand can be home to tens of thousands of microorganisms. A gram of lakebed soil (about a teaspoon) can harbor billions of microorganisms, including 30,000 different types of bacteria, viruses, fungi, algae, and arachaeans.^{434,435} Cyanobacteria and cyanotoxins are prevalent in the surface crusts of desert soil and playas, and have been documented in air over Great Salt Lake and in dried lakebed sediments.⁴³⁶ Toxins produced by cyanobacteria have been linked by a few studies to neurodegenerative diseases like ALS, Parkinson's, and dementia.⁴³⁷

Viable microbes in dust can travel thousands of miles from their original source.⁴³⁸ Infectious diseases such as SARS, meningococcal meningitis, COVID-19, tuberculosis, coccidioidomycosis (Valley Fever), pneumonia from multiple infectious agents, and Rift Valley fever can be spread by desert dust.^{12,439,440} These microorganisms can cause allergic outbreaks far from its source.^{440,441} Significant loads of microorganisms and toxic biogenic allergens may be transported via these processes.^{12,439}

Given that the Great Salt Lake is the end destination of the discharge of numerous sewage treatment plants, it is not surprising that multiple pathogenic bacteria species, including antibiotic resistant ones, are found in Great Salt Lake dust. Among them, *Streptococcus*, *Klebsiella*, and *E-coli*, as well as lipopolysaccharide (LPS) endotoxin.⁴⁴²

Various species of cyanobacteria populate Great Salt Lake and are a foundational part of the food web of the lake.⁴³⁶ Cyanobacteria are capable of producing a wide array of bioactive substances that are toxic to the brain (neurotoxins), the liver (hepatotoxins), and cells in general (cytotoxins). These cyanotoxins can have both acute and chronic adverse health impacts.⁴⁴³ Catastrophic incidents of acute exposures have been well documented.⁴⁴⁴⁻⁴⁴⁷ There is emerging evidence that one of these neurotoxins, -Methylamino-L-alanine (BMAA), a non-proteinogenic amino acid produced by cyanobacteria, is a risk factor for multiple neurodegenerative diseases that include ALS and Parkinson's disease.^{448,449}

Some scientists believe that cyanotoxins present in Persian Gulf desert dust are responsible for an abnormal rate of ALS among relatively young military personnel who deployed in the first Gulf War.⁴⁵⁰ And there is evidence that BMAA and other neurotoxins such as methylmercury act synergistically, which would be particularly relevant for a population exposed to Great Salt Lake dust.^{451,452} There is some evidence that cyanotoxins are a risk factor for cancer, especially liver cancer.⁴⁴⁹ Cyanotoxins have been documented to be in both the air and soil around the Great Salt Lake.

Interactions of Dust and a Shrinking Lake with Other Air Pollutants

Fossil fuel-sourced air pollution typical of urban areas is affected by mineral dust. The surfaces of mineral dust particles provide sites for numerous types of trace gas reactions and act as a catalyst for those reactions.⁴⁵³ Highly reactive (and therefore biologically harmful) gases like HONO (nitrous acid) are produced.⁴⁵⁴ Metal oxides like titanium in dust particles can participate in atmospheric chemical reactions that enhance the toxicity of pre-existing pollution. The mixing of anthropogenic pollution and dust particles that remain in the atmosphere after a windstorm can increase the formation of secondary organic aerosols (PM), ozone, nitrogen dioxide (NO₂), volatile organic compounds (VOCs), and nitrate compounds.⁴⁵⁵

In the case of the Great Salt Lake ecosystem one reaction is particularly notable. Halogen-bearing dust, that which contains chlorine and bromine from the US Magnesium plant, emitted from the Great Salt Lake lakebed, facilitates the formation of nitryl chloride (ClNO₂) which photolyzes to regenerate NO₂ and a chlorine radical.^{456,457} The chlorine radical is very unstable and reacts with VOCs to form secondary organic aerosols and ozone.⁴⁵⁸

Because soil in the Great Salt Lake lakebed is predominantly alkaline, the dust derived from that alkaline soil captures acid gases including sulfur dioxide and nitrogen oxides. When adsorbed onto alkaline dust particles they form sulfates and nitrates.^{459,460}

The toxicity of dust particles originating from the lakebed is likely to become enhanced as they arrive over the Wasatch Front because the particles act as a platform for adsorption of toxic chemicals and heavy metals that are part of urban pollution emissions typical of the Wasatch Front.^{461,462}

Such mineral dust surface reactions are often an unrecognized and underappreciated source of increased toxicity of particulate pollution in the urban atmosphere. One example is mineral dust particles promoting the formation of nitrated PAHs, forming highly toxic NPAHs (nitropolycyclic aromatic hydrocarbon) that are known carcinogens.⁴⁶³

Replacing lake surface area with a highly reflective dried-up lakebed increases the temperature and the solar reflectivity of the lake ecosystem. Heat and short-wave UV solar radiation are catalysts for the formation of ozone.^{432,464} So as the Great Salt Lake shrinks, it can be expected that ozone concentrations along the Wasatch Front will increase on that basis. Ozone has most of the same clinical consequences to human health that particulate pollution has, although thought to be generally less potent in causing cardiovascular mortality.⁴⁶⁵

Highlighting the public health impact of ozone is a study of Utah children published in December 2024 showing that modest increases in prenatal ozone exposure (preconception and all trimesters of pregnancy, especially the second trimester) were associated with a significantly increased risk of intellectual disability in children.⁴⁶⁶

Contamination from US Magnesium

Beginning in 1972, utilizing a system of evaporation ponds and magnesium chloride naturally present in Great Salt Lake brine, production of various products including magnesium, chlorine, multiple chloride products, and lithium got underway in Stansbury Basin on the southwestern shore of Great Salt Lake. Stansbury Basin is a natural depression of the lakebed bounded on three sides by natural terrain. The operation has been managed by various owners and companies for forty years; production continued with periodic interruption until 2022.

In 1990, the EPA declared the owner Magnesium Corporation of America, or MagCorp, the worst polluter in the country.⁴⁶⁷ The EPA said Magcorp's pollution "not only accounted for 92% of toxics released to Utah's air but also for 73% of all toxics released to Utah's overall environment of land, air and water." Among the toxins released from the plant were various organochlorides, including dioxins, furans, hexachlorobenzene, and PCBs.⁴⁶⁸

For years the plant illegally managed its toxic waste using open-air, earthen ditches and ponds. It was declared a Superfund site in 2009. The Utah Department of Environmental Quality announced in 2016 that the company's toxic waste was leaking into groundwater underneath the plant and into Great Salt Lake. Naturally that means those toxins have also contaminated the lakebed and would probably be found in the lakebed dust.

In 2021 the company now calling itself US Magnesium signed a consent decree with the EPA to create a barrier wall around the 1,700 acres of its highly acidic, toxic wastewater ponds to prevent them from reaching Great Salt Lake, and to construct a filtration plant to treat its wastewater. But the company admitted three years later in 2024 that it has stopped work on that barrier wall. Additionally, the control plan included using water to flood the retention pond repeatedly to gradually create a "salt cap." That plan depends on there being enough water in the lake to operate the plant's pumps, and that appears to be in jeopardy.

The bottom line is that it is highly likely that the numerous toxins generated by the plant are already found in Great Salt Lake dust from the area near the plant, and if the lake continues to shrink the contamination will only get worse.

Great Salt Lake Toxins Can Combine to Increase Danger

Although each adsorbed toxin to Great Salt Lake dust (heavy metals, toxic chemicals, plastic nanoparticles, microorganisms) has its own biochemical toxicity, at the most basic level, most of them share the same pathophysiologic pathways that result in, for example, oxidative stress and inflammation. There is great overlap in the potential to provoke similar adverse health outcomes. Simultaneous or even consecutive exposure to multiple contaminants, all of which are in concentrations theoretically below toxic levels, does not mean the

combined exposure is non-toxic: a little bit of ultrafine particulate matter coated with a little bit of heavy metals and/or a little bit of toxic chemicals and/or a little bit of plastic nanoparticles and/or cyanotoxins does not mean a little bit of health hazard. The cumulative toxic burden is at least additive and, in some cases, synergistic.

Great Salt Lake dust is toxic to human health even if it only consists of common earth crustal elements. But the dust can also act as a Trojan horse, carrying with it a wide array of additional toxins that can have significant adverse health impacts on virtually all organ systems, causing harm to all age groups of the population. But as with most environmental toxins, the greatest and most long-lasting harm will be to those in the earliest stages of human development- those in utero, infants, and children.

Figure 25: Dust is a toxic trojan horse



Dust from the Great Salt Lake is harmful in its own right. But even worse, it picks up and tags along toxins from the lake to the Wasatch Front, increasing the public health threat.

The Looming Healthcare Costs and Economic Losses from the Health Impacts of Great Salt Lake Dust

This report did not attempt to quantify the economic impacts of a drying Great Salt Lake on the Utah economy as such an analysis requires a comprehensive evaluation of a myriad of economic sectors beyond the scope of this work. Yet there is a pressing need for these economic losses to be quantified, and no research has yet been completed which adequately assesses the far-reaching economic consequences of a desiccated Great Salt Lake. One study initiated by the Great Salt Lake Advisory Council (GSLAC) attempted to quantify these economic impacts, and in the interest of providing thoughts for subsequent research endeavors, we sought to provide some input on the scope of this urgent problem.

The Great Salt Lake Advisory Council contracted with environmental consultants EConorthwest and Martin & Nicholson Environmental Consultants to produce a report published in late July 2025, titled *Economic Costs of Declining Water Levels in the Great Salt Lake*. The report was the first formal attempt we have seen which estimates the economic costs of a shrinking Great Salt Lake, and it represents a good start to this critical discussion quantifying the costs of Utah's failure to protect the Great Salt Lake.

However, the report only looked at a small fraction of the relevant research regarding the economic costs of the health and worker productivity impacts. The report's estimate of economic costs from the public health consequences of lakebed dust (PM₁₀ and PM_{2.5}) is slightly less than \$4 million if 7% of the particulate matter in northern Utah counties comes from the Great Salt Lake lake bed, and slightly more than \$17 million if the lakebed is responsible for 30% of that particulate matter. In either case, those numbers are almost certainly underestimations of the costs by what could be several orders of magnitude. What follows cites only a fraction of the research relevant to this topic.

An article in the *Lancet*, one of the world's most respected medical journals, states:

*Pollution is very costly; it is responsible for productivity losses, health-care costs, and costs resulting from damages to ecosystems. But despite the great magnitude of these costs, they are largely invisible and often are not recognised as caused by pollution. The productivity losses of pollution-related diseases are buried in labour statistics. The health-related costs of pollution are hidden in hospital budgets. The result is that the full costs of pollution are not appreciated, are often not counted...*⁴⁶⁹

Most particulate pollution studies of the last 10–15 years use measurements of PM_{2.5} in their methodology. The GSLAC report appears to use the assumption that 20% of PM_{2.5} in Northern Utah counties comes from Great Salt Lake dust. We use that same baseline for most of our calculations.

The economic losses from the health impacts of dust and other air pollution consequences of a shrinking Great Salt Lake could be costing the Utah economy billions of dollars.

There are numerous angles to analyze the economic costs related to poor health outcomes from air pollution in general. For example, an international study found a 1 ug/m³ increase in PM_{2.5} causes a .8% reduction in real GDP that same year.⁴⁷⁰ Utah's GDP was \$308 billion in 2024.⁴⁷¹ If Great Salt Lake dust caused a 20% increase in yearly average PM_{2.5} in Northern Utah (about 2 ug/m³) and 90% of Utah's GDP comes from Northern Utah (\$277.2 billion),⁴⁷² then that is a loss of \$4.44 billion/year.

The World Bank says that the overall cost of global air pollution on health and well-being was approximately \$8.1 trillion, or 6.1% of GDP, in 2019.⁴⁷³ If Northern Utah accounted for \$277.2 billion of Utah's GDP, and experienced the global average of GDP loss from air pollution, then that study suggests air pollution would be costing Northern Utah's GDP nearly \$17 billion each year. If Great Salt Lake dust and increased ozone from the lakebed was responsible for 20% of the overall pollution burden in Northern Utah, that would be \$3.4 billion.

A recently published study by Utah academics estimated that air pollution costs Utah's economy \$1.8 billion annually, about half of which came from health impacts. But their study noted that national studies found a much larger range of economic impacts in Utah, \$6.2–8.6 billion.⁴⁷⁴ In line with many other studies, this study found that the average Utahn loses about two years of life expectancy from our air pollution, primarily PM_{2.5}. If one fifth of that exposure is due to Great Salt Lake dust, then dust is responsible for 4.8 months of life lost. What is the economic value of 4.8 months of a person's life? A quality adjusted year of life (QALY) has been estimated at between \$50,000 and \$150,000 depending on numerous factors. If so, using an average of \$100,000, the economic cost of a loss of 4.8 months of life would be about \$40,000. That number times 3 million people that live in Northern Utah is \$140 billion. Amortized over 70 years, the number is \$2 billion per year.⁴⁷⁵

Earlier in this report, it was estimated that the economic cost of the respiratory deaths due to the contraction of the Salton Sea was about \$150 million for each one foot drop in the lake level.³⁶ Extrapolating from that study to the Great Salt Lake and Utah's population, based solely on comparing the size of the exposed lakebeds, would suggest an economic loss in Utah of \$31 billion since 1986, or \$795 million per year just in respiratory deaths.

Air pollution is probably responsible for about 20% of Alzheimer's globally. The most recent and largest study to date has found that for every 10 ug/m³ long term PM_{2.5} exposure, the risk of Alzheimer's increases about 17%.⁴⁷⁶ Ozone is an additional risk factor for Alzheimer's, and as we detailed earlier in the report, a dried up Great Salt Lake bed will contribute to higher ground level ozone in Northern Utah.⁴⁷⁷ Alzheimer's is just one of many long-term, costly diseases known to be caused by air pollution.

The Alzheimer's Association states that there are 38,300 Utahns diagnosed with Alzheimer's as of 2024.⁴⁷⁸ If 20% of those cases are

due to Utah's air pollution (7,660 cases) and if between 7% and 30% of Northern Utah's particulate pollution comes from the Great Salt Lake bed (as stated in the GSLAC report), then between 536 and 2,298 of those current cases could reasonably be attributed to a dried-up Great Salt Lake. Using that same percentage of Alzheimer's cases and data from the Alzheimer's Association, the cost of just unpaid care by relatives of those Alzheimer cases caused by Great Salt Lake dust would be between \$11.792 million and \$50.556 million.

Particulate pollution increases the risk of multiple types of cancer. For example, per one study, an increase of 1ug/m3 long term PM2.5 exposure is associated with a 1.4% increase in the risk of lung cancer.⁴⁷⁹ There is an 8% increase in breast cancer risk for a 10 µg/m3 increase in long term PM.25 exposure.⁴⁸⁰

Recently, about 4,100 Utah women have been diagnosed with breast cancer per year.⁴⁸¹ Eight percent, or 328, of those can be reasonably attributed to air pollution. If Great Salt Lake dust contributes 20% of the overall Northern Utah PM2.5, then 66 cases of breast cancer could be attributed to lakebed dust. What is the economic cost of 66 cases of breast cancer? Costs vary widely depending on the stage of the cancer, the phase of treatment, the age of the patient, and many other factors. In 2020 dollars, the initial year of diagnosis and treatment of breast cancer averages about \$44,000. Cost of cancer in the last year of life averages much more, around \$110,000.⁴⁸² That would bring the medical costs of just new breast cancers from Great Salt Lake dust to over \$2.9 million per year. Medical costs are just part of the overall cost to society which also include many other factors, such as lost wages, extra child care, and decreased worker productivity.

Using similar methodology for lung cancer, 1,876 cases of lung cancer would normally occur in a population the size of Utah. But Utah's lung cancer rate is about half that because of lower smoking rates. But in that case, air pollution would cause a higher percentage of Utah lung cancer. Taking these factors into account, if 14% of lung cancer is attributed to 10 ug/m3 long term exposure to PM2.5, and 20% of PM2.5 in Northern Utah is attributable to Great Salt Lake dust, then about 52 cases of lung cancer in Utah could be attributed to that dust. The average lifetime medical cost of a case of lung cancer is about \$282,000.⁴⁸³ Multiply that by 52 and the figure would be \$14.66 million. If one continued this exercise for the long list diseases associated with air pollution, and therefore Great Salt Lake dust, the end result would be far greater than the numbers cited in the GSLAC report.

The risk of a preterm birth is increased about 8% for every 10 ug/m3 PM2.5 during pregnancy.⁴⁸⁵ If 2 ug/m3 PM2.5 in Northern Utah is due to Great Salt Lake dust, then 1.6% of preterm births in Northern Utah are due to Great Salt Lake dust. About 9.4%, or 4,220, of births in Utah are preterm annually.⁴⁸⁶ If 90% of those occur in Northern Utah, that would be 3,698. If the Great Salt Lake dust is responsible for 20% of PM2.5, it is

responsible for 1.6% or 59 pre-term births. The average cost of a pre-term birth throughout the birthed person's lifetime is \$76,153.⁴⁸⁷ That would mean that Great Salt Lake dust would cost over \$4.5 million a year just from pre-term births.

A quantitatively similar effect on the risk of low-birth-weight syndrome is also found with air pollution.⁴⁸⁸ However the economic cost for low-birth-weight syndrome is greater, about \$114,437.⁴⁸⁹ Annual cost of Great Salt Lake dust for its contribution just to this poor pregnancy outcome would be nearly \$6.8 million. These are just two of multiple poor pregnancy outcomes that have been proven to be associated with maternal air pollution exposure.

This exercise could be repeated with dozens of other air pollution related morbidities and causes of mortality such as heart attacks, strokes, respiratory deaths, diabetes, and hospitalizations for infections.

The GSLAC report includes an acknowledgement of air pollution's impact on mental health and suicide, but the impact of pollution on brain function, behavior, and overall physical activity go far beyond depression and suicide. There is no mention in the GSLAC report on the economic consequences of proven air pollution impacts on intellectual capability, education attainment, worker productivity, or crime rates. Air pollution, even at low levels typical of developed countries, has an adverse effect on the physical and mental capabilities of workers, and therefore worker productivity, beyond their association with defined and diagnosable diseases. Some of these effects are acute, occurring in real time, contemporaneous with the exposure. However, the physiological damage from persistent chronic exposure is not measurable until long after.

Each 1 ug/m3 PM2.5 during prenatal to mid childhood has been found to be associated with a loss of intelligence on the order of .27 IQ points.⁴⁹⁰ Under the assumption that 20% of PM2.5 in Northern Utah comes from Great Salt Lake dust, that is an average loss of IQ of .54. While quantifying the economic repercussions of these consequences is difficult, it is not completely unavailable to empirical evidence.

One study found the economic value of a country was reduced by 4% for every one-point drop in national IQ average. Extrapolating from these above studies to Utah suggests that Great Salt Lake dust would drop Northern Utah's economic output by 2%, or \$4.8 billion, just from the impact on childhood brain development.⁴⁹¹

Individually, cognitive ability in childhood is positively associated with earnings potential and economic output in adulthood. Estimates range from .5% to 2.5% per IQ point.⁴⁹² Using the conservative value of 1.4% per IQ point, the implied life time monetary value of an IQ point as of 2021 is \$10,600–\$13,100.⁴⁹² If 90% of Utah's 45,000 births (2022) were in Northern Utah, and each of those 40,500 children lost .54 of an IQ point from Great Salt Lake dust, the economic loss to those eventual adults would be a .76% loss of lifetime earnings, which would be somewhere

between \$,5724 and \$7,074. Multiplied by 40,500, this is an annual economic loss of between \$231,822,000 and \$286,649,700 just from the impact of Great Salt Lake dust on the IQ of Utah's newborns and infants.

Numerous studies show that air pollution impairs judgement, executive functioning, cognition, office worker productivity, and academic performance of students, including same-day pollution decreasing student test scores on the day of the test. All of this has life-long impact on earnings potential.^{493,494,495} Pollution on the day of a critical exam, like SATs, MCAT, or LSAT, can affect scores that have lifelong impacts on careers and earnings potential.⁴⁹⁶

Air pollution increases student and teacher absenteeism. A 10 ug/m³ increase in daily PM_{2.5} is associated with a 5.7% increase in student absenteeism, a 13.1% in teacher absenteeism, and a 28% increase in student referrals to administration for behavioral discipline. If Great Salt Lake dust is responsible for only 20% of average PM_{2.5}, then it's contribution to these kinds of effects would also be about 20%.⁴⁹⁷

A 10% increase in same day PM_{2.5} is associated with a .14% increase in violent crime, and a 10% increase in same day ozone is associated with a .35% increase in assaults.⁴⁹⁸

The loss of worker productivity with air pollution has been documented in employment ranging from physically demanding jobs like professional soccer players⁴⁹⁹ and agricultural workers⁵⁰⁰ to non-physical jobs like baseball umpires,⁵⁰¹ call center representatives,⁵⁰² judges,⁵⁰³ and stock traders.⁵⁰⁴

Utah citizens deserve a comprehensive analysis of the economic consequences of the health impacts of allowing Great Salt Lake to continue contracting. Such an analysis would include all the outcomes we have cited and many others known to be related to air pollution. If done correctly, such a report would find the total cost to be a staggering amount, i.e. billions of dollars.

Conclusion

Scientific measurement of the toxicity of Great Salt Lake dust is still early and therefore very much incomplete. But enough research specific to Great Salt Lake has been done, and extrapolation from the massive body of worldwide research from other locations and other sources of air pollution can be applied, such that we can say with confidence that Great Salt Lake dust is already harming humans in northern Utah. The health hazard to 2.5 million people will be substantial and the failure of state government profound if Great Salt Lake is allowed to continue to shrink or disappear.



THE ECONOMICS OF GREAT SALT LAKE DUST MITIGATION



SECTION THREE

How Much Would It Cost to Prevent Great Salt Lake Dust Emissions?



The Great Salt Lake beneath a twilight sky. Raising the lake's water level is the most inexpensive means of preventing the lakebed's toxic dust from harming public health. Image from Wikimedia Commons.

Given the litany of public health impacts associated with dust emissions and the toxic characteristics of Great Salt Lake lakebed dust, it is in the public's interest that this dust be prevented from becoming airborne. The least expensive means of keeping lakebed dust from exposing downwind populations to a multigenerational public health crisis is to simply deliver more water to the Great Salt Lake. There is an array of simple water policy changes which could easily increase water flows to the Great Salt Lake, although these policy changes are politically unpopular with some water lobbyists and Utah legislators.

The 4,200 Project

Over the last few decades, while the Great Salt Lake began its 21st century decline, the Utah Legislature refused to pass legislation to incentivize water conservation efforts and shunned opportunities to protect the aquatic habitat of the Great Salt Lake. Much of the historic thinking around the Great Salt Lake was that water entering the lake was “wasted” because it could no longer be used by farms and cities upon entering the brackish waterbody. Over this same period of time, many other western states implemented ambitious water conservation efforts and some excellent policy tools to protect aquatic ecosystems for future generations. Having refused to follow this path, Utah is now decades behind other western states in incentivizing conscientious water use and reducing upstream water demand to share water with ecosystems.

In 2022, the Great Salt Lake reached a record low water level which generated headlines in newspapers around the globe. Much of the national media was highly critical of Utah's attitudes about water, its extremely cheap municipal water rates, its nation-leading municipal water use (per capita), its archaic system of secondary water systems which flood irrigate suburban grass with lake tributary water, and its governor calling upon residents to pray for rain as an answer to the state's reluctance to modernize its water policies. Public awareness for the plight of the Great Salt Lake shifted the cultural pendulum and there was immense pressure on the Utah Legislature to act.

A number of bills were passed which took some baby steps toward modernizing Utah's water policies to begin incentivizing water conservation. While most of these bills represented progress, they were small in scope. However, they were often presented as gigantic accomplishments when in fact they were rather tepid compared to the policies implemented by many communities outside of Utah.

At the same time, new legislation that eliminated wasteful water use was shunned, and newly proposed diversions of Great Salt Lake water continue to move forward. Although many cities and towns have jumped their water conservation programming forward with new incentives, policies, and educational efforts, saving the Great Salt Lake requires strong leadership from the state of Utah.

The 4,200 Project is a comprehensive toolbox of policy solutions to raise Great Salt Lake water levels. These solutions range from tax and water rate incentives to legal amendments of instream flow law to create a free-market method for delivering water to the lake. If Utah is serious about saving the lake, it needs to be transparent about what is being proposed and implemented. The state also needs to get serious about regulating upstream water uses to clamp down on speculation and frivolous uses of upstream water that make little sense in the Great Salt Lake watershed. There are a litany of reasons why restoring water levels in the Great Salt Lake is essential, and it is clear that delivering more water to the lake is the least expensive alternative for Utah. No single piece of evidence demonstrates that fact more than the dust pollution crisis being brought to the Wasatch Front by Utah's failure to restore lake levels.

Failure to properly prevent dust emissions from becoming airborne could send the Wasatch Front down the same costly path as Owens Valley in California where the diversion of the Owens River by the Los Angeles Department of Water and Power in the 20th century dried up Owens Lake. The drying of this saline lake left behind roughly 100 square miles of exposed lakebed.¹ This desiccated lake became the largest source of PM₁₀ pollution in the United States² and created numerous severe public health problems for the residents of Owens Valley.

There are two different ways to prevent toxic lakebed dust from becoming airborne: raising water levels, which is more affordable, and using engineered solutions. Utah is currently pursuing the more costly

and elaborate engineering methods to keep Great Salt Lake lakebed dust out of the air because our state refuses to properly regulate upstream water diversions.



The 4,200 Project is a comprehensive solution of policies to deliver water flows to the Great Salt Lake. Utah has many tools available to raise water levels of the lake if it chooses to use them. Between the regulatory environment, the policy sector, and the taxes and financial incentives at our disposal, saving the Great Salt Lake is possible.

Solution 1: Raise Great Salt Lake Water Levels

The most straightforward way to prevent dust emissions from the Great Salt Lake lakebed is to increase the water level of the Great Salt Lake to cover the exposed lakebed with water. This will not only mitigate dust emissions, but it will also support the \$1.3 billion Great Salt Lake economy and conserve the habitats of 330 migratory bird species that originate from every country in the Americas.

We know how to raise lake levels: use less water upstream so more water makes it to the Great Salt Lake. Both the Utah Rivers Council³ and Great Salt Lake Strike Team⁴ have calculated “repayment” budgets for water deliveries to the lake. These repayment budgets show the amount of water we need to free up and deliver to the Great Salt Lake each year for the next 10, 20, or 30 years, above and beyond the amount of water that already flows to the lake. In simpler terms, you can think about these inflow goals as the annual payment on a mortgage. If we meet these annual payments every year for the next 10, 20, or 30 years, we will have paid off the “water debt” we accrued by raising the Great Salt Lake back to 4,198 feet in elevation. This is akin to making your last house payment and then owning your home.

Raising water levels at the Great Salt Lake will mitigate dust emissions, support the \$1.3 billion Great Salt Lake economy, and provide viable habitat for 330 species of migratory birds.

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Although each scenario assumes different starting and ending elevations, the figures are in the same ballpark as each other. Table 2 shows our calculations of how much additional water must get to the lake in various time periods to rise to 4,198 feet in elevation — its minimum ecologically healthy level. It’s worth mentioning that the Great Salt Lake Commissioner showed similar but lower inflow goals in a nonbinding strategic plan for the lake.⁵ Although raising water levels to 4,198 feet will not entirely solve all air quality problems from ambient lakebed exposure, it will greatly mitigate the impacts. Unfortunately, given Utah’s failure to raise lake water levels or even stop new upstream diversions, we’re unlikely to reach 4,198 feet again during this century without greater intervention.

Table 2, partially adapted from the Great Salt Lake Strike Team’s work, presents two scenarios for consideration. One scenario assumes that Great Salt Lake water inflows will remain at 21st century average levels of 1,643,000 acre-feet per year. The other scenario assumes that Great Salt Lake water inflows will decline and stabilize at a lower level of 1,059,000 acre-feet per year, like what occurred between 1988 and 1992. This period was selected because it represents a good low runoff period over several years.

Table 2: Annual Water Debt Repayment Deliveries Needed to Raise the Great Salt Lake to 4,198 Feet from 4,191 Feet

Scenario	Timeline		
	10 Years	20 Years	30 Years
1988–1992 Drought Period (streamflow of 1,059,000 ac-ft/year)	1,702,363	1,443,181	1,356,788
21st Century Average (streamflow of 1,643,000 ac-ft/year)	1,118,363	859,181	772,788

Projections of how long it will take to fill the Great Salt Lake from 4,191 feet to 4,198 feet based on various water inflow and conservation scenarios.

The question is whether Utah is on track to provide at least 772,788 acre-feet of additional water to the Great Salt Lake every year.

The state of Utah has implemented a few water conservation programs over the last few years, oftentimes decades behind conservation policies, incentives, and programming implemented in other western states. As described below, water conservation does not automatically equal more water to the Great Salt Lake, in contrast to how the discussion is talked about and presented in much of the Utah media.

Utah has also implemented other policies, some of which are presented as helping to raise Great Salt Lake water levels. The policies that some have contended will deliver substantial amounts of water to the lake include Agricultural Optimization, Secondary Metering, the Great Salt

Lake Watershed Enhancement Trust which includes donations of water, general municipal water conservation, and agreements with mineral extraction companies. By examining how much water, if any, each of these programs is conserving and shepherding to the Great Salt Lake, we can see whether Utah is on track to meet any of its inflow goals to raise Great Salt Lake levels.

It's important to recognize that a water donation will only help Utah meet the above-stated inflow goals if it meets two important criteria.

There is virtually no measurement to ensure that conserved water is entering the lake, though much of the public presumes it is.

First, water donated to the Great Salt Lake must be tracked and measured to ensure that it actually reaches the lake. It is not sufficient to reduce water demand through a conservation program upstream of the lake and hope or presume the saved water flows into the waterbody. Many water managers simply leave saved water in the water supply system, either in an upstream reservoir or in an aquifer. Gauges, telemetry sites, or other measuring devices must be used to ensure that water saved through conservation programs or via donated water actually enters the Great Salt Lake. Unfortunately, there is virtually no measurement to show that conserved water is entering the lake, even though much of the public presumes that is happening.

Second, water donated to the Great Salt Lake must be water that was not already flowing into the lake. In other words, the water must be “new.” If the water that is donated was already flowing into the lake, then “donating” this water to the lake merely preserves the status quo. The donation may ensure that the donated water will not be taken out of the lake in the future, which is beneficial for the Great Salt Lake. However, it does not serve to increase the amount of water entering the lake, which is what is needed to halt and reverse the decline of the Great Salt Lake and meet inflow goals.

Agricultural Optimization

Overview of Efforts Implemented by Utah to Save the Great Salt Lake



Sprinklers irrigating farmland in Cache Valley, Utah. While policies and appropriations regarding agricultural water conservation are in place, there is no data to show that they are having any effect. Image from Wikimedia Commons.

Agricultural Optimization is a program the Utah Legislature established in 2019 to help agricultural producers improve the efficiency of water use in their farming operations. Since Utah agriculture accounts for some 80–84% of all water used in Utah, the thinking is that investing in water efficiency measures in the agricultural sector will automatically benefit the Great Salt Lake. Under the program, an agricultural producer can receive a grant from the state for up to 75% of the cost of an optimization project, such as upgrading to a more efficient sprinkler system or lining a canal.

In theory, the saved water would be delivered to the Great Salt Lake, so the program has been pitched by some Utah legislators and the governor as being the Great Salt Lake’s salvation. However, if one is using lake water deliveries from the program as the yardstick to measure its benefits, then Agricultural Optimization is a total failure. That’s because once an optimization project is complete, the agricultural producer gets to keep the water saved from the project. The producer is then free to do what they like with this saved water, which could include using it somewhere else on their farm, selling it to a real estate developer, or in theory donating it to the Great Salt Lake assuming their transfer is not blocked by other farmers on their canal and the water can physically be delivered to the lake with ease.

By not requiring any water to be delivered to the Great Salt Lake in exchange for the investment by taxpayers, the program makes it totally optional for farmers to provide any water to the lake. Because farmers

are often strapped for working capital, they are inclined to sell their water to nearby municipal users or nearby farmers in the same canal system. The Agricultural Optimization proponents also failed to think through whether the water on a piece of farmland can even be readily delivered to the lake since other water right holders on the canal will be impacted if water is transferred out of the system. This impact can include reduced head pressure in the canal and reduced return flows entering the system for other farmers to use.

Agricultural producers are supposed to report data on water savings, crop production, and other relevant metrics to the Department of Agriculture and Food. To date, the Utah Legislature has appropriated over \$250 million to the program. Although some have claimed that the program will provide substantial amounts of water to the Great Salt Lake, no data exists to support this claim. The Utah Legislative Auditor found that from FY2020 to FY2024, the Department of Agriculture and Food (UDAF) “has not ensured that enough data was collected to evaluate or support preliminary claims of early success.”⁶ As a result, the auditors found that “from Fiscal Years 2020-2024, UDAF has spent \$65 million on projects without clear transparency on their purpose and outcomes.”⁷

In other words, the state has no data to show whether the program is reducing overall water use on farms or whether the program is helping deliver any measurable water to the Great Salt Lake. It is impossible to know how much water has been saved and whether the lake has benefited from any additional water delivery. It’s possible that some saved water was delivered to the Great Salt Lake, but after tens of millions of dollars of investment by Utah taxpayers and the dire need to raise Great Salt Lake water levels, proponents of the program need to demonstrate progress or suspend funding in favor of other measures to raise water levels.

Given the lack of data, we cannot confidently identify any water deliveries to the Great Salt Lake from this program.

Secondary Metering

Secondary water systems are wasteful in almost every regard. Many secondary water systems use unlined, dirt canals to transport water to an end user or to a pipe for end user distribution.⁸ These unlined canals can be highly inefficient, resulting in seepage and evaporation losses of 30–50% or more.⁹ Of the approximately 260,000 secondary connections in the state, just 15% are metered.¹⁰ This means that the vast majority of secondary water users have little or no idea of how much water they use, resulting in huge water waste.¹¹

Very few American cities use untreated canal water to flood irrigate grass landscapes in the 21st century. Secondary water systems are highly inefficient. Pressurized water systems used to deliver water to urban populations are the standard in the developed world, which is why most municipalities outside Utah purchased irrigation canals and converted

Most secondary water users have little or no idea how much water they use, leading to immense water waste.

them to treated culinary systems or delivered the water back to aquatic ecosystems, or both. Utah's refusal to modernize archaic water diversion systems of tributary water represents backward thinking which will hamper any efforts to help the Great Salt Lake rebound and thrive for future generations.

Secondary water systems are a connected series of old agricultural diversions that were converted when the agricultural land was converted for municipal use. These diversion systems now supply untreated water to residents for lawn and garden use with some historic agricultural uses remaining.¹²

Most secondary water users have little or no idea how much water they use, leading to immense water waste.

Since most secondary users pay very low, fixed rates for vast quantities or unlimited amounts of water, they do not get effective price signals to use less water. It is analogous to the price one pays for an all-you-can-eat buffet. You can go back for seconds and thirds. Secondary water's price per additional unit consumed is zero; it's an all-you-can-use buffet. The lack of a strong price signal means that users are not incentivized to use appropriate amounts of water, leading to frequent overuse.¹³

While metering secondary water systems is a step in the right direction, it only addresses one of the core problems of secondary water waste. It is unlikely that secondary metering is contributing substantial water volumes to the Great Salt Lake. The secondary water system in Utah generally suffers from a lack of data, a problem created in part by the lack of metering systems in both unlined canals and among end users. Now that some meters are being installed, theoretically more data will become available over the next 7–10 years, albeit a long wait for information to quantify how much water is being used by end users, lost in canals along the way, and delivered to the Great Salt Lake because of meter installation.

Secondary metering is a program that has seen significant investment from the Utah Legislature with over \$250 million in appropriations. Additionally, a law was passed mandating that most secondary providers have meters installed by 2030.¹⁴

Even if all secondary systems had meters installed today, that would not necessarily translate into water inflows for the Great Salt Lake. In order to produce water for the lake, water saved through the secondary metering program needs to be purposely sent to the lake — most likely through a Utah Code 73-3-30 change application — and monitored to ensure the saved water actually makes it there. However, since secondary water rights are owned by the entity delivering the secondary water, this entity is likely to maintain possession of their water unless incentivized to do something else with it.

Even if all secondary systems had meters installed today, that would not translate into water inflows to the Great Salt Lake.

Because of the lack of information on how much water demand has been reduced in a secondary system from metering and where that saved water went, we cannot say that this program has delivered any measurable water to the Great Salt Lake.

Great Salt Lake Watershed Enhancement Trust

Unlike the Agricultural Optimization program, the Great Salt Lake Water Enhancement Trust (GSLWET) has clear information on the water it has produced for the Great Salt Lake. In 2023, the GSLWET engaged multiple outside entities in transactions to secure water inflows to the Great Salt Lake. Table 3 provides a summary of these transactions at the time of our analysis, which are pre-2025 transactions.

Table 3: GSLWET Instream Flows for Great Salt Lake

Water Right Holder	Water Right Holder	Change App. No.	Instream Flow Period	Div. Amount (ac-ft)	Dep. Amount (ac-ft)	Original Place of Use	New Place of Use	Impact on GSL?
North Point Consolidated Irrigation Company (LDS Church's share of 5785 shares)	59-6084	a51083	Permanent	20,650.23	8,762.58	Diversion from Jordan River @ 2100 S into Surplus Canal for agricultural use in the NPCCI's service area	Remain in Jordan River to go to Farmington Bay	Prior to the change application, the State Engineer calculated that 8,762.58 ac-ft of the 20,650.23 ac-ft water right was depleted. The remaining 11,887.65 ac-ft was assumed to return to the Surplus Canal, where it may have been used by downstream users. The State Engineer has decided that any water left in the Jordan River that exceeds the historical depletion of 8,762.58 ac-ft may be used by other downstream users on the Jordan River prior to the water reaching the GSL. This change application will provide (at minimum) 8,762.58 ac-ft and (at maximum) 20,650.23 ac-ft to the GSL, depending on use by downstream Jordan River users.
Kennecott Utah Copper LLC	59-30	a50506	Permanent	17,174.50	17,174.50	Diverted out of Jordan River into North Jordan Canal (near River Oaks Golf Course), which sends water to pump stations for Kennecott's copper mine or stays in canal to go to Kennecott Smelter on north end of Oquirrh	Either Kennecott Mine/Smelter OR C7 Ditch to Lee Creek to GSL	Prior to change application, the State Engineer assumed the water was entirely consumptively used by Kennecott. Now, Kennecott can consumptively use however much of the 17,174.50 ac-ft it needs for its operations and send the remainder to the GSL. Kennecott is supposed to restore the USGS Gage at Lee Creek (No. 1072840) to measure the amount of water discharged to the GSL under this change application, but it's unclear if that has happened. The online web portal for the gage shows the latest available data is from April of 2008. It's unclear how much (if any) water is going to the GSL.
Kennecott Utah Copper LLC	59-3518	146437	Until October 2031	18,386.77	18,386.77	Diverted out of Jordan River into North Jordan Canal (near River Oaks Golf Course), which sends water to pump stations for Kennecott's copper mine or stays in canal to go to Kennecott Smelter on north end of Oquirrh	Either Kennecott Mine/Smelter OR stay in Jordan River to go to Farmington & Gilbert Bay	Prior to change application, the State Engineer assumed the water was entirely consumptively used by Kennecott. Now, Kennecott can consumptively use however much of the 18,386.77 ac-ft it needs for its operations and send the remainder to the GSL. In 2022, Kennecott reported sending 2,862 ac-ft to the GSL and in 2023 they reported sending 18,386.77 ac-ft to the GSL.
Central Utah Water District	59-5334	146438 IS1947	Until September 2031 If the new application is approved, it would extend instream flow to Aug 2034	2,927	2,927	Kennecott originally owned this water right. When it owned it, it diverted water out of the Jordan River at two points: 1) into the Utah and Salt Lake Canal or 2) into the North Jordan Canal (near River Oaks Golf Course). From either diversion, water was sent to pump stations for Kennecott's copper mine or stays in canal to go to Kennecott Smelter on north end of Oquirrh. CUWD bought this water right from Kennecott Copper and planned to use it for future CUP development. However, the CUWD has never put this water right to beneficial use (at least in the 21st century) and instead has filed multiple extension of time requests to demonstrate future public use and/or multiple nonuse applications (essentially all of which were granted).	Stay in the Jordan River to go to Farmington & Gilbert Bay	Since this water right was not being used by CUWD prior to this change application, it is possible that the water was already staying in the Jordan River and flowing to the GSL. It is also possible that Kennecott Copper was still diverting this water (after selling it to CUWD). If the former is true, then this change application will add no new water to the GSL. If the latter is true, this change application will add 2,927 ac-ft of water to the GSL. The CUWD is required to install and operate the streamgages necessary to track this water and report that to the Division of Water Resources. This change application could provide 0 ac-ft to 2,927 ac-ft of new water to the GSL, depending on where the water was put prior to this change application.
Jordan Valley Water District	57-3575	IS0174 IS1983	Until June 2033 If the new application is approved, it would extend instream flow to Aug 2034	5,565.91	2,359.91	Diverted out of Jordan River for agricultural use in Salt Lake County.	Stay in the Jordan River to go to Farmington & Gilbert Bay	Prior to the change application, the State Engineer calculated that 2,359.91 ac-ft of the 5,565.91 ac-ft water right was depleted. The remaining 3,206 ac-ft was assumed to return to the Jordan River, where it may have been used by downstream users. The State Engineer has decided that any water left in the Jordan River that exceeds the historical depletion of 2,359.91 ac-ft may be used by other downstream users on the Jordan River prior to the water reaching the GSL. This change application will provide (at minimum) 2,359.91 ac-ft and (at maximum) 5,565.91 ac-ft to the GSL, depending on use by downstream Jordan River users.

Documented transactions of water provided to the Great Salt Lake through GSLWET. Many such transactions have stipulations that may reduce how much water actually reaches the lake.

Utah's water rights system is complicated and so is the process of legally and physically moving water from one place of use to another — especially for novel uses like instream flows to the Great Salt Lake. Many of the water transactions listed in Table 3 contain certain stipulations that could reduce the amount of water sent to the lake in any given year. For example, both water rights numbers 59-6084 and 57-3575 were used for farming prior to being dedicated as instream flows to the lake. Although these water rights are entitled to divert up to a combined 26,216.14 ac-ft, the Utah State Engineer assumed that much of this diverted water would be returned to the system via return flows for users downstream. Therefore, only the amount of water that was assumed to be depleted by these water rights (a combined 11,122.49 ac-ft) is guaranteed to make it to the lake. The remaining water may still be used by downstream users. Whether that downstream use actually occurs or the full 26,216.14 ac-ft make it to the lake can vary from year to year.

Similarly, some water rights holders have dedicated their “excess” rights to the lake but retained the right to use this water if they so desire. Such is the case with water rights 59-30 and 59-3518, which, if left unused by the water rights owner, could deliver up to 35,561.27 ac-ft of water to the lake. However, if used by the original owner, these rights could deliver as little as zero ac-ft of water to the lake.

There are some water rights that were dedicated to the lake but had not been put to use for the prior several decades, such as rights number 59-5334. It’s unclear where this water went when it was left unused. If it remained in the Jordan River and flowed to the Great Salt Lake, then dedicating it to the lake could protect and preserve inflows to the lake but would not supply any new water to help meet the state’s inflow goals. On the other hand, if this water did not originally flow to the lake and was caught in a reservoir or sent down a canal, then dedicating it to the lake would create new water for the lake and help the state meet its lake water debt repayment needs.

Overall, the GSLWET transactions could provide as much as 67,704 ac-ft of water to the lake under the right conditions, or as little as 14,122.49 ac-ft under adverse conditions.

One important aspect of this program that gets little attention but we feel obliged to note is the legal status of instream flows. There is a substantial difference between leasing instream flows for a temporary period of time and protecting instream flows in perpetuity. Perpetuity is a legal term that is widely used in land conservation efforts and conservation easements to denote the permanent protection of lands by parties that are committed to guaranteeing the protection of said lands.

Instream Flows

Legislation passed in Utah’s 2022 legislative session expanded the legal definition of instream flows by finally allowing individuals and institutions to hold instream flows, but only on a temporary basis.¹⁵ The entire concept of ecosystem protection is based on permanence, and protections that are designed to be temporary do not provide a sustainable solution. Individuals in Utah are not allowed to permanently dedicate their water rights to the Great Salt Lake, which means this flawed measure does not create true legal protection for the lake.¹⁶ This preclusion strategy likely helps avoid threats to existing or new water diversions, such as the proposed Bear River Development, slated for 2028.

The Utah Statehouse refuses to recognize the personal liberty of water rights holders to permanently devote their water rights to the Great Salt Lake. There are no permanent, legal instream flows recognized by Utah law for individuals or nonprofit conservation organizations on either rivers or lakes because of this preclusion. This fact has been contested by some politicians who wish to portray themselves as saving the lake, but the Utah Legislature intentionally avoided creating a legal tool to permanently dedicate water to the Great Salt Lake by private parties including land trusts and conservation organizations.

Any plan to save the Great Salt Lake must ensure that Utah law recognizes the ability of individuals and private institutions to permanently designate water for rivers and the lake.

Under current Utah law, only three select state agencies are allowed to permanently or temporarily convert existing water rights to instream flow rights.¹⁷ These agencies are the Division of Forestry, Fire, and State Lands (DFFSL), the Division of Wildlife Resources, and the Division of State Parks. Gifting permanent instream flow rights to state agencies raises concerns about whether those agencies will always enforce or utilize their instream flow rights. As two scholars from the University of Oregon Law School put it, “when the state, rather than an individual, holds all instream flow rights, this gives the state the discretionary authority to waive enforcement of that right, essentially subordinating the instream right to more junior diversionary uses of water.”¹⁸

Gifting all the permanent instream flow rights to the government requires placing significant faith in those with administrative control over these agencies — the Utah Legislature and the governor. There are times when the whims of either the statehouse or the governor are subject to special interest pressure and do not align with the best interest of the Great Salt Lake. Allowing only three state agencies to hold permanent instream flow rights relegates all others to temporary instream flow rights, thereby hurting our chances of securing adequate water flows for the Great Salt Lake.

Any plan to save the Great Salt Lake must ensure that Utah law recognizes the ability of individuals and private institutions to permanently designate water for rivers and the lake. Without legal protection for water for the Great Salt Lake, efforts to raise lake levels may be a wishful act because such water can be diverted away by the few state agencies that can hold instream flows, and therefore will not permanently protect the Great Salt Lake.

Since Utah law prohibits all but three state agencies from holding permanent instream flow rights,¹⁹ any instream flow rights acquired by the trust can only go to the lake for a maximum of 10 years. The Trust could potentially donate their acquired water rights to one of the three aforementioned state agencies, who could turn those rights into instream flows. Since these three agencies can extinguish their instream flow rights should they be forced to by political forces, this entire effort does not offer the permanence the Great Salt Lake needs.

The cumulative population of nonprofit conservation organizations and philanthropists across the country could raise hundreds of millions of dollars over time to dedicate water to the Great Salt Lake if only Utah legislators would allow water rights holders to permanently designate their water rights in a stream or lake. Instream flows enable “win-win” transactions between a willing water right seller and a willing buyer for conservation purposes.

The Utah Legislature should amend Utah’s instream flow statute (Utah Code § 73-3-30) to allow private individuals to hold permanent instream flow rights for the benefit of rivers and lakes.

Municipal Water Conservation



Water waste in Salt Lake City, Utah. While many Utah cities have improved their water conservation efforts, urban Utah residents still waste water in massive quantities because our cities have America's cheapest water rates. Photo courtesy of E.P. Kosmicki.

Over the past several years, municipalities have improved their water conservation efforts partly in response to the Great Salt Lake crisis and to save their customers money through deferred costs from demand reduction. Like other programs listed in this section, we have been unable to find comprehensive data on how much water was saved in the Great Salt Lake Basin through these efforts and where that saved water went. Reducing municipal water use means leaving water in a reservoir or in an aquifer. The public should not assume that municipal water conservation automatically means leaving water in a river that flows to the Great Salt Lake.

While there is potential for these efforts to provide new, measurable water to the Great Salt Lake and thereby help Utah meet its inflow needs, without data demonstrating deliveries to the lake from municipal conservation efforts, one cannot conclude that these efforts have produced water for the lake. Although water conservation is a very important means of reducing water demand, saved water must be transferred to the Great Salt Lake along with a robust means of measuring these water deliveries. Otherwise, the benefits of water demand reduction go primarily to water suppliers in helping them prepare for the following year's water deliveries.

Compass Minerals Water Donation

Compass Minerals announced it had entered into an agreement with the Division of Forestry, Fire, and State Lands to leave water in the Great Salt Lake. Local media picked up the story and erroneously reported that the deal would provide the lake with an additional 200,000 acre-feet of water per year, which they claimed would help Utah meet its inflow goals for the lake.

While Compass's actions are laudable, the reality is that this deal preserves the status quo but does not provide a new source of water for the lake. Upon reviewing the water rights involved in the deal, it became evident that most of the water Compass Minerals plans to donate to the lake is water that was already going to the lake, either intentionally or due to nonuse by Compass.

Most of the water Compass Minerals plans to donate to the lake is water that was already going to the lake, either intentionally or due to nonuse by Compass.

There are three buckets of water rights involved in this deal, which the agreement refers to via the following names: progressive water rights (13-246, 13-3569, & 13-3091), donation water rights (13-3457 & 13-3404), and non-consumptive water rights (13-1109, 13-3345, 13-3592, 13-3800, 13-3871, 13-3887, & 35-2343). Compass and the state struck a deal pertaining to the progressive water rights that allows Compass to scale up and down its use of Great Salt Lake water depending on the elevation of the lake. When the lake is above 4,198 feet, Compass can deplete the full 156,000 acre-feet of water allowed by these water rights, but must reduce usage as the lake level drops. Below 4,190 feet, Compass cannot use any of this water. The truth is that this is largely what Compass has already been doing. Due to infrastructure limitations, Compass has not used its full allotment of water granted by these water rights since 2017. Instead, it has used some fraction of that water based on what it is able to divert given the current lake level, which has limited its ability to use these water rights. Therefore, this scaling agreement legally crystalizes what Compass was already doing in practice but does not deliver additional water to the Great Salt Lake.

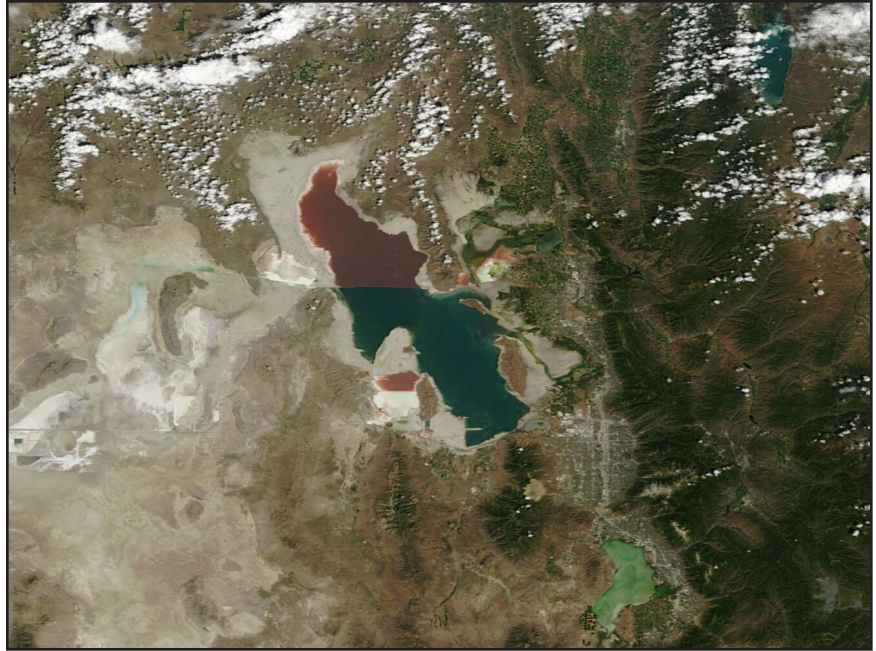
While Compass is prevented from increasing its water demand at low Great Salt Lake water levels under the new agreement, additional proposed mineral extraction uses now being pursued at the Great Salt Lake from new companies and/or new, additional uses of water could increase the use of lake water in coming months and years. These new uses have been encouraged through legislation passed by the Utah Legislature in 2022 and 2023. The proponents of these new mineral extraction efforts are pursuing new technologies which they claim will not use more water, but since their technology is unproven, these claims are just that — unproven.

Additionally, the water rights in the donation and non-consumptive buckets consist exclusively of water that was already flowing to the Great Salt Lake. Some of this water is water that Compass owned the right to use but had not yet put to use, while the rest of it is water that was non-consumptively used, meaning Compass diverted the water but

returned all of it to the lake after use. Therefore, neither of these buckets produces new water for the Great Salt Lake.

In total, this agreement is a good thing in so far as it ensures that Compass Minerals doesn't increase its depletion of Great Salt Lake water in the future above and beyond what it had historically put to use. However, it will not help Utah raise Great Salt Lake levels or meet its inflow goals because it doesn't produce any new water for the lake.

Is Utah Meeting its Inflow Goals?



The Great Salt Lake with exposed lakebed around its edges. Although many cities and farms are reducing water demand through water conservation, very little saved water is being delivered to the lake as a result. Image from Wikimedia Commons.

Of the major programs Utah has invested in and claims will help secure water for the Great Salt Lake, we were only able to see proof that one program is actually getting water to the lake: GSLWET. If we assume that the GSLWET's transactions always supply the maximum amount of water to the lake — a combined total of 67,704.41 acre-feet at the time of this analysis — we can measure how close Utah is to meeting its inflow goals.

Recall from Table 2 that given average 21st century streamflow conditions, Utah needs to deliver an additional 772,788 acre-feet of water to the Great Salt Lake every year for the next thirty years to raise the lake from 4,191 feet back to 4,198 feet. Utah is currently delivering just under 9% of this additional water, or approximately 67,700 acre-feet. To meet the inflow goal set out by this scenario, we need to dramatically scale up efforts and find an additional 705,088 acre-feet of water that we can direct to the Great Salt Lake every year for the next 30 years.

That is the best-case scenario. If we choose any other scenario from Table 3 — such as a drier climate scenario — we fall much further behind inflow goals. Given this fact, it’s clear that to meet inflow goals Utah needs to dramatically amplify efforts to provide water to the lake.

Table 4 shows the gap between the amount of water Utah’s programs have successfully delivered to the lake so far (67,7000 acre-feet) and the total inflow goal for each scenario.

Table 4: Remaining Annual Water Needed to Raise Great Salt Lake from 4,191 to 4,198 Feet After Accounting for 67,700 acre-feet of Additional Inflows

Scenario	Timeline		
	10 Years	20 Years	30 Years
1988–1992 Drought Period (streamflow of 1,059,000 ac-ft/year)	1,634,663	1,375,481	1,289,088
21st Century Average (streamflow of 1,643,000 ac-ft/year)	1,050,663	791,481	705,088

After accounting for the 67,700 acre-feet of additional inflows from existing Utah programs, these are the updated projections for how long it will take to fill the Great Salt Lake from 4,191 feet to 4,198 feet.

Solution 2: Mitigate Dust Emissions with Costly Engineering Measures

If Utah refuses to implement solutions to raise Great Salt Lake water levels, they will have to instead resort to engineering measures to mitigate Great Salt Lake dust. It is likely this would be a very expensive endeavor.

There have been a few estimates of the cost of engineered mitigation measures at the Great Salt Lake. Most notable among these is in the Great Salt Lake Advisory Council’s *Assessment of Potential Costs of Declining Water Levels in Great Salt Lake*.²⁰ In that report, Great Salt Lake dust mitigation costs are estimated by dividing total expenditures on dust mitigation in other areas (Owens Lake and the Salton Sea) by the area of land mitigated. This produced a cost-per-acre estimate, which was then multiplied by the estimated number of acres of dust-producing land at the Great Salt Lake. Other cost estimates have been mentioned in official reports as well, but these lack any discussion of methodology or the assumptions that went into the estimate, making it difficult to assess their robustness.

While these cost estimates have their own merits, they only provide a relatively high-level summary of potential Great Salt Lake dust mitigation costs and do not address how costs might change if different mitigation technologies are used or Great Salt Lake water levels fluctuate.

These estimates only show what the initial capital costs and annual operating costs might be for dust mitigation. Dust mitigation infrastructure has a limited lifespan while the need to mitigate dust does not end. It continues to exist as long as the lakebed remains exposed. Therefore, after a certain period of time, dust-mitigating infrastructure needs to be maintained and eventually replaced. Past cost estimates do not address this reality.

In the last few years, Utah has passed legislation to authorize the construction of more dikes around the Great Salt Lake to push the remaining lake water column diminishing over time into a smaller and smaller area. We have not estimated the costs of this dike construction, which some legislative leaders appear eager to implement even though it could cost billions in taxpayer spending over time.

Translating Owens Lake Dust Mitigation Costs to the Great Salt Lake

California's Owens Lake provides one of the clearest examples of the use of engineered dust suppression technologies to mitigate dust emissions from a dried-up saline lake. Dust emissions from the desiccated Owens Lake were so severe they became the largest source of PM₁₀ pollution in the country. In 1987, the EPA determined that this PM₁₀ pollution exceeded the legal limit, which triggered the creation and implementation of a plan to mitigate the dust emissions. For the next several decades, the Los Angeles Department of Water and Power used various mitigation technologies to reduce or eliminate dust emissions in Owens Valley. This real-world experience offers an ideal place to find information on potential costs to mitigate dust at the Great Salt Lake.

A National Academy of Sciences report examined the mitigation methods used at Owens Lake and describes a number of relevant characteristics of each method, including cost, water consumption, and ideal operating conditions.²¹ Table 5 summarizes the mitigation measures used at Owens Lake, as adapted from the National Academy of Science report on Owens Lake dust mitigation efforts.²²

Table 5: Dust Mitigation Measures Used at Owens Lake

Mitigation Measure	Mitigation Measure	Water Requirement
Shallow Flooding	Flood or saturate surface soils with water, typically from May to October.	2.7–3.2 ft/yr
Shallow Flooding with Dynamic Water Management	Same as regular shallow flooding, but only flood when dust is observed. This reduces overall water use.	2.6 ft/yr
Brine with Shallow Flooding Backup	Flood emissive areas with brine that leaves behind salt crust when evaporated. Periodic reflooding is needed to regrow salt crust when it thins.	0 ft/year
Managed Vegetation	Propagate native plants on emissive surfaces. 47 plant species have been identified for appropriate use at Owens Valley, but most mitigation involves saltgrass.	1.1–2.6 ft/yr
Gravel	Cover emissive surfaces with 2-4 inches of gravel.	0 ft/yr

A catalog of mitigation tactics the Los Angeles Department of Water and Power uses to combat dust emissions from Owens Lake's dry lakebed. Some of these tactics use much more water than others.

Since dust mitigation measures have been in place for many years, good data exists on the various costs, effectiveness, and suitability of different engineered solutions, which were listed in the National Academy of Sciences report previously mentioned. Most of these mitigation measures last for a period of roughly 20 years — although some can be stretched to as many as 30 years under the right conditions.

It's worth noting that the Los Angeles Department of Water and Power has also used one additional mitigation measure called tillage with a backup that consists of wetting and raking emissive lands to create small berms positioned perpendicular to prevailing winds.²³ The unevenness of the surface slows wind speeds, and the clumping of the soil creates heavier particles that are more likely to stay on the ground. However, costs for this mitigation measure were not fully documented and so it was eliminated from further consideration in this study.

The National Academy of Sciences report did not include water purchase costs in their figures showing the costs of construction and maintenance of the infrastructure associated with each mitigation measure. However, the report notes that the Los Angeles Department of Water and Power spent approximately 21% of their total mitigation budget on water for the mitigation measures.

To calculate the total cost of a mitigation measure, we increased capital and operating costs of mitigation measures requiring freshwater by 21% to account for the cost of acquiring water. This figure isn't exactly correct since this water acquisition cost varies by the specific type of mitigation

program, but it offers a reasonable estimate. Table 6 shows total capital and operating costs by mitigation measure. Note that shallow flooding and shallow flooding with dynamic water management have the same costs, so they are lumped together and called “Shallow Flooding.”

**Table 6: Cost of Dust Mitigation Measures
Used at Owens Lake, per acre**

Mitigation Measure	Capital Costs (\$/acre)	Operating Costs (\$/acre/year)
Shallow Flooding	\$49,126–\$60,500	\$532–\$641
Brine with Shallow Flooding Backup	\$37,500	\$360
Managed Vegetation	\$37,873–\$68,002	\$3,025–\$3,328
Gravel	\$57,800	\$360*

Different dust mitigation measures used at Owens Lake have different per acre costs for installation and operations.

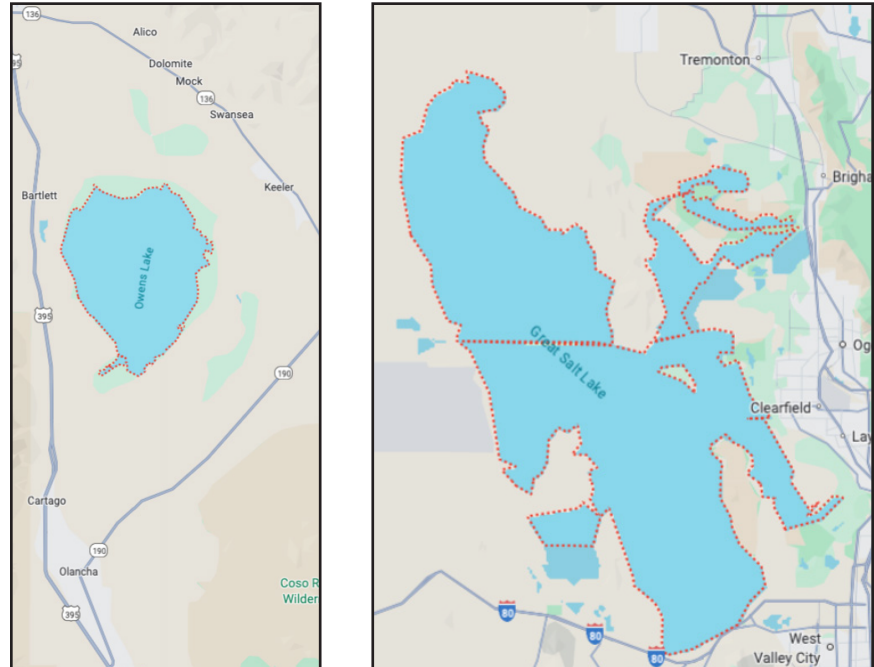
**The operating costs for gravel mitigation have been found by the Los Angeles Department of Water & Power to be higher than this observation because periodic flooding deposited silt into the gravel bed which required raking the gravel.*

Increased Costs at the Great Salt Lake

Key differences between Owens Lake and the Great Salt Lake mean mitigation measures and costs aren’t apples-to-apples comparisons. The most serious of these differences, which comes with the potential for higher costs for Utah, may be the reduced accessibility for construction on the Great Salt Lake.

Owens Lake is surrounded on all sides by paved highways, allowing construction crews access to areas to construct engineered mitigation projects. The Great Salt Lake only has roads along its eastern and southern ends. Much of the Great Salt Lake lakebed lies in remote areas difficult to access to the north and west. Driving off-road to reach dust hotspots on the western or northern side of the Great Salt Lake may or may not be possible, and building new roads may be necessary. Heavy equipment may get stuck on lakebed surfaces; many visitors to the Great Salt Lake have experienced this, a problem that in turn can damage surface crusts and create new dust hotspots.

Figure 26: Proximity of Major Roads to Owens Lake and the Great Salt Lake



Much of the Great Salt Lake lakebed is further from roads and harder to access than Owens Lake's lakebed. This means that the costs of implementing engineered dust mitigation measures at the Great Salt Lake are likely higher than those at Owens Lake. Image from Google Maps.

This means it is likely easier to get tractors, people, equipment, and other materials to the Owens Lake lakebed than the Great Salt Lake's. In fact, it's probable there are some areas of Great Salt Lake that are impossible to access. It is fair to presume that the difficult access to parts of the Great Salt Lake will increase mitigation costs. To account for this, we chose the high-end cost estimate for a mitigation measure wherever a range was presented.

Calculating Mitigation Costs

Using the cost-per-acre estimates for each mitigation measure, we were able to calculate the present value cost of mitigating one acre of land with a given mitigation measure for 20, 40, 60, 80, and 100 years via the following equation:

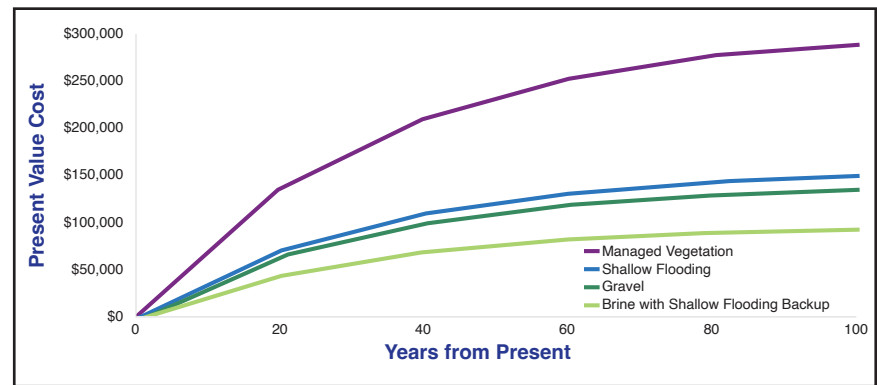
$$PVcost = C + O\left(\frac{1 - (1 + r)^{-n}}{r}\right) + \frac{C}{(1 + r)^a}$$

Where C represents first year capital costs, $O\left(\frac{1-(1+r)^{-n}}{r}\right)$ represents the annual operating costs for n years discounted for inflation by rate r (3%), and $\frac{C}{(1+r)^a}$ represents the cost of rebuilding the capital infrastructure a years from the present. If multiple rebuilds need to take place (e.g., a rebuild 20 years from the present and again 40 years from the present), then the $\frac{C}{(1+r)^a}$ is added again for each rebuild such that the equation looks like:

$$PVcost = C + O\left(\frac{1-(1+r)^{-n}}{r}\right) + \frac{C}{(1+r)^{20}} + \frac{C}{(1+r)^{40}}$$

Figure 27 shows present value costs of mitigating one acre with each method for 20, 40, 60, 80, and 100 years.

Figure 27: Present Value Cost of Mitigating One Acre of Land with Different Methods for Various Time Periods



Projections of the present value costs of potential dust mitigation measures at the Great Salt Lake. Using managed vegetation like saltgrass proves to be the costliest measure.

Over multiple years, managed vegetation is the most expensive mitigation measure, shallow flooding and gravel are nearly tied for second-most expensive, and brine with shallow flooding backup is comparatively the least expensive.

Low-end Cost Estimate of Great Salt Lake Dust Mitigation

As mentioned in the previous section, we produced two estimates of the number of dust-producing acreages for various Great Salt Lake water levels: a low-end estimate showing currently identified hotspots and a high-end estimate showing potential hotspots that increase over time from changes to the bed surface. This section describes how much it may cost to selectively mitigate dust emissions from only the hotspots identified by Dr. Perry's survey, referenced here as the low-end cost estimate.

As Great Salt Lake water levels decline, more hotspots are exposed, and more engineered solutions must be installed. To simplify our analysis, we assumed that Great Salt Lake water levels and the acreage of dust hotspots would remain fixed for the next several decades at three separate water surface elevations — 4,194 feet, 4,188 feet, and 4,170 feet. This is an unrealistic assumption. In reality, lake levels will fluctuate between different elevations over any given time period. By comparing the costs of mitigation with different technologies at different levels, we can determine the relative difference in mitigation costs for different Great Salt Lake levels.

Figure 28 shows the estimated cost of mitigating dust emissions from the Great Salt Lake at three separate elevations — 4,194 feet, 4,188 feet, and 4,170 feet — using different mitigation measures. The model assumes that the dust mitigation measures are installed in a one-year period then calculates operation and maintenance costs for the subsequent 19 years.

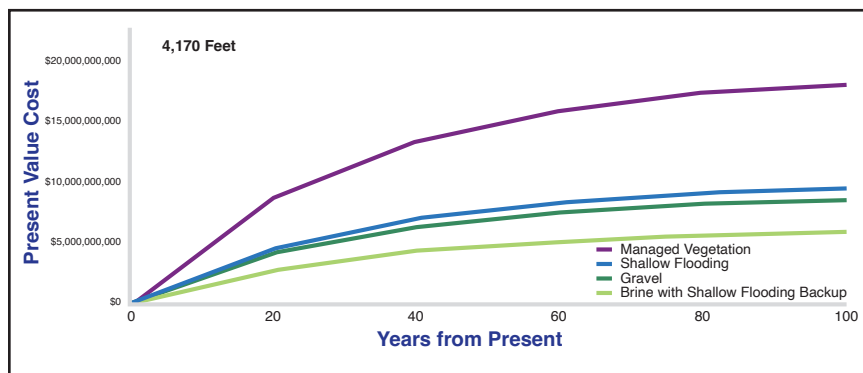
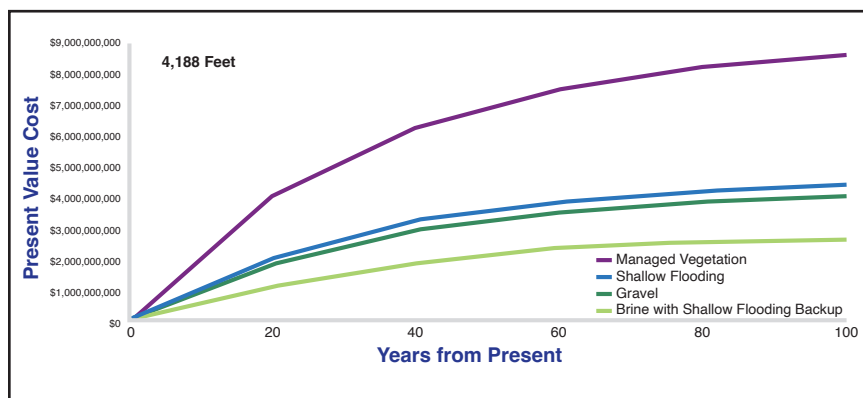
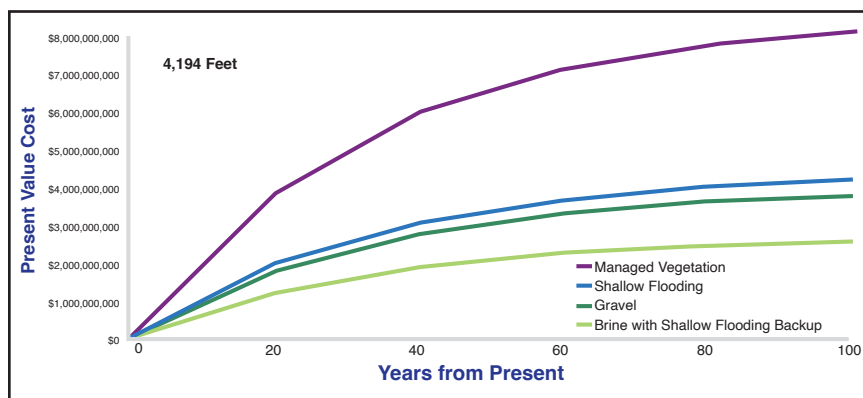
The lower the Great Salt Lake becomes, the higher the mitigation cost. At the record low elevation of 4,188 feet, mitigation costs range from just over \$1.2 billion for 20 years to over \$4 billion for 20 years depending on the mitigation measure used. After a century of mitigation, those costs are expected to rise to nearly \$8.5 billion for the most expensive mitigation measure (managed vegetation). These costs decrease only slightly when the Great Salt Lake is at 4,194 feet in elevation.

Predicting future Great Salt Lake elevation levels beyond a year or so is extremely difficult since one must predict the total snowpack and runoff for the next winter, soil moisture levels, future water diversion totals in the face of unknown reservoir levels, and then factor in groundwater inflows and contemplate new upstream water diversions over the same period of time. Furthermore, as Great Salt Lake water levels drop, salinity increases, which changes evaporation rates and makes the reliability of predictive forecasts over a long period of time even more unreliable. For these reasons, forecasts of future Great Salt Lake water levels over multiple years are not dependable. However, there is still immense benefit to contemplating very low water levels, especially in considering the costs and impacts to public health from a drying Great Salt Lake, which is crucial given that other saline lakes across the globe have disappeared entirely.

For the purpose of this discussion, we contemplated a nightmare scenario where the Great Salt Lake completely dries up (i.e., falls to elevation 4,170), and it is clear that mitigation costs will run much higher. Over the first 20 years of mitigation, costs are estimated to range from a minimum of roughly \$2.7 billion up to almost \$8.6 billion.

All costs are represented in 2024 dollars, meaning future costs are discounted for inflation.

Figure 28: Low-end Dust Mitigation Costs for Various Great Salt Lake Water Surface Elevations



The low-end cost estimates for four different dust mitigation measures based on different water levels at the Great Salt Lake. Costs go up as the lake's level goes down because there is more dust to mitigate at lower water levels.

Table 7 shows the 40-year costs for the different mitigation measures under three different water level scenarios. The estimated acreage of exposed dust hotspots is likely on the low side, particularly for lower elevations that have not been observed before. Estimating hotspots at these lower elevations is a best guess since they are currently underwater.

Table 7: 40-Year Low-end Cost of Mitigation for Different Water Levels

GSL Water Surface Elevation	Exposed Dust Hot Spots (acres)	Cost of Mitigation Measures			
		Shallow Flooding	Brine With Shallow Flooding Backup	Managed Vegetation	Gravel
4,194 Feet	28,306	\$3,080,247,626	\$1,884,708,934	\$5,959,371,148	\$2,777,458,810
4,188 Feet	29,822	\$3,245,265,149	\$1,985,678,088	\$6,278,631,409	\$2,926,255,085
4,180 Feet	37,360	\$4,065,572,920	\$2,487,599,224	\$7,865,685,133	\$3,665,926,476
4,170 Feet	63,267	\$6,884,755,133	\$4,212,570,247	\$13,319,971,663	\$6,207,982,643

A breakdown of the low-end costs for different dust mitigation measures depending on the elevation of the Great Salt Lake's water surface level and the acreage of exposed dust hotspots.

High-end Cost Estimate of Great Salt Lake Dust Mitigation

This section describes how much it may cost to mitigate dust emissions at the Great Salt Lake if up to 24% of the exposed lakebed needs to be covered by air quality mitigation measures. This cost projection represents the high-end estimate, with all costs shown in 2024 dollars.

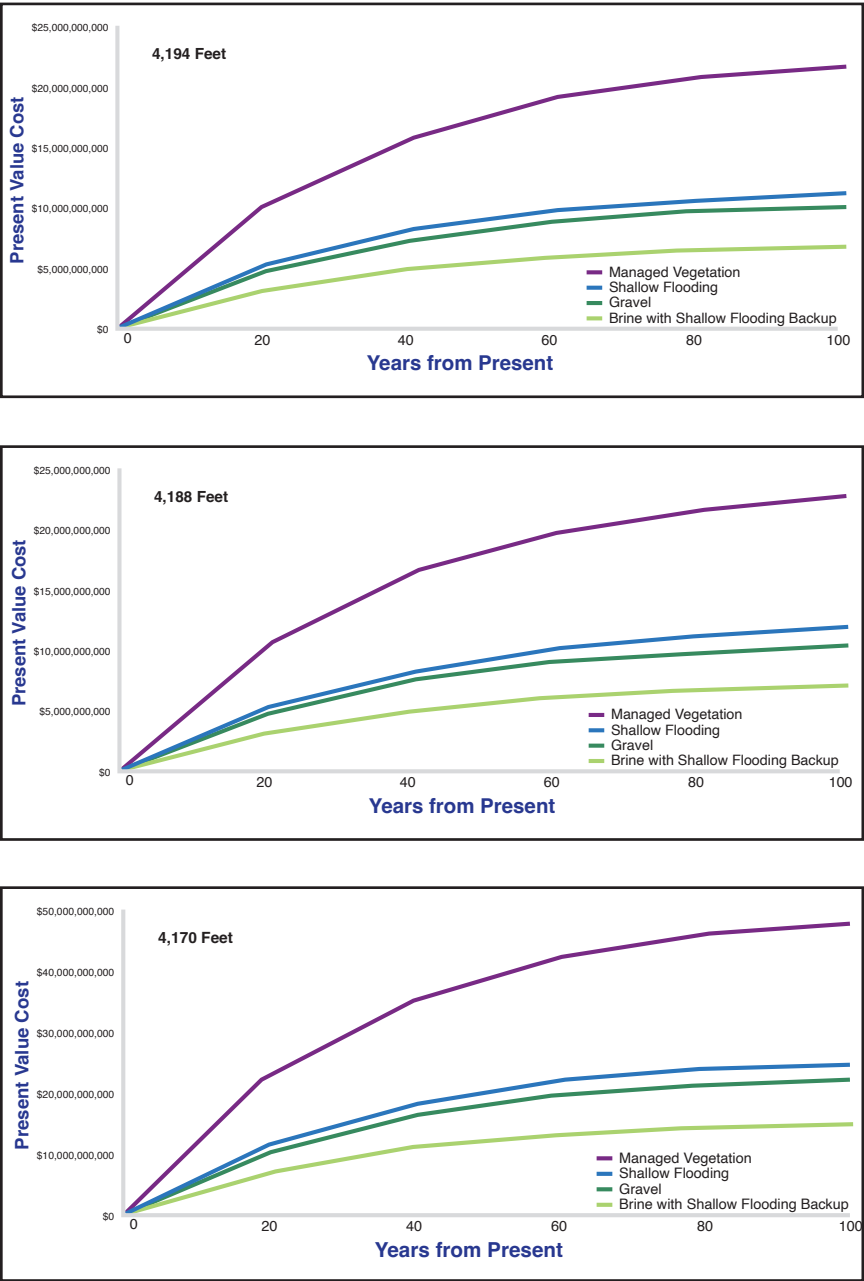
Figure 29 charts the estimated cost of mitigating dust emissions from the Great Salt Lake at the same three elevations shown previously — 4,194 feet, 4,188 feet, and 4,170 feet — using different mitigation measures.

We should also note that there are multiple methodologies by which one could project a 24% mitigation scenario. One is to take 24% of the entire exposed lakebed (which would be in reference to what is considered a full Great Salt Lake), as in figure 4 in section one which was built off of data from Tarboton. Another is to multiply the currently observed and conservatively projected acreage of hotspots — which represent roughly 9% of the total lakebed — up to 24% instead. This second methodology is simpler and more straightforward than the first, so we built the following 24% scenario via this methodology.

As before, the lower the Great Salt Lake becomes, the higher the mitigation costs. However, in this higher cost estimate, mitigation costs across the board are substantially higher. For example, at the record low lake elevation of 4,188 feet, mitigation costs range from \$3.4 billion for 20 years to nearly \$11 billion for 20 years, depending on the mitigation measure used. After a century of mitigation, it's expected those costs will rise to as much as \$22.8 billion for the most expensive mitigation measure (managed vegetation).

If the lake were to fall to 4,170 feet, costs would run much higher. Over the first 20 years of mitigation, costs are estimated to range from a minimum of roughly \$7.2 billion up to \$22.8 billion. After a century of mitigation at this level, the least expensive mitigation measure would cost \$15.3 billion while the most expensive mitigation measure would cost close to \$50 billion.

Figure 29: High-end Dust Mitigation Costs for Various Great Salt Lake Water Surface Elevation



The high-end cost estimates for four different dust mitigation measures based on different water levels at the Great Salt Lake.

Table 8 shows the 40-year costs for the different mitigation measures under three different water level scenarios.

Table 8: 40-Year High-end Cost of Mitigation for Different Water Levels

GSL Water Surface Elevation	Exposed Dust Hot Spots (acres)	Cost of Mitigation Measures			
		Shallow Flooding	Brine With Shallow Flooding Backup	Managed Vegetation	Gravel
4,194 Feet	75,293	\$8,193,458,686	\$5,013,325,764	\$15,851,927,253	\$8,845,779,818
4,188 Feet	79,327	\$8,632,405,296	\$5,281,903,715	\$16,701,159,549	\$9,319,673,105
4,180 Feet	99,378	\$10,814,423,968	\$6,617,013,935	\$20,922,722,454	\$11,675,412,906
4,170 Feet	168,290	\$18,313,448,653	\$11,205,436,858	\$35,431,124,623	\$19,771,471,451

A breakdown of the high-end costs for different dust mitigation measures depending on the elevation of the Great Salt Lake's water surface level and the acreage of exposed dust hotspots.

Appendix 1: Dust Physics Sources

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